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Ontological Information

Investigation into the properties of ontological information

Rodzaj pracy: Praca doktorska

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Abstrakt

Tematem pracy jest zbadanie własności informacji ontologicznej. Informacja ontologiczna jest to informacja zdefiniowana jako element natury odpowiedzialny za jej organizację. Praca jest oparta na analizie koncepcji informacji która charakteryzuje się obiektywnością istnienia i nie ma przypisanego znaczenia czy relacji z wiedzą, poznaniem, czy procesami kognitywistycznymi. W toku pracy ustalono, że można przypisać ontologicznej informacji następujące własności: obiektywność istnienia, brak znaczenia w sensie epistemicznym i rolę w organizacji natury i sztucznych obiektów. Pojęcie ontologicznej informacji pozwala na zmianę interpretacji modeli matematycznych informacji, umożliwia rozstrzygnięcie problemu informacji jako abstraktu i jako konkretu, oraz prowadzi do przedefiniowania pojęcia danych i pojęcia informacji.

W pracy przedstawiono zagadnienie własności informacji ontologicznej w oparciu o metaanalizę filozoficznych rozważań dotyczących zjawiska informacji. Celem pracy było ustalenie własności informacji ontologicznej.

Zastosowano metodę analizy koncepcyjnej.

Wykorzystano materiały źródłowe (306) i pozycje bibliograficzne z Internetu (47).

Słowa kluczowe:

a) **information**, ontological information, epistemic information, physical information

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Roman Krzanowski

1 Introduction

1.1 Objectives and justification

This study investigates the properties of information as a physical phenomenon. This information is epistemically neutral.[1] Its existence and properties do not depend upon a communication process or a cognitive process. This information is perceived as a structure, organization, or form of natural and artificial (artifacts) objects.[2] This information is therefore mind-independent, without any inherent meaning, and ontologically and epistemically objective (the meaning of this term will be explained in the subsequent sections).We will denote such information with the predicate “ontological” as in “ontological information”, as well as by the symbol “I_O” and the indexed term “information$_O$.”

Ontological information, or information as a physical phenomenon, is a fairly recent concept by philosophical standards. Most of the literature referred to in this study has been published in the last 70 years or so, although we may speculate that concepts similar to ontological information have long existed in the vague and foggy, quasi-theological intuitions of Tao or Dao (Chan 2018), *Logos* (in the sense intended by Heraclitus),[3] the ancient cosmological theories of Platos’ *Forms*, Aristotelian *eidos*, and Democritus’ atomic theory of the universe and matter (Rovelli 2016), and it is only recently that the modern concept of ontological information has become gradually recognized in its own right in the physical sciences.

We define ontological information as being objective and mind-independent. The terms “objective” and “mind-independent” may seem synonymous, but this is not true for all aspects. “Objective” denotes the ontological status of something, as opposed to the “subjective”, which depends on something other than itself for its existence, such as a human agent. “Mind-independent”, meanwhile, denotes the property of being independent of the mind, as opposed to “mind-dependent” phenomena such as pain, joy, and love.

[1] A concept is “epistemically neutral” when it does not have intrinsic epistemic import, or in other words, it does not mean anything by itself.
[2] The synonymity of the terms “structure”, “form”, “organization”, and “information” should not be accepted *a priori* despite the fact that these terms are often used synonymously.
[3] Heraclitus used the word Logos to denote *a principle of order and knowledge that is common to all* (Audi 1999). Logos can take several meanings depending on the historical period or the philosophical school it is used within (e.g., Audi 1999, Bollack 2016).

However, being "mind-independent" does not necessarily imply objective existence, even if that is often the case.[4]

In this study, we assume that ontological information, or information$_O$, exists much like energy, entropy, and other physical phenomena exist (i.e. mind-independent, measurable, and quantifiable). In the research literature from the last 70 years or so,[5] information$_O$ has been recognized as a physical phenomenon in different domains under different names to refer to information that is detectable, observable, measurable, and quantifiable. In other words, information$_O$ has been attributed properties that make it more than an empty concept.[6] In this study, we therefore neither try to prove the existence of information$_O$ nor analyze how its existence has been justified. We simply focus on investigating its properties instead.

It seems that a contemporary, comprehensive, and complete description or conceptualization of the world, or indeed the universe, is impossible without some notion of form, organization, or structure.[7] We call this form-giving constituent ontological information.[8] A reductive description of the world in purely mechanical terms for the groups of elements is incomplete, so some form must be added to it. This means that the elements making up the world, whatever they may be, must have some organization or form to have become something. On the other hand, the existence of form by itself (i.e. pure form, abstract form) is difficult to conceptualize if you are not an idealist. Indeed, only Plato and some modern Platonists grant existence to "pure" forms.[9] This means that form must belong to something physical, and these two things, namely the form and the material being formed, together constitute what exists. We see this idea

[4] The interpretations of "objective" and "subjective" in this context are provided in later sections, although the ideas of ontological and epistemic objectivity and subjectivity have been discussed by John Searle (Searle 2013a, 2013b, 2015a, 2015b).

[5] A selection of authors from this relatively short time span ensures that the meanings of the terms used in these writings have a significant chance of being similar, if not the same, so there is no need to "translate the meaning." This problem arises when comparing terms separated over time, context, or culture, such as when comparing ancient Greek writings on hylemorphism with contemporary works on matter and structure.

[6] A non-empty concept is one that has (i) a material, physical existence or, logicians, (ii) a clear definition (Chischolm 2011). In this study, we focus on the first meaning. This interpretation is consistent with definitions of the existence/reality of physical phenomena in scientific realism (e.g., Worrall 1982, Chakravartty 2017).

[7] Von Baeyer quotes eight synonyms for form: arrangement, configuration, order, organization, pattern, structure, and relationship. The term "relationships among the parts of the physical system" seemed to him the most general term that could cover "applications in mathematics, physics, chemistry, biology and neuroscience" (Baeyer von 2005, p. 22).

[8] Some denote this information as *the primary ontological unit of the universe* (Hayot and Pao 2018, p. 9).

[9] Modern Platonists claim *...that there exist such things as abstract objects — where an abstract object is an object that does not exist in space or time and which is therefore entirely non-physical and non-mental. Platonism in this sense is a contemporary view* (Balaguer 2016). The topic is much larger and relates to some fundamental disputes in philosophy between the nominalism and realism of abstract concepts, as well as touching upon the essence of what is information and how we should understand it. Please see the comments from Paul Davies later and the discussion on the nature of information in the later chapters.

of the form and what fills it recurring several times in modern research,[10] although under different names, such as modern hylemorphism (e.g., Turek 1978), paninformatism (e.g., Dodig Crnkovic 2012), or the matter–energy–information complex (e.g., Mynarski 1981, Polkinghorne 2000, Hidalgo 2015). We will not speculate at this point about which of the above labels, among the other possible ones, is the right one to use, because the implicit presuppositions in such a labeling may color our understating of I_O.

However, not everyone agrees with the view that physical reality is some combination of matter and form, whatever that may be. In a crude approximation, structural realism, in its ontological variety, assumes that whatever exists are just “structures or structures of structures”, nothing else. What occupies these structures or what these structures are comprised of is either unknown or beyond our cognitive ability. Thus, there is nothing to know other than structures, whatever they are.[11] This position seems a little too extreme, however, so it is not discussed further here.

This work was carried out for three reasons: First, despite the abundance of publications on the topic of information, we are still unsure about what information fundamentally is. Second, despite the many publications discussing the concept of ontological information (or the concepts similar to it),[12] we are still unsure what properties can be, or should be, attributed to it. Last but not least, nobody has explored what implications adopting such a concept of information will have for our understanding of the nature of information, the concept of computing, and the concept of pan-computationalism, the concept of communication, information sciences, and the philosophy of information, epistemology, and cosmology. This study aims to at least partially fill these gaps.

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[10] William Jaworski argues that the hylemorphic structure is the best (and perhaps only) way to explain the persistence of individuals who change their matter over time. Hylemorphism claims that some individuals, paradigmatically living things, are composed of physical materials with a form or structure that is responsible for them existing and persisting as the kinds of things they are. One objection to hylemorphism is that an account of the physical materials that comprise something is sufficient to account for everything it is and everything it does. William Jaworski, however, argues that this objection fails insofar as hylomorphic structure is the best, and perhaps only, way to explain the persistence of individuals who change their matter over time (Jaworski 2018). The same claim was made almost 40 years later by Krzysztof Turek in his 1978 article on the concept of information and its relation to the restricted form of hylemorphism (Turek 1978).

[11] For a quick overview of structural realism see, for example, Ladyman (2019) or Frigg and Votsis (2011, p. 227-276).

[12] There are studies in physics (e.g., Carl von Weizsäcker (1971), Frank Wilczek (2015), Sean Carroll (2017), Carlo Rovelli (2016), Paul Davies (2019)), cybernetics (e.g., Kowalczyk 1974), computing (e.g., Stefan Mynarski (1981), Gordana Dodig Crnkovic (2012)), biology (e.g., Erwin Schrödinger (2004), Thomas Nagel (2012),Ricardo Sole and Santiago Elena (2019)), cosmology (e.g., Michał Heller (1987, 2014), Tom Stonier (1990), John Polkinghorne (2000), Carlo Rovelli (2016), Paul Davies (2019)), philosophy of science (e.g., Krzysztof Turek (1978), John Collier (1989), Keith Devlin (1991), Jacek Jadacki and Anna Brożek (2005), Martin Schroeder (2005, 2014, 2017a, 2017b) that discuss the concept of ontological information , and they will be analyzed in detail.

We first need to explain the predicate "ontological" in the context of the term "ontological information." A claim may be subjective or objective and such claims may concern types of knowledge (epistemic claims) or the underlying mode of existence (ontological claims). Claims of knowledge about objects that exist independently of us—such as molecules, rivers, mountains, and so on—are epistemically and ontologically objective. Indeed, all epistemic and ontological claims about physical phenomena are of this sort. In contrast, claims of knowledge about the things whose existence depends upon us (i.e. *they exist only when experienced by a subject*) are epistemically and ontologically subjective. Such claims concern our knowledge of notions like feelings, pain, inspiration, and so on.[13] There can also be epistemically subjective claims about ontologically objective objects, such as noting the beauty of the landscape, where the landscape (the object of knowledge) exists independently of us, while its "beauty" is a subjective experience. Claims about consciousness, however, are, according to Searle, epistemically objective but ontologically subjective (see also Chalmers 2014).[14]

The ontological objectivity of information means that information does not depend upon the mind (any mind) for its existence. In other words, it does not require the involvement or even presence of a cognitive agent to bring about its existence. Information therefore exists objectively in the sense explained above, so it is ontologically objective (in the sense above), leading to the term "ontological information". Ontological information (information existing objectively) is also epistemically objective, because as an object of knowledge, it exists independently of the mind. (It is knowledge about concrete objects.) Information that depends upon the mind for its existence—such as pain, beauty, and other abstract concepts—is both ontologically and epistemically subjective at the same time. Meanwhile, information that depends upon the mind for its existence but refers to an object that is ontologically objective (i.e. a concrete object) is ontologically subjective but epistemically objective. In general, for any information that depends upon the mind (i.e. *something that is experienced by the subject*) but refers to object that may exist subjectively or objectively, we will call epistemic (i.e. mind-dependent) information or

[13] See John Searle's (2015a, min.1:40) lecture at Google Academy for his detailed explanation of objective/subjective ontological and epistemic claims. The objective/subjective examples were borrowed from Searle's lecture on the Philosophy of Mind (Searle 2013a). See also Searle (2015b).

[14] One question where philosophers do not converge upon a single answer concerns the existence of abstract concepts such as mathematical objects or universals. See the discussion on the abstractness of mathematical objects, such as from Linnebo (2017, 2018). According to him, abstract objects lack spatiotemporal identity and are causally inefficacious (see also Rosen 2020). In this work, we assume that abstract objects do not exist in the same manner as concrete things, but this discussion will be extended in Chapter Four. The idea that the mind is not a separate thing (Descartes's view) is surprisingly not new. At the same time as Descartes theories about the mind–body problem were published, Newton claimed something very modern: He wrote that *the distinction between the ideas of thinking and extended substances cannot be so 'lawful and perfect' as Descartes claims, so that both can pertain to the same created substance, that is, that bodies can think or that thinking substances can be extended*. This quotation is from Guicciardini (2018, p.134), who was referring to Newton's work *De Gravitatione*. Of course, Newton's motivations for this claim were far from modern.

$information_E$ for short. However, we will now postpone further discussion of $information_E$ and its relation to $information_O$ until Chapter Four.

The notion of information as ontologically objective and fundamentally free of value or meaning may be, and has been, contested, because it significantly changes the way we view the nature of information. Indeed, understanding the concept of ontological information may require a so-called "gestalt switch" (Chalmers 1994, p. 96),[15] which is not an easy thing to do for everyone, because a paradigm shift is always painful.[16] However, those who would deny the existence of ontological information would need to explain away all the facts presented in this study, as well as resolve the concrete–abstract dichotomy signaled by Davies, for example. Ontological information cannot be simply wished away, as some have already tried.[17]

1.2 Why is this study important?

We lack a fundamental understanding of the concept of information. We even lack a single, generally accepted definition of information, as we indicated earlier. For some of the more inquisitive minds, this situation is unsettling. Ratzan (2004) observes that *if we don't know what information is, then how can we expect computers to manipulate it for us*? (ibid., p.2). In other words, how can we "use" information if we are unsure what it is? Hintikka (2007) observed that *our life is increasingly dominated by computers, which are nothing but machines for processing information. Hence it is important for each of us to master this concept intellectually and to have ways of gaining an overview over the different kinds of information we receive* (ibid., p. 189). It therefore falls upon us, the philosophers, to do something about this situation, because the general public is unconcerned by these nuances. Indeed, it seems that *panem et circenses* is a satisfactory description here.

If we do not know what information is, how can we make far-ranging claims about living in the information age, existing in an information-based society, being immersed in information, and acting as information-processing machines?[18] Do we even know what we are claiming? Without precise

[15] This comment should not be seen as an endorsement of Kuhn's view on science (Kuhn 1962).
[16] Note: Despite the claims of objectivity for scientific theories, which is certainly a target, the adoption of a specific theory is largely a matter of social acceptance. Commenting on Newton's theory of Universal Gravitation, Guicciardini notes *It is often the case that the attitudes, mindsets and cultural fashions of a social group play a role that is difficult to demonstrate precisely because they act tacitly as presuppositions that determine what is to be accepted and what rejected* (Guicciardini 2018, p.154). The resistance to ontological information may share these origins.
[17] Personal communication during the seminar at The Warsaw Politechnique, November 2019.
[18] This claim (i.e. that we are information-processing machines of sorts) has several versions. The most simplistic and obviously false one is that we are Turing machines (e.g., Penrose1989, Searle 1998). Statements of the rather obvious fact that we, and indeed all living organisms, are information-processing systems (i.e. a system in the sense

terminology, any discussion is pointless, because we would never reach stable conclusions for any topic. When researchers talk about information in biology, physics, statistics, cosmology, communication, social sciences, and so on, they may talk about the same thing or maybe somewhat similar things, or maybe they are all talking past each other. How would we know? We simply need precision!

We may also mention a few other potential benefits to this study. The notion of ontological information may reshape our understanding of information, or at least put it in a different light. The notion of ontological information may also suggest a solution to the physical–abstract dichotomy that persists in almost every discussion on the nature of information. Furthermore, it may also justify modern claims about the prominent role of information in nature, because ontological information is, after all, an intrinsic part of nature.

Of course, every new endeavor to define information has begun with high hopes, so this study, like any philosophical enquiry, must be taken with a degree of caution and viewed as a contribution to the discussion rather than the final word on the matter, which is good thing to remember when reading this or any other philosophical work.

To make some closing observations, the multiple theories about the nature of information and the numerous definitions attest more to our ignorance than our knowledge. The existing conceptualizations and quantifications of information, of which we have aplenty, include the Shannon–Weaver–Hartley formula for information entropy, Fisher's information, and the Solomonoff–Kolmogorov–Chaitin algorithmic complexity measure, to list just a few attempts at quantifying information. As we will argue later in this study, however, these are not the answer. Just like we cannot claim that the common measure of mass explains what mass is, we cannot claim that the Shannon measure of information, or any other measure, explains what information is.[19] Shannon (1956) actually warns us against overextending his

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of *a set of connected things or devices that operate together* (System 2019)) are often found in research publications. One of the first researchers to claim this was Polish psychiatrist Antoni Kępiński. He formulated the concept of information–energy metabolism as a model for a human organism (Maciuszek 1996). On this topic, also consult Rudnianski (1981), Kaplan (1989), Maturana (1970), Maturana and Valera (1980), Bajić and Wee (2005), and Smith et al. (2009). You may also find some early intuitions defining information/knowledge as "food for the soul (thought)" in Plato's Protagoras: 313c5-314b5. Nowadays, nobody believes such claims are metaphors or exaggerations—they are statements of fact. There is even a neologism coined for this occasion, namely *inforg*, where *Inforgs are informationally embodied organisms, entities made up of information that exist in the info sphere. These informationally embodied organisms are also called natural agents* ('What is inforg?' 2019). The term's origins can be traced to Luciano Floridi (2013).

[19] This is the kind of critique that Hook and Huygens formulated against Newton's theory of light, saying *a mathematical property was not sufficient grounds for a philosophical explanation: the latter could be achieved only by stating what the nature of flight was and how the phenomena of light were causally linked to its nature*

concept of information entropy, which he denotes as a measure of information, beyond what he proposed.[20]

The models of quantum mechanics (QM) represent a good example, but not the only one, of quantifications that do not explain the nature of what is being quantified. It has been said many times that we do not know what QM formulas mean. They do not explain the nature of the modeled phenomenon, but they still give accurate predictions for experiments, so we use them anyway.[21] To explain what something really is, we need something other than just a formula (i.e. a rule) that associates a numeric symbol (i.e. a number)[22] with some non-symbolic phenomena, even if there are so many of these formulas and numbers around.[23] The role of philosophy in science is to explain the nature of reality, not just model it. However, the pure mathematical models of physical phenomena—while providing good predictive tools, like the QM ones do—lack a grounding in what actually exists (e.g., multiverse and string theories), so they do not explain what they are actually modeling (e.g., Piglucci 2010, p.32).

1.3 Main theses

This study assumes that ontological information (I_O) exists as a physical phenomenon. We also initially assume that ontological information can possess four properties:[24] (1) *ontological objectivity* (OO), meaning that it has the features of a non-empty, spatiotemporal, concrete (i.e. not abstract) concept that exists as part of the external (to us), mind-independent world; (2) *structural representation* (SR) meaning that ontological information is perceived as a structure, form, or organization of nature; (3) *physical embodiment* (PE), meaning that ontological information always exists within a physical carrier; and (4)

(Guicciardini 2018, p.88). We now know that Hook and Huygens' critique, while correct in principle, was totally misplaced in the case of Newton's theory of light. The conceptual emptiness of mathematics was abhorred by Newton, who preferred the geometrical formulation of his laws to be closer to reality than the abstract formulas of infinitesimal calculus that were preferred by Leibniz. See also Feynman and Bourbaki's comments on the semantic emptiness of mathematics (Shapiro 2000, p.39).

[20] It will be repeated a few times in this work that uncritically equating thermodynamic entropy with Shannon's concept is a mistake. The claim that both entropies measure disorder is very superficial and inaccurate. Entropy (a residual) exists even in highly ordered (i.e. predictable) structures (Atkins 2010, p. 56). So beyond the syntactic similarity between Shannon's entropy of information and some entropy formulas, the similarities are rather inaccurate.

[21] See Feynman's comments on QED. He states that theories do not explain the "why", so what is essential in theories is *whether they give good predictions* (Feynman 1988, p. 10). Similar views on QM have also been attributed to Bohr (e.g., Piglucci 2010, p. 29). Of course, this is an expression of a certain attitude in the philosophy of science, namely instrumentalism, and maybe this is the best we can hope for in QM.

[22] We disregard here all the questions regarding the very nature of a number.

[23] The relation of mathematical structures to the structures of nature, in Heller's view, is surprising for its accuracy and predictive capacities with some mathematical models (Heller 2014).

[24] These four properties have been derived from several previous studies into ontological information by the author (see Krzanowski 2016, 2017a, 2017b, 2017c, 2018).

epistemic neutrality (EN), meaning that ontological information exists independently of the mind and has no inherent semantic value.

As we have said, these four properties represent our initial attempt at defining the characteristics of ontological information. The objective of this study is to establish a minimal set of properties that can be attributed to ontological information, which maybe the same as the initially proposed set or some subset thereof. What is more, this study may redefine these properties, combine them into a more succinct set, or propose further properties. The properties formulated in this study are grounded in the research of selected areas of science and technology.

Ontological information may also have additional properties that we do not know yet or expect it to have. These may be properties related to, for example, the permanence and conservation of information; the causal power of information, if any, although the causality of ontological information may be implied from it being a physical phenomenon; or phenomena such as the growth, creation, or destruction of information. However, only those properties deemed essential to the nature of ontological information will be discussed, although we do concede that this choice may be somewhat arbitrary.

1.4 Outline of the work

This study investigates the properties that can be attributed to the concept of ontological information over a total of six chapters. The first chapter provides some necessary contextual information for the study, defines the objectives of the study, and provides the justification for undertaking the work. The second chapter, meanwhile, begins the search for the properties of ontological information. Here we review some claims about the concept-bearing characteristics of ontological information by authors such as Edmund Kowalczyk (1970), Keith Devlin (1991), John Polkinghorne (2000), Charles Seife (2006), Frank Wilczek (2015), Sean Carroll (2016), Carlo Rovelli (2016), John Barrow (2017), Paul Davies (2019), and Richard Sole and Santiago Elena (2019). Much of this research has been published in the first two decades of the 21st century, so it is as current as research can reasonably be. These studies provide invaluable intuitions about how information connects with the properties we attribute to ontological information, and they emerge from fundamental studies of nature that were employed to elucidate the essence of some complex natural processes.

In Chapter Three, we review the studies of Carl von Weizsäcker (1970), Krzysztof Turek (1978), Stefan Mynarski (1981), Michał Heller (1987, 2014), John Collier (1989),Tom Stonier (1990), Jacek Jadacki and Anna Brożek (2005), Gordana Dodig Crnkovic (2012), Thomas Nagel (2012), and Cesary Hidalgo (2015). The studies provide a diverse range of perspectives on the idea of information, because they were conducted by researchers from a wide range of fields, including computer scientists, philosophers, physicists, biologists, and cosmologists. However, they all see information as something of, and indeed in, nature, so it has the properties we would attribute to ontological information. The authors' works are presented with direct quotations from their publications, which are subsequently thoroughly analyzed. Chapter Four then attempts to formulate a frugal list of properties that can be attributed to ontological information. To do this, we collect the main observations about information from Chapters Two and Three and try to reduce the number of properties to the most essential set for ontological information. We do it by finding the commonalities and similarities between claimed properties and synthesize similar properties into one. Next, Chapter Five discusses how ontological information may change our perception of several concepts related to information. These include, among other discussed issues, the concept of information itself, the concept of epistemic information, the relationship between ontological information and data, the problem of the existence of information, and the role of quantified models of information. Finally, Chapter Six summarizes the main findings of this study, lists a selection of the questions and problems that this work did not cover, and outlines possible directions for future research.

1.5 Methodological remarks

1.5.1 The method of analysis

The analysis method used in this study resembles that used in the analysis of the classical works of the Pre-Socratics, Plato, and Aristotle. The method comprises a detailed reading of the original text, the identification of relevant fragments, and their extensive analysis and interpretation. The method has been used in the past quite extensively, such as by Thomas Aquinas in his famous commentaries on Aristotle. It has also been used by modern scholars of philosophy with the best of results. An exposition of classical works through this method reveals their depth and gravity in an unparalleled way. These detailed treatises are the paragon of philosophy and represent philosophy at its best. While not dreaming of equaling these works, we adopted their method in the hope that as it has been applied successfully in the past to elucidate complex ideas like *phronesis*; it may also succeed in revealing the nature of information (Reeve 1995, 2000).[25]

[25] This is how the method was described by John Cooper when reviewing C.D.C. Reeve's translation of Aristotle's Metaphysics. When commenting on Reeve's book in the last page of the volume (Reeve 2000), he wrote, *it is a completely fresh, independently motivated philosophical reading of lots and lots of Aristotelian texts, assembled in order to buttress an ongoing interpretive project, and quoted in full and then analyzed step by step in the surrounding discussion. I am sure that any reader will find the book a spirited and instructive effort to deal intelligibly with these often quite daunting materials* (Reeve, op.cit).

1.5.2 How do we refer to information in this work?

The key term in this study is “information”, and if this is not qualified by a predicate, subscript, or other qualifier, it is a place holder, a generic term that does not signify any specific understanding of information by itself. Indeed, this term can be loaded with any sort of meaning associated with this concept. We therefore take the generic meaning of the term “information” as it is defined in its Wikipedia entry (‘Information’ 2018).While the quality of Wikipedia entries is not regarded as being on par with those of more established lexicons and dictionaries from research institutions such as The University of Oxford (OED), The University of Cambridge (Cambridge English Dictionary), and The University of Leeds (Collins), we may safely claim that Wikipedia entries better reflect the common or popular usage of terms. The unqualified term “information” may be used in a variety of contexts without further clarification about what it exactly means, such as in the generic statements like “This study is about information”, “Large quantities of information are stored”, “We are living in the information age”, “We are drowning in information”, or “Information technology controls the world.”

When we need to be more specific, we use additional qualifiers to specify the kind of information we mean, such as predicates, descriptions, contexts, subscripts, or specific names. For example, in some of the reviewed work (e.g., von Weizsäcker), the author begins the analysis by asking something along the lines of “What is information?” implying that it is a generic concept yet to be defined. In these and similar examples, the term “information” needs further clarification, or such sentences will seem rather empty when not referring to any specific concept. When a different, more specific meaning is being attributed to the term, it will be indicated by a subscript or qualifier. For example, information$_E$ denotes epistemic information, while information$_O$ denotes ontological information. In addition, information$_D$ is used to refer to the term’s common meaning as set down in mainstream English dictionaries. What is more, we may also refer to abstract information as information$_A$, which is synonymous with information$_E$, and to concrete or physical information as information$_C$ instead of information$_O$. Information predicated as “semantic information” refers to information that is interpreted for semantic value, while biological information denotes information interpreted within the context of biological systems. Likewise, quantum information denotes information conceptualized in the context of quantum mechanics. The term “information” may also be qualified by an author’s name to reflect his or her work, such as Shannon’s information, although this is technically incorrect because Shannon did not explicitly define the term “information” but rather its measure. Likewise, Turek’s information denotes the concept of information as defined by Turek, while Stonier’s information reflects the concept of information set out by Stonier, and so on.

1.5.3 A few technical terms

We need to explain two key terms, namely "physical phenomenon" and "mind-independent." We quite often refer to information as a physical phenomenon, but the term "physical" may have many interpretations, and some of these may put this work in the wrong light. So, what do we mean by the term "physical" in this study? The appropriate meaning of "physical" for this study is about *relating to things you can see or touch, or relating to the laws of nature: the physical world, or all physical objects that occupy space* ("Physical" 2018a). Thus, the term "physical" includes both living and non-living things, although this does not imply physicalism or physical reductionism. The term may also mean *having material existence**:** perceptible especially through the senses and subject to the laws of nature* ("Physical" 2018b). The antonyms for the term "physical" are immaterial, nonmaterial, and nonphysical, while its synonyms include: "*material, physical, objective mean of or belonging to actuality. Material implies formation out of tangible matter; used in contrast with spiritual or ideal it may connote the mundane, crass, or grasping; physical applies to what is perceived directly by the senses and may contrast with mental, spiritual, or imaginary; objective may stress material or independent existence apart from a subject perceiving it* ("Physical" 2018b).

A narrower meaning of "physical" often used in the philosophy of science (Stoljar 2017) is of *or relating to natural science, of or relating to physics, or characterized or produced by the forces and operations of physics* ("Physical" 2018b). Such an interpretation would, or may, imply physical reductionism, but simply put, physical reductionism would mean that everything can be reduced to a few basic physical laws and phenomena,[26] and this is certainly not the meaning being implied or intended in this study. To

[26] We need to explain some of the complexities for the term "physical reductionism." Taking apart the term "physical reductionism", we have a reductionism denoting the proposition that one concept can be expressed completely by another, with "physical" denoting the physical nature of whatever this predicate is. Put together, "physical reductionism" denotes the notion that everything can be described in terms of physical phenomena or seen as physical phenomena. If information, as we claim here, is of a physical nature, then reducing everything to energy–matter–information—as is often suggested in the studies of authors like Heller (1987, 2014), Mynarski (1981), and Turek (1978)—would be a physical reductionism of sorts. Yet this would not endanger the concept of information$_0$, because we assume that information is physical and exists as a phenomenon in its own right (i.e. it would be a non-eliminative reductionism). This reduction would eliminate esoteric concepts of information as immaterial thoughts but not information as physical entities. However, an extreme, or eliminative, physical reductionism would claim that everything is reducible to some basic physical laws and phenomena, and nothing else exists. This would apparently eliminate information$_0$ as a physical phenomenon in its own right, but under closer scrutiny, this may not be the case. The claim that at the root of everything are some basic physical laws is rather an empty claim, because the question then arises as to what these laws are. They do not have carriers aside from their mathematical expressions, which may account for some Platonic forms existing in the Platonic realm. As we will see, several studies suggest that physical laws are expressions of information or information itself. Thus, from this view, eliminative physical reductionism, as we call it, would not lead to the elimination of information$_0$ but rather to paninformatism, an idea that not many studies would support. For references on reductionism see Ney (2019) and Van Riel and Van (2019).

make things less confusing, we may often use the term “mind-independent” or “objective”, rather than physical. Indeed, the adjective “objective” has a specific meaning in this work, as explained earlier.

The term “mind-independent” also has some interpretation issues, however. Taken at face value, it would imply a form of dualism where the mind stands in opposition to the physical world, as if it is something apart from the physical world. We do, however, assume that the mind is the non-reducible part of the physical world (in the sense of the (first meaning of physical); this assumption is not so popular, but it can be argued for (see John Searle’s (2015a, 2015b) lectures on the theory of the mind. Searle denotes his claim about the nature of the mind as biological naturalism. In this study, the term “mind-independent” means that the existence of information, or its definition, is not contingent on the existence of a mind, whether artificial or natural.[27]

We also occasionally refer to information as a “phenomenon” while also using this term when referring to notions like “the information-processing phenomenon as computing.”A phenomenon is not understood here in the Kantian sense, like in the *phenomena-noumena* division. Instead, a phenomenon denotes *any object, fact, or occurrence perceived or observed*. *We have biological phenomena, geological, chemical, social, nuclear, and electrical, etc. In general, phenomena are the objects of the senses (e.g., sights and sounds) as contrasted with what is apprehended by only intellect* (“Phenomenon” 2018). Natural phenomena include things like “*weather, fog, thunder, tornadoes; biological processes, decomposition, germination; physical processes, wave propagation, erosion; tidal flow, and natural disasters such as electromagnetic pulses, volcanic eruptions, and earthquake and many others*” (“List of natural phenomena” 2018). In other words, anything that occurs in nature is a phenomenon, so we can refer to chemical reactions as chemical phenomena. We may also refer to biological processes as biological phenomena. In the same way, we can refer to ontological information as a natural phenomenon, because it exists in nature.

Last but not least, when we talk about Platonic form, we write “Form” with a capital “F.” The meaning of the term “form” with a lower case “f” is left rather open to fit with the context that the term is used within. What is more, all quotes from non-English texts have been translated by the author.

[27] It should be noted that Newton did not accept Descartes’ dualism, and he had quite a modern view. He wrote that *the distinction between the ideas of thinking substances and extended substances cannot be so lawful and perfect as Descartes claims so that bodies can pertain to the same created substance, that is, that bodies can think or that thinking substances can be extended* as reported by Guicciardini (2018, p.134). However, we should add that Newton’s argument was based on theological grounds, which was not the case for Searle.

1.6 A word of caution

The study does not purport to develop a new theory of information, a fresh concept of the universe, or a revolutionary theory of matter, energy, and substance, nor does it propose a new abstract computing machine. The objective of this study is merely to show that based on our current understanding of certain natural phenomena, we have good reason to claim that the conceptualization of information that we commonly hold (i.e., as a semantic or epistemic concept) has certain incongruities, so it is insufficient for completely describing the phenomenon of information. It therefore follows that a different view of information is needed.

This work also does not aspire to develop a new branch of physics or a new theory of everything. The boldest claim we venture to make is that this study aims to demonstrate that information can be conceptualized as a physical, concrete entity rather than as an abstract notion related to knowledge communication, or meaning. This study endeavors to justify such a view and show that it fits well with other concepts of information.

In addition, this study does not propose a formal definition of information, so readers should not expect to find such a definition here. Instead, this study investigates the properties of ontological information, ones that can be deduced from insights, scientific studies and intuitions, and previous research. Thus, this study formulates a list of properties that are, or can be, attributed to the concept of ontological information, along with a justification for the selection of these properties.

It also needs to be highlighted that this is a study of "ontological information" not an "ontology of information." An ontology of information would investigate the ontological properties of various ontologies, with each ontology corresponding to a specific concept of information. We would also have to accept some ontological position or ontological system to define these "ontologies" of information. Such studies would deviate from what is intended here.

This study investigates the properties of one concept of information, namely ontological information, rather than the ontologies of different concepts of information or some formal ontology for a generic concept of information, if such a thing even exists.[28] The word "ontological" in ontological information can be understood along the lines of how it was explained earlier in this chapter. Moreover, this study

[28] See the discussion on the nature of ontology in the works of Ingarden (1964), Jacquette (2002), Effingham (2003), Smith (2003), Floridi (2013), Perzanowski (2015), and Bilat (2018), for example.

does not investigate pure ontology, virtual ontologies, the ontologies of some domain, or the ontology of computer constructs.[29] We need to be explicit about this.

Last but not least, a word of caution: As we have said, the concept of ontological information is a metaphysical concept. Metaphysics here is understood as investigating questions about the general nature of reality. We may also say that metaphysics is the study of the fabric of reality, of concepts such as space, time, causation, existence, and, to reflect our own case, information. For reasons already explained, the focus on metaphysics also implies that this study is primarily concerned with the metaphysical aspects of the studied concept rather than with mathematics, computing, communication, biology, cosmology, or physics.

1.7 Larger context of the study

It seems that providing some larger context for this study into the nature of information may help better understand the position of this study in relation to the ongoing discussions about information. We begin with a trivial observation, namely the only claim about information that almost everyone would agree upon: We do not have a universal concept of information that satisfies everyone. Quantifications such as Shannon–Weaver–Hartley, Fisher, Kolmogorov-Chaitin, and the scores of other mathematical formulas that are denoted as information measures (or forms of information measures) (see Burgin 2010), are designed for specific purposes under specific assumptions and with a preconceived idea of what information is. The ideas behind these models do not necessarily reflect a general understanding of what information is. For some researchers, for example, there is no information outside Shannon's theory of communication and the derived or related conceptualizations. Shannon's theory and metrics fulfill a specific purpose, so they are useful, highly useful even, but the pragmatic (domain-specific) or operational (technical) successes of this idea do not translate into a metaphysical status. Therefore, we may say they are rather metaphysically neutral.[30]

[29] We refer here to works like those of Noy and McGuinness (2018) and Guarino (1998), although this is just a small sample from the vast sea of publications on the topic of the use of ontological concepts in computer science.

[30] We may even say that Shannon's work on the theory of communication has led to certain distortions in the concept of information, and we still largely live under his shadow. To be fair, though, the subsequent misinterpretations and distortions of his theory of communication were not of his doing but rather his followers (against Shannon's and others' better advice). The gravitational-like pull of certain ideas that is unexplainable by reason alone can be seen in many other cases in philosophy. For example, the captivating effect of Descartes' philosophy prompted Strawson to say that *[Descartes] produced a captivating and striking world picture, dominated by particular interest or a particular attitude, and correspondingly liable to distortion, to exaggeration, and finally even to incoherence* (Strawson 1992, p.16). The centuries-long battle between the advocates of Cartesian vortexes and ether in the Continental Europe and the English followers of Newton's "action at a distance" gravitational theory is another example of how some concepts can throw along shadow

Moreover, the multiple classifications of information have not led to common classification criteria or differentiation/classification factors, because they are too divergent and often contradictory. It seems that the range of concepts associated with "information" is so wide that it renders them almost meaningless. This situation is illustrated by the summary of classifications presented in Table 1.[31]

Author	**Classes, groupings, or differentiating features**
Lensky (2010)	Information as: • a difference that makes the difference; • the values of characteristics in the processes' output, capable of transforming structure; or • something that modifies a knowledge structure.
Buckland (1991)	Information is: • information- as-a-process; • information-as-knowledge; and • information-as-a-thing.
Losee (1998)	Information as: • a meaning and the use of a message or knowledge; • a fundamental characteristic of physical systems and structures (or a structure itself); • related to data transmission in communication systems; and • an output of the process.
Wersig and Neveling (1975)	Information as: • a structure independent of any human perception; • the knowledge built upon the perceived structure of the world; • the "message" or its meaning; • the effect of communication; and • the process of communication.
Nafria (2010)	Information as: • ontological–epistemic; • semiotic (syntactic, semantic, and pragmatic); and • discipline-based.
Adriaans (2019)	Information as: • quantitative (i.e., using mathematical formalism, such as Shannon's information entropy, Kolmogorov, Fisher); and • qualitative (the state of an agent).
Floridi (2013)	Information as a multi-dimensional concept that is:

over humanity's ability to reason (Guicciardini 2018). See also the warnings of Shannon (1956) and Pierce (1961).

[31] These are, of course, not all the classifications of information, because such a list would be extremely long. For example, John Collier (1989) classified theories of information into mathematical theories of information, communication theories, algorithmic or computational theories, physical information theories, and measurement theories. Giovanni Sommaruga (1998) proposed three classes of concepts of information: ordinary language concepts, information theoretical concepts, and formal theoretical concepts. Peter Adriaans and Johan van Benthem (2008), meanwhile, proposed three major concepts of information: Information-A including knowledge and logic, information-B including probabilistic and information-theoretical formulations, and Information-C covering algorithmic and code-compression conceptualizations. Information B and C are quantifiable. Other classifications of information can also be found, but listing them all would be nonsensical, because what really matters is the weakness they share.

- analogue, digital, or binary;
- primary, secondary, meta-, operational, and derivative.

Table 1. A summary of selected classifications for information.

The conclusion is rather self-evident and unilluminating because it is rather obvious: Information is a polysemantic concept with many, often contradictory, definitions. Indeed, most people who write about information confess to having the same impression[32]

So, where does this study fit in with the larger research about information? In an attempt to simplify our conceptualizations of information, we propose two views of information: ontological and epistemic. Ontological information, the concept of information that we explore in this study, is an element of nature, and it exists objectively, independent of any cognitive agent. Epistemic information focuses on concepts of knowledge, cognitive agents and cognition, messages, and communication. We posit that most concepts of information fall into one of these two classes, with some concepts being an unholy mix of the two (see later for more about the concrete–abstract controversy). The relationship between epistemic and ontological information is discussed in somewhat more detail in Chapter Five.

1.8 Chapter summary

The primary aim of this study is to establish a minimal set of properties for ontological information in the light of current research. This study assumes that ontological information exists, so it does not debate this matter. It also postulates that ontological information is an objective (mind-independent), physical phenomena. It is perceived as a structure, organization, or form of natural objects and artifacts and has no inherent meaning or value, at least when we refer to meaning or value for a cognitive agent. The concept of ontological information represents information on a more fundamental level than most of the current (i.e. at the time of writing) concepts of information that have been formulated in communication theory, computing, information sciences, cognitive sciences, AI, biology, popular works on information, and library sciences, as well as in different strands of pancomputationalism, natural computing, and digital physics. Furthermore, this research studies "ontological information" not the "ontology of information." Thus, the study investigates the properties of one concept of information, namely ontological information, rather than the ontologies of different concepts of information or the ontology for a generic concept of information, if such a concept even exists. We consider the concept of ontological information as a metaphysical concept here. This means that we study what the object is as a constituent of physical

32 This conclusion is shared by many researchers investigating the nature of information. See, for example, Wersig and Neveling (1975), Janich (2006), Floridi (2013), Nafria (2010), and Adriaans (2019).

reality, so this is not an investigation of virtual ontologies, the ontologies of some domain, or some ontology of computer constructs. In addition, this is not a study of pure ontology or some form thereof. It has already been briefly explained what ontological information is, so this study attempts to establish its properties. However, why do we choose to undertake this study? We do not know what information is. The existing conceptualizations of information, such as Shannon and Hartley's celebrated formula, are not the answer here, as we will see. We need something else. Any attempt to understand the nature of information is important for one obvious reason: If we claim that we and everything else that exists is made of information, we need to know what we are talking about.

2 Conceptualizing Ontological Information: Intuitions

The word "intuitions" here refers back to the studies of the pre-Socratic philosophers, where a philosopher's world view was reconstructed, often from dispersed fragments, quotations, and partial sentences rather than complete works. In this chapter, we examine some short studies that have discussed the concept of information as an objective, physical phenomenon. Quite often, these studies are just a paragraph or even a sentence in length and feature little supportive discussion. They therefore qualify as intuitions (in a sense explained) rather than arguments. Whatever the length of these fragments, though, they provide valid, unique insights into the studied concept of information. Our use of these short pronouncements may be regarded as being analogous to the reconstruction attempts of pre-Socratic philosophy, which was founded on dispersed fragments and third party quotations, up to a point, of course.

2.1 Intuitions

The sources used here are not precisely comparable to the pre-Socratic sources, but they still need to be combed through for relevant sentences and observations. Our observations come from the works of Edmund Kowalczyk, Keith Devlin, Frank Wilczek, John Barrow, Sean Carroll, Richard Sole and Santiago Elena, Carlo Rovelli, Charles Seife, John Polkinghore, and Paul Davies. All these scholars have indicated the presence of some form of organization in nature, one that is ontologically objective, all pervading, and fundamental. They rarely denote a special term for this, generally referring to it as just information with specific properties or certain utilitarian or explanatory functions or powers. However, the concept of information that they describe bears a remarkable similarity to what we call ontological information in this study.

A note of explanation is warranted here: The physical theories of Wilczek, Barrow, Rovelli, Seife, and Davies are provided here without comments, because interpreting their physical theories is not part of this study. This means we do not focus on the physical theory itself and its description of reality but rather on the role of information in describing the reality elucidated by the theory. In these cases, information is not an integral part of the theory but rather something that emerges as a consequence of the theory or in support of it.

2.1.1 Edward Kowalczyk and the theory of coupling

In the context of cybernetics, Edward Kowalczyk (1970)[33] developed the theory of information in the early seventies of the twentieth century. Kowalczyk faced the same problem as Paul Davies did almost 50 years later, namely how to reconcile the obvious physical character of information with its abstract, semantic dimension.[34] Kowalczyk's view of information reflects his interests in cybernetics in its "regional version", which fuses information processing, computing, and system control theory.[35] He states that *information is clearly the third basic element of nature, besides matter and energy* (Kowalczyk, op.cit., p. 12). This is one of the first statements about information that Kowalczyk makes in his study, but as we will see, it seems hardly justified in light of what he wrote later. Furthermore, Kowalczyk states that information is quantifiable, because technical applications of information require information to be quantified. However, information has *semantic aspects related to non-technical applications* (ibid., p.12), and it is *a factor controlling flow of energy and matter in artifacts (machines) and biological organisms directing them to effective and purposeful action* (ibid., p.12). In this cybernetics-inspired view, information is carried by specific physical signals, and sequences of these signals form a message. Information emerges in the communication (or signal-exchange) process between the signal's source and the receiving system (artificial or biological, per Kowalczyk's comment). Any given message contains information if it triggers a change of state for the receiving system, and this interpretation was clearly inspired by cybernetics. Thus, a message may or may not have information, so information is not an intrinsic property of a signal message (ibid., p.13) but rather exists "in the eye of the beholder." This perspective on information conflicts with the previous claim that information is one of the three fundamental elements of reality, because it suggests that a significant portion of the macro-scale reality is observer-dependent. Kowalczyk seems to be aware that his concept of information is incomplete (ibid., p.14, ft. 2.), but this is intuited in Kowalczyk's work rather than recognized and explained.

Kowalczyk derives the concept of information from the theory of coupling (ToC).[36] The ToC[37] is an epistemic theory, so it is concerned with what we know and how we know it. It claims that there is a

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33 Edmund Kowalczyk was professor of cybernetics at The Warsaw Polytechnic in the sixties and seventies of the 20th century. He specialized in the theory of communication, cybernetics, and the theory of information (Kowalczyk, 1974).

34 Davies states in his 2019 book that *the challenge to science is to figure out how to couple abstract information to the concrete world of physical objects* (Davies 2019, p. 35). See the later section on Paul Davies's work.

35 "*Cybernetics is control theory as it is applied to complex systems*" ("Cybernetics" 2019).The modern origins of cybernetics are traced to Norbert Wiener's book *Cybernetics* (1948). Kowalczyk uses the definition of cybernetics as adopted in the non-Western countries of the so-called Eastern Bock, where the science of control (cybernetics) also included *all sorts of information processing*. In this view, computer science and the theory of information and communication were parts of cybernetics.

36In Polish, the original term used to describe the ToC was "odbicie", which would be translated into something like mirroring or reflection. However, these terms do not correctly render the definition associated "coupling" between the objectively existing reality and our consciousness. This coupling is a causal relationship between signals from the environment, which are perceived as messages, and the object immersed in it, particularly a human subject (ibid., p.14). The coupling occurs when the receiving system responds to the message by changing its state. There is also coupling in inorganic systems, according to Kowalczyk, such as chemical, mechanical, and physical systems. However, these couplings are not information processes because such *systems do not have an awareness of the change of the system state nor do they have an ability to record the past states* (ibid., p.15). However, in a footnote to this claim, Kowalczyk states *that it does not mean that in the world of in animate matter, there is no exchange of information between components of this world. Otherwise there would not be a feedback loop between these objects* (ibid., p. 16). This statement seems to contradict the previous claims about information, according to which information requires awareness understood as consciousness rather than a mechanistic response.

Kowalczyk claims that information is an aspect, or an element of, animate objects, technology, and society, and it is used for a purposeful action, namely control and regulation (ibid., p.21). He brands this view of information as philosophical and differentiates this definition from the quantifiable concept of information related to the organization, properties, and relations of material objects. However, this "quantifiable information" is not an intrinsic property of the states of matter but rather our knowledge of them or the degree of our lack of precise knowledge about these states in probabilistic quantifications (ibid., p.21).

Now, how can we summarize Kowalczyk's concept of information? Kowalczyk intuits the physical and abstract dimensions of information, but he does not propose a coherent resolution for this dichotomy. He tries to create a concept of information based on assumptions from cybernetics and concepts of physics, such as entropy (ibid., p.21. ft.7), Shannon's theory encompasses communication and concepts of meaning and consciousness in human agents, but these things are hard to reconcile in one coherent package, as many writers have later observed and experienced (e.g., Davies, von Weizsäcker, and even Floridi in his General Definition of Information). Moreover, cybernetics does not seem to be the right perspective within which to define a fundamental element of the universe, which is what Kowalczyk's information is supposed to be. The reasons behind Kowalczyk's concept of information may be better understood if one is more aware of role attributed to cybernetics in non-Western countries ("Cybernetics" 2019).

with the ToC by Kowalczyk. The translation of "theory of coupling" rather than the verbatim translation "theory of reflection" more accurately reflects the definition of the ToC.

[37] The Kowalczyk's TOC has nothing to do with Shannon's theory of communication often referred to as the ToC.

2.1.2 Keith Devlin and information that we can manipulate

Keith Devlin claims that information may be regarded as a fundamental element of the universe, much like how we see energy and matter.[38] He states, (1) *man can recognize and manipulate 'information,' but is unable to give precise definition as to what exactly it is being recognized and manipulated*. Furthermore, he writes that (2) *Perhaps information should be regarded as (or maybe is) a basic property of the universe, alongside matter and energy (and being ultimately interconveritible with them).* Next, he writes, (3) *in such a theory (or suggestion for a theory, to be more precise), information would be an intrinsic measure of the structure and order in parts or the entire universe.* Finally, he talks about this (4) *being closely related to entropy (and in some sense its inverse)* (Devlin 1991, p.2). Note that the bracketed numbers are used to indicate the specific claims.

In Devlin's study, the term "information" must be interpreted within the context of the study itself and should not be connected with other theories of information. Devlin is very cautious about what he claims. For example, he says in (3) that his concept of information is merely a suggestion for a theory. Yet he sees the need for the ontological-like information that exists in nature rather than in the mind. Why is this? It appears that for Devlin, this "information" has great utilitarian value. Devlin sees information as a concrete entity that can be used and manipulated (1). Devlin's information is therefore a basic element of the universe, together with matter and energy, where "universe" here refers to physical reality. For Devlin, the term "physical" means ontological or "what is" (2). One accepted version of scientific realism claims that "*what can be manipulated, exists*" (Hacking 1982, pp. 71-87). Devlin's information can be manipulated, so it is real, and it exists in the same sense as other physical phenomena that can be manipulated, such as electrons and photons.

Devlin does not give us a definition for information but instead offers a description. Information may avoid a precise definition if it is a basic element of the natural world on par with energy and matter, as Devlin suggests. As such, basic concepts cannot be defined by other concepts, simply because they cannot be reduced to anything else. Other things may be reducible to them, but they are not reducible to other things, because this is what being basic (conceptually) means. The conceptual "buck" stops right there, because fundamental objects can only be described. Devlin's information may be interconvertible with matter and energy, but he does not explain what this "interconvertibility" would entail.[39] The claim in (3)

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[38] Keith Devlin "*is the Director of the Stanford Mathematics Outreach Project in the Graduate School of Education. His research interests include: theory of information, models of reasoning, applications of mathematical techniques in the study of communication, and mathematical cognition.*" ("Keith Devlin at Stanford University" 2019).

[39] We can only guess that "interconvertibility" may mean something like $E=mc^2=I$, where I is information and the rest is the well-known mass-energy equivalence.

that information is *"an intrinsic measure of structure and order of all the universe*" is left unexplained by Devlin, but we may interpret it as claiming that information is some kind of intrinsic metric of order, although what this "intrinsic measure" may be is again not explained. Finally, in (4), Devlin suggests that information is related to entropy and possibly its inverse. Again, there is no explanation what this means, but we may hazard that more entropy means less information and less entropy means more information. This claim seems to be either a reflection of Shannon's communication theory and his information entropy or some play on the commonly associated meaning of entropy as disorder, as opposed to information as order. However, we cannot push this interpretation too far if we are to avoid attributing to the author something that he was unwilling, or unable, to say.

2.1.3 Frank Wilczek and the unification of matter and information

Frank Wilczek[40] implies that information is a fundamental aspect of the world, and the concept of information, at least in the meaning he describes, may facilitate the development of a fundamental unification theorem in physics. We are not told in detail, however, how this "unification theorem in physics" would be accomplished. Wilczek states:

> *The unification of forces and the unification of force with substance are very well advanced theoretical programs…they have achieved a significant explanatory power, and they suggest essentially new effects accessible through concrete, doable experiments…There are two other unifications in fundamental physics that I think would be most desirable, but where existing ideas are less mature. One is the unification of our description of matter and information. The former is based, speaking very broadly and roughly, on equations that describe flows of energy and charge. These equations are derived, formally, by manipulation of a quantity called action. Action has some interesting connection to entropy, and entropy has close connections to information, so the possibility of a unified theory is tantalizing*. (Wilczek 2015, p.402, 320n)

Wilczek claims that his ideas about information and its function in physical theories are in the early stages of development but have great explanatory potential. Wilczek's information, as he sees it, plays an explanatory role in the well-recognized phenomenon of thermodynamic entropy, and through entropy, information is related to basic physical concepts of matter and energy (Wilczek's claim). Thus, information in Wilczek's view is not an abstract notion that depends upon the presence of the mind. It is a realization of the state of a physical system and a physical property of nature. Being embedded in the

[40] "*Frank Wilczek is considered one of the world's most eminent theoretical physicists. He is known, among other things, for the discovery of asymptotic freedom, the development of quantum chromodynamics, the invention of axions, and the discovery and exploitation of new forms of quantum statistics (anyons). Professor Wilczek's interests include: 'pure' particle physics, the behavior of matter at ultra-high temperature and/or density, the application of insights from particle physics to cosmology, the quantum theory of black holes*" ("Frank Wilczek" 2018).

state of a physical system, information is connected to the fundamental laws and phenomena of the universe, much like entropy is. Wilczek may have The Second Law of thermodynamics in mind here.[41] Entropy may therefore play an explanatory role in "*the unification of our description of matter and information",* but this is conjecture, an intuition on Wilczek's side and nothing more (i.e. it is not supported by any argument).

2.1.4 John Barrow and maximum information content

John Barrow,[42] like Wilczek, connects information with the basic properties of the universe. This connection is achieved through the link between entropy and the concept of information in relation to the arrangements of constituents forming large cosmic structures. This is what Barrows claims:

> *It is possible to relate the notion of entropy, which is a measure of disorder, to the more general and fruitful notions of "information"…We can think of the entropy of a large object like a black hole as being equal to the number of different ways in which its most elementary constituents can be rearranged in order to give the same large-scale state. This tells us the number of binary digits that are needed to specify in every detail the internal configuration of the constituents out of which the black hole is composed. (Barrow 2007, p.179)*

Furthermore, Barrow states:

> *One interesting development that has emerged from the study of black holes and information is a new fundamental principle governing the maximum information content of the volume of space. It appears that the maximum information content is determined by the surface area of the volume, just as for a black hole. More interesting still, the maximum information content within a bounding surface area corresponds to the information, or entropy, that results, if it is the surface of a black hole of the same volume. (ibid., p.188)*

Barrow claims that entropy is a measure of disorder that can be related "*to the more general and fruitful notions of 'information."* While this point is interesting, it is not novel, because most researchers suggest some kind of equivalence (whether conceptual or numeric) between entropy (the state of a physical

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41 *The second law states that there exists a useful state variable called entropy S. The change in entropy delta S is equal to the heat transfer delta Q divided by the temperature T(i.e. delta S = delta Q / T). For a given physical process, the combined entropy of the system and the environment remains a constant if the process can be reversed. If we denote the initial and final states of the system by "i" and "f": Sf = Si (reversible process). The second law states that if the physical process is irreversible, the combined entropy of the system and the environment must increase. The final entropy must be greater than the initial entropy for an irreversible process: Sf > Si (irreversible process)* (Benson 2015).

42 *John D. Barrow is a cosmologist, theoretical physicist, and mathematician. He is a professor of mathematical science at the University of Cambridge and Director of the Millennium Mathematics Project. He is the author of several books including: Pi in the Sky,* The Origin *of the Universe (Science Masters Series), The Artful Universe, The Constants of Nature: From Alpha to Omega—the Numbers That Encode the Deepest Secrets of the Universe, and The Book of Universes* ("John D. Barrow" 2019).

system) and information, but such comparisons are very nebulous. Barrow claims that there are similarities between entropy and information, but information is a much more portent concept. He suggests that information may measure a basic property of the universe, namely the maximum information content in a volume of space. For Barrow, information and entropy express "disorder."[43] We may argue whether entropy is really disorder or simply the magnitude or size of a state space of a system, but Barrow immediately provides the proper conceptualization of entropy as "*the number of different ways in which its most elementary constituents can be rearranged*", which clearly denotes the magnitude/size of the system state space. With this formulation of entropy, entropy then becomes a concept closer to that of the degrees of freedom in a system or even the probability of a given sign occurring in a message, at least with an extended interpretation of the probability space from the physical state space to the message source state space. The differences, however, are significant between the state of a system as a whole and the occurrence (or the probability thereof) of a single message. This can be viewed as the key difference between information entropy (as defined by Shannon) and thermodynamic entropy. (See later for a discussion of the quantification of information.)

From a description of the real (physical) phenomena, Barrow moves on to the realm of quantification, claiming that information expresses the number of binary digits that *"specify in every detail the internal configuration of the constituents of the black hole.*" This is effectively the Solomonov–Kolmogov–Chaitin complexity measure rephrased. This measure, expressed in a digital string of zeros and ones, like any other measure, is an interpretation or symbolization of a physical phenomenon rather than its explanation. In other words, we assign a certain function or number/symbol to a certain physical feature of nature. The Solomonov–Kolmogov–Chaitin complexity measure, in Barrow's discussion, is not a measure of a message but rather one of the states of organization for a large-scale cosmic phenomenon. Barrow's measure is therefore a measure of certain property of a natural object, namely a measure of the maximum information content for a volume of space, so it quantifies how much information (conceived as a binary sequence) can be contained in that volume of space.

Barrow proposes that "information" expresses certain fundamental properties of the universe, and no other concept can do this as well. For Barrow, information exists in nature and can be measured, so it is related to the organization of natural phenomena. This measure seems to express certain natural/physical properties, such as the maximum information content of a volume of space, at the fundamental level, so it

[43] John Wheeler discusses the idea of the entropy of a black hole as a measure of the surface area of the horizon of the black hole and entropy as a measure of lost information, attributing this relation to Bekenstein (Wheeler 1989, p. 312-313). He even states that *giving us its (physical entities) as bits [1/0 domain or yes/no indications as he puts it], the quantum presents us with physics as information* (ibid., p.313). His treatment of information is done in the light of information theory, which is effectively a reinterpretation of Shannon's Theory of Communication.

determines other properties of a volume of space. Thus, information for Barrow has the characteristics that we would normally require from a physical phenomenon: quantifiability (i.e. a numeric representation), a physical or concrete realization, and explanatory power for certain physical phenomena. (See the discussion of scientific realism in work by such as Worrall (1982), Chakravartty (2017), and Liston (2019). Nevertheless, quantifying a phenomenon does not explain its nature, as we discussed earlier in the case of quantum mechanics.

2.1.5 Sean Carroll, information, and non-trivial insights into the world

Sean Carroll,[44] like the above authors, perceives the term "information" in relation to the fundamental properties of the universe. He posits that *Words like 'information' are a useful way of talking about certain things that happen in the universe…the fact that information is an effective way of characterizing certain physical realities in a true and non-trivial insight into the world* (Carroll 2017, p.296). For Carroll, "information" therefore has operational import: It facilitates the explanation and characterization of "physical realities."

Carroll distinguishes two kinds of information: one associated with the physical aspect of the world and one associated with knowledge. This is what he writes:

> *We tend to use the word "information" in multiple, often incompatible, ways. In chapter 4[of his book], we talked about conservation of information in the fundamental physical laws. There, what we might call the "microscopic information" refers to a complete specification of the exact state of a physical system that is neither created nor destroyed. But often we think of a higher-level macroscopic concept of information, one that can indeed come and go; if a book is burned, the information contained in it is lost for us, even if not to the universe. (ibid., p.297)*

Carroll sees "information" as a multivalent concept, but in this multitude, he distinguishes two major kinds of information: information as knowledge, such as that contained within books, and information as the state of a physical system. He refers to the former as higher–level information, meaning that this higher-level information must have some fundamental, perhaps physical, base or lower level. He also ties his second kind of information to physical laws. The idea of information as something fundamental to a basic description of the universe and its structure is also expressed by Carroll in this fragment:

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[44] *Sean Michael Carroll is a theoretical physicist specializing in quantum mechanics, gravity, and cosmology. He is a research professor in the Department of Physics at the California Institute of Technology. He has been a contributor to the physics blog Cosmic Variance, and has published in scientific journals such as Nature as well as other publications, including The New York Times, Sky& Telescope, and New Scientist* ("Sean M. Carroll" 2019).

> *The term "information" here requires caution, because scientists use the same word to mean different things in different contexts. Sometimes "information" refers to the knowledge you actually have about a state of affairs. We may also call the "microscopic" information: the complete specification of the state of the system. When we speak of information being conserved, we mean literally all of this. [These] two conservation laws, of momentum and information, imply a sea change in our best fundamental ontology. The old Aristotelian view was comfortable and, in a sense personal. When things moved, there were movers; when things happened, there were causes. The Laplacian world-view is based on patterns, not on nature and purpose. (ibid., p.34)*

In the above passage, Carroll introduces the concept of information as "*the knowledge you actually have about a state of affairs*. This perception of information contrasts with the physical interpretation as "*the state of the system*." What Carroll offers here is an interesting suggestion: The concept of information in nature is not necessarily related to Aristotelian *eidos* but rather to the Laplacian view of nature, so we eliminate the Aristotelian "enigmatic" nature of things (*eidos*) and purpose (*telos*, where things have *telos* because of *eidos*).[45] We are then left with just concepts of the structures or patterns that form nature (the Laplacian view of nature).The term Carroll uses to denote this information, namely "microscopic information", is a little misleading, but we need to consider that "microscopic" does not relate to the size but rather to the level of specification. Thus, "microscopic information" is "*the complete specification of the state of the system*", implying that it is complete on all levels of organization. This is another way to say that the "microscopic information" is the state of the system or its structure/organization of parts. Carroll also proposes that the law of conservation of information is as fundamental in the universe as the law of conservation of momentum. What such a law would mean, however, is not clear. For Carroll, the concept of information is a fundamental idea behind the shift from the Aristotelian world view to the Laplacian one (i.e. the shift from nature as essences to nature as organization), with organization being the *essence*, form, or *eidos* in this view. The concept of information was not around at the time of Laplace, so he could not use it. We have it now, however, and the concept of information illuminates the nature of the Aristotelian–Laplacian shift. Now nature is a pattern, and information is patterns of organization. In this view, the terms *eidos*, *telos*, and "Form" or "form"[46]are too nebulous, so they may be substituted with a more concrete idea of information as a pattern or organization in nature. Such a change would also attribute quantifiability to information, because while one cannot quantify *eidos*, one can certainly quantify structure under some abstractions.

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[45] This was the Aristotelian explanation of gravity.

[46] The difference between "Form" and "form" was explained in Chapter One.

2.1.6 Ricardo Sole and Santiago Elena, information, and the critical mutation rates of viruses

Ricardo Sole[47] and Santiago Elena[48] claim that the concept of information plays a critical role in explaining viral evolution (i.e. the evolution of viruses), which cannot be explained by any other concept. They write that:

> *One particular unexpected consequence of the quasi-species nature of viral populations is deeply tied to information. This is known as the error catastrophe problem. Eugene predicted that mutation imposes a limit on the amount of information (in terms of genome length, υ) that is consistent with stable information. Specifically, it was shown that there is a critical mutation rate $\mu_C \approx 1/\upsilon$ beyond which no Darwinian evolution can occur. His theoretical work thus made a key prediction: no viable sequences would be observable for mutations higher than the critical one, i.e. $\mu > \mu_C$ .In that case random drift would be observed. Instead, below the threshold, selection operates and information may be maintained in a stable way. (Sole and Elena 2019, p.45)*

While the "*error catastrophe problem*" can be explained with some form of description, like with the mutation rate, the use of the concept of information provides a frugal description that is lacking in other explanations. In other words, the term "information" has an explanatory power that other concepts lack. The information that Ricardo Sole and Santiago Elena are referring to is the structure of the genome (i.e. "*the amount of information (in terms of genome length i.e.* υ*)*"). In explaining this information, there is no reference to meaning or communication. This information is purely the length (the numbers of genes) of the viral RNA or DNA. In this case, the concept of information explains why certain biological (natural) processes do or do not occur. Indeed, there is a certain property of a biological system that relates to information, much like with molecular weight or molecular composition. These processes therefore depend upon information or the organization of nature. To put this differently, these natural systems (viruses) have to have a certain measurable property for evolution to take place, and this property is best denoted as information. What is more, this information is a precondition on the molecular level for Darwinian evolution to take place. The existence of molecular mechanisms alone is not in itself sufficient for evolution to occur, because these structures must have certain characteristics that can be best described as information. We need to add that Sole and Elena's conclusions about the role of information

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[47] Ricardo Sole is an *"ICREA research professor (the Catalan Institute for research and Advanced Studies) currently working at the Universitat Pompeu Fabra , where he is the head of the COMPLEX SYSTEMS LAB located at the PRBB (left picture). He has degrees in both Physics and Biology at the University of Barcelona and received a PhD in Physics at the Polytechnic University of Catalonia.* ("Ricardo Sole" 2019).

[48] Santiago Elena *holds a Ph.D. in Molecular and Evolutionary Genetics, Universitat de València. His scientific interests are related with the evolutionary biology of microbes. More concretely, he has focused on the mechanisms that generate and maintain the genetic variability of RNA viruses.* ("Santiago Elena" 2019).

in evolution relate to the evolution of viruses. Any generalization to the evolution of more complex organisms would need to be confirmed.

2.1.7 Carlo Rovelli, information, and physics

Carlo Rovelli[49]claims that *many scientists suspect today that the concept of 'information' may turn out to be a key for new advances in physics. Information is mentioned in the foundations of thermodynamics, the science of heat, the foundation of quantum mechanics and in other areas besides, with the word quite often used very imprecisely* (Rovelli 2019, p. 209).

For Rovelli, information as a concept is used in fundamental areas of physics (e.g., QM, thermodynamics). Furthermore, he writes, *why is the notion of information useful, perhaps even fundamental, to understanding the world? For a subtle reason: it measures the ability of one physical system to communicate with another physical system* (ibid., p.212). Referring to the idea of Democritus where atoms combine to form structures (i.e. an atom can be compared to the letters of the alphabet), he writes: *If the atoms are also an alphabet, who is able to read the phrases written within this alphabet? The answer is subtle: the way in which the atoms arrange themselves is correlated with the way other atoms arrange themselves. Therefore, a set of atoms can have information in the technical, precise sense described above, about another set of atoms* (ibid., p. 213).

The comment on Democritus' idea is quite interesting in that it substitutes the concept of the nature of things as *eidos/Form* with the mechanistic concept of a structure that determines all the properties of nature. We also saw this in Carroll's reference (as discussed earlier) to the Laplacian view of nature. Could we therefore hazard to claim that the concept of ontological information is closer to the mechanistic view of Democritus than the elusive *Form* or *eidos*? Maybe these two concepts are two sides of the same coin? Furthermore, Rovelli says:

> *The world isn't, then, just a network of colliding atoms: it is also a network of correlations between sets of atoms, a network of real reciprocal information between physical systems. Later he claims that today's physicists commonly accept the idea that information can be used as a conceptual tool to throw light on the nature of heat. More audacious, but defended today by an increasing number of theorists, is the idea that the concept of information can be useful also to the mysterious aspects of quantum mechanics (ibid., p.261-217).*

[49] Carlo Rovelli is *an Italian theoretical physicist and writer who has worked in Italy, the United States and since 2000, in France. His work is mainly in the field of quantum gravity, where he is among the founders of the loop quantum gravity theory. He is the director of the quantum gravity group of the Centre de Physique Théorique (CPT) of the Aix-Marseille University.* ("Carlo Rovelli" 2019).

Rovelli posits that "*the entire structure of quantum mechanics can be read and understood in terms of information*." He formulates (ibid. 217) two principles, which in his view would "*express the entire formal structure of QM*" in terms of information. These principles are: (1) The relevant information in any physical system is finite, and (2) you can always obtain new information on a physical system.

This "relevant information" is information about the state of a system that allows us to predict future states. He explains the claim that "*information in any physical system is finite"* by stating that "*the number of alternative results that can be obtained measuring the physical system (in the finite region of its phase space) in quantum mechanics is finite*." This is an important observation, because it stipulates that the amount of information in the universe at any given time is not infinite, as would be suggested by the classical mechanics of continuous space and time).The fact *"that only a finite number of possibilities exists* "is a reflection or result of the granularity of quantum mechanics.[50]

Rovelli attributes physical presence to information. He writes, "*the white ball in my hand has information about the fact that the ball is in my hand. We are dealing with physical facts, not mental notions. Information in this sense—correlation between states of systems—is ubiquitous throughout the universe* (ibid., p.224). The "*correlation between states of systems*" is another name for the organization of matter, and it is the term used in this study to refer to information. Rovelli closes his discussion of the concept of information by claiming that:

> *It should be clear that the notion of information plays the central role in our attempts to understand the world. From communication to the basis of genetics, from thermodynamics to quantum mechanics and up to quantum gravity, the notion of information is gaining ground as a tool for understanding. The world should not be understood as an amorphous ensemble of atoms but rather as a game of mirrors, founded on the correlation between the structures formed by combinations of these atoms (ibid., p. 226).*

Rovelli postulates that information is a critical concept in basic physical sciences and biology. Information is the organization of nature or its elementary particles and "*the structures formed by combinations of these atoms.*" The "*organization of nature*" is obviously something that exists independently outside of the mind, and he also says this about information in a physical system: "*We are dealing with physical facts, not mental notions*." From the perspective of this study, this is an important observation, because abstract things are things of the mind, such as thoughts or epistemic information, at least for as we define it. The "structures of atoms", meanwhile, are physical things, so they represent

[50] *According to recent developments in the quest to devise a so-called "theory of everything", space is not an infinitely divisible continuum. It is not smooth but granular, and the Planck length gives the size of its smallest possible grains* (Johnson 1999). The implications for the concept of information are significant.

ontological information. These structures "give" shape to nature, or to put it differently, nature can be seen as structures, which in some sense are information, or at least they express it.

2.1.8 Charles Seife, information and physical laws

For Charles Seife,[51] information is a basic property of the universe, with it having a physical (rather than abstract) nature and being subject to physical laws. He writes:

> *Information is much more than the redundancy in the general's code or, later, the ons and offs of computer switches…there is something about information that transcends the medium it is stored in. It is a physical entity, a property of objects akin to energy or work or mass. Indeed, it would become so important that scientists would soon learn to recast other theories in terms of the exchange or manipulation of information. Some of the most fundamental rules in physics are, deep down, actually laws about information (Seife 2006, p. 56).*

The reference to "*the redundancy in the general's code*" relates to Shannon's measure of information, because one interpretation of Shannon's measure of information is the redundancy in the coding of the message in the communication channel. Next, the phrase "*the ons and offs of computer switches*" is talking about the representation of information as binary code or symbolism. Seife posits that these conceptualizations of information do not really reflect what information is. Seife also posits that physical processes (i.e. "*the most fundamental rules in physics*") are de facto information processes (i.e. processes in which information is manipulated). In Seife's writing, we therefore have an indirect reference (i.e. he talks about it without naming it) to the concept of pancomputationalism, where every natural process is a form of information processing and therefore computation as it is generally understood. Seife goes even further, however, because he claims that physics itself may be fundamentally about information (*"the most fundamental rules in physics are, deep down, actually laws about information*"). This is obviously conjecture, yet pancomputationalism in its many different forms has been proposed several times, so maybe we are not so far from actually recognizing this idea as having some merit (e.g., Zuse 1970, von Weizsäcker 1971, Floridi 2004, Dodig Crnkovic, 2011, Piccinini 2017, etc.).

2.1.9 John Polkinghorne, information, matter, and energy

For his part John Polkinghorne,[52] brings the concept of information into the matter–energy complex as an idea for solving the mind–body dualism problem. Polkinghorne writes:

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[51] *Charles Seife is the author of several books, including Proofiness and Zero, which won the PEN/Martha Albrand Award for first nonfiction and was a New York Times notable book. He has written for a wide variety of publications, including The New York Times, Wired, New Scientist, Science, Scientific American, and The Economist.* ("Charles Seife" 2019)

> *in addition to traditional descriptions in terms of matter and energy, there is a need to introduce a third fundamental concept of a pattern-forming character that will embrace these emergent properties of holistic order. Information may be a suitable word for it. It carries with it just a glimmer (no more) of the integration of the material with something that begins to look a little like the mental. Just as relativity theory has integrated matter and energy into a single account, so one might hope for an eventual discovery that would integrate the triad: matter-energy-information (Polkinghorne 2000, p. 96).*

For Polkinghorne, "information" is a necessary element for fully describing nature alongside matter and energy. The "information" he talks about is not a thought or some other product of the mind, which we would usually classify as an abstract entity,[53] but rather a real thing. For Polkinghorne, "information" has a physical presence, and it is concrete. He denotes his proposal of the information, matter, and energy triad as "holistic order." Thus, on the one hand, we have the Aristotelian hylemorphism of substance and *eidos*, while on the other hand, we have Polkinghorne's "holisticism" of matter–energy–information. This is certainly a daring analogy considering that the word "holistic" does not get a good press, with it often being associated with New Age pseudo-mysticism. The over-interpretation of the term "holistic" may take Polkinghorne into never-never land ("A world of fantasy we enter in our dreams" 2019), which is perhaps why Polkinghorne qualifies his view by saying, "*a glimmer (no more) of.*" In disputing Polkinghorne's views, we may remind ourselves that Heraclitian views, despite the volumes of press attention, are not justified as being more accurate than those of Polkinghorne's. Polkinghorne suggests in his writings that if information is a property of the mind (i.e. the mind processes information, or the mind is information, or the mind is composed of information), because of how it combines with matter and energy to create physical reality, the problem of dualism is explained/settled, at least in his view.[54] This view would imply that the mind is an integral part of the matter–energy complex.[55] Of course, being a theologian, Polkinghorne may have allowed himself to be more relaxed in suggesting a hypothesis on the far frontiers of science or on the boundary between theology and science. However, the view that the mind is a part of the natural world but still not reducible to it (having no ontological presence) is not too

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[52] *John Polkinghorne is most notably known for his ground-breaking work in bringing science and theology together. He is a British mathematical physicist and Anglican priest. He was selected as a fellow of the Royal Society based on his mathematical models used to calculate the paths of quantum particles. He was the recipient of the 2002 Templeton Prize* ("John Polkinghorne" 2019).

[53] See the discussion about abstract vs. concrete information in Chapter Five.

[54] Polkinghorne, op. cit., p.97.

[55] Polikghorne continued his discussion of the role and function of information in nature in his later book (Polikghorne and Beale 2009).

far removed from the biological naturalism of Searle, a researcher who does not have theological inclinations by any measure.[56]

2.1.10 Paul Davies and abstract and concrete information

Paul Davies,[57] meanwhile, conceptualizes information as an essential/constituent element of all living things, with it having a real physical and causal nature. Davies writes, *it is thus no surprise that many scientists now choose to define life in terms of its informational properties: 'a chemical system in which the flow and storage of energy are related to the flow and storage of information' in the way biophysicist Eric Smith expresses it* (Davies 2019, p. 26). He then adds that *the idea of information derives originally from the realm of human discourse. Used in this sense, it is a purely abstract concept. On the other hand information clearly plays a physical role in the world, not least in biology. The challenge to science is to figure out how to couple abstract information to the concrete world of physical objects* (ibid., p.35).

Davies observes how the concept of information evolved from the abstract notion associated with the functioning of the mind (e.g., thoughts, ideas) to one that relates to the origins of life with causal powers in the physical realm. Davies points out that information became preferred by "*many scientists now*" to explain natural processes "*in the world, not least in biology.*" Davies gives us an interesting insight into this idea of information. The term "information" originated in relation to a person (vide *informare*), [58]so it is in origin an anthropomorphic-centered concept (i.e. the idea of information derives from the realm of human discourse). Along with the development of natural sciences, however, the concept of information has moved into nature's realm. We thus became able to relate this concept of information to the ideas that were originally conceived to describe the properties of nature, such as form or *eidos*, organization, and order. We could then detect not just strong similarities but almost equivalence between human-centered information and some properties of nature. This shift in our perception of information implies that limiting information to its epistemic version is a strong anthropomorphization of information and nature, at least if we consider information to be a constituent of it. As in many other concepts and ideas that came before (e.g., "Anthropomorphism in science" 1968), to understand what information (or in our case, ontological information) is, we need to remove ourselves from the picture (i.e. de-anthropomorphize it). After all, on the 24-hour clock of the universe's history, we came to this place less than two minutes ago,

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[56] See also Boehm (1980) and Chalmers (1994).

[57] *Paul Davies is a theoretical physicist, cosmologist, astrobiologist and best-selling science author. His research interests have focused mainly on quantum gravity, early universe cosmology, the theory of quantum black holes and the nature of time. He has also made important contributions to the field of astrobiology* ("Paul Davies'" 2019).

[58] *Early 14c., "to train or instruct in some specific subject", from Old French informer, enformer "instruct, teach" (13c.) and directly from Latin informare "to shape, give form to, delineate", figuratively "train, instruct, educate", from in- "into" (from PIE root *en "in") + formare "to form, shape", from forma "form")* ("Informare"2019).

at 11:58:43 ("History of The Earth in 24 hours" 2019). We arrived at a fully furnished house as guests. Note, however, that the Anthroponcene is a recent event with a rather dubious provenance (e.g., Edwards 2015, Waters et al. 2016).

Davies indicates the perennial problem that we have with the concept of information, namely "*how to couple abstract information to the concrete world of physical objects.*" Von Weizsäcker (see the next section), Kowalczyk, and others also ran into this dilemma and failed to resolve it. Information as knowledge, ideas, or thoughts is an abstract concept (this is our information$_E$), but information as a physical phenomenon is real and physical. Indeed, how can one thing (i.e. information) be abstract and physical at the same time? Or is it just one of these things? This is a problem for the philosophy of information and also maybe metaphysics, and at this point, definitions that attempt to be "comprehensive" by trying to account for abstract and physical aspects under one term generally fall apart (see, for example, Floridi's (2013) General Definition of Information (GDI) concept or Carl von Weizsäcker's (1971) information). One solution suggested by this study is to deal with two different concepts and not question this. Indeed, unless we make the content of the mind and consciousness an integral part of physical reality, we will always stumble at this point. Just as a reminder, the term "physical" in this context does not mean something is reducible tithe fundamental laws of physics but rather exists in reality as part of the world of concrete, measurable, detectable objects. The possible "*glimmer of solution*, "taken from Polkinghorne's statement, to the concrete–abstract problem for information is presented in Chapter Five. In the next chapter, we review several studies that discuss the concept of ontological information in more detail, while we will postpone a synthesis of these studies until Chapter Five.

2.2 Chapter summary

The observations in this chapter stem from the works of Edmund Kowalczyk, Keith Devlin, Frank Wilczek, John Barrow, Sean Carroll, Ricardo Sole and Santiago Elena, Carlo Rovelli, Charles Seife, John Polkinghore, and Paul Davies. Kowalczyk intuits physical and abstract dimensions of information, but he does not propose a coherent resolution to this dichotomy. He tries to create a concept of information based on assumptions from cybernetics, concepts of physics like entropy, Shannon's theory of communication, and the concepts of meaning and consciousness in human agents. His concept of information therefore comes out as seeming rather incoherent. Keith Devlin, meanwhile, claims that information may be regarded as a fundamental element of the universe, much like how we see energy and matter. Likewise, Frank Wilczek speculates that information is also a fundamental aspect of the world, and he hints that the concept of information, in the meaning he describes, may facilitate the development of a fundamental unification theorem in physics. However, this suggestion is then abandoned by Wilczek without further elaboration. John Barrow, like Wilczek, connects information with the basic properties of the universe. This connection is forged through the link between entropy and the concept of information as a measure of, or in relation to, arrangements of the constituent elements that form large cosmic structures. It seems that Barrow's intuitions are correct, yet his explanation of entropy and information is not worked out in detail. Sean Carroll, like previous authors, perceives the term "information" as being related to the fundamental properties of the universe. Ricardo Sole and Santiago Elena, meanwhile, claim that the concept of information plays a critical role in explaining viral evolution (i.e. the evolution of viruses), something that cannot be explained by any other concept. For Rovelli, information as a concept is used in fundamental areas of physics. For Seife, though, information is again a basic property of the universe, with it being physical in nature (rather than abstract) and subject to physical laws. Next, Polkinghorne sees information as a third constituent of nature in a complex of matter, energy and information. Finally, Davies sees two types of information, namely abstract and concrete, and he is puzzled by this dichotomy, because abstract information exists outside of space and time (as abstract things do),but the second type of information is physical and exists in nature.

While it may seem that the authors' expressed views do not necessarily converge onto some coherent whole, we can claim that all these scholars perceive information as having a concrete, physical existence. Moreover, these authors attribute to the concept of information properties such as causality in the physical world, quantifiability, a close relationship with the structure of matter or the universe, and usability. They also indicate that the concept of information is the only concept that can explain certain phenomena, including the forming of black holes and the natural evolution of viruses (and by extension, Darwinian evolution).The presented conceptualizations of information differ radically from the conceptualization of information that is employed when describing information from the perspective of semantics. Thus, the review clearly, at the very least, indicates that there is more to information than semantics, which is an assumption of this study.

3 Conceptualizing Ontological Information: Studies

To delve further into the properties of information as a natural (i.e. objective, physical) phenomenon, we selected the research of cosmologist Michał Heller (1987, 2014); physicists Carl von Weizsäcker (1970), Krzysztof Turek (1978), and Tom Stonier (1990); philosophers John Collier (1989) and Thomas Nagel (2012); and computer scientists with philosophical leanings, or conversely philosophers with an interest in computer science, Mynarski (1981), Jacek Jadacki (2005), Gordana Dodig Crnkovic (2012), and Cesary Hidalgo (2015), as well as philosopher and concert pianist Anna Brożek (2005).

3.1 Studies

Diverse perspectives from scholars in different fields (e.g., cosmologists, philosophers, physicists, computer scientists, etc.) are important for this study. Keeping a narrow focus on one or two disciplines, such as mathematics or computing, or limiting views to just one or two authors would lead to this study presenting conclusions that were narrowly conceived, idiosyncratic, specialized, and domain specific. Such conclusions would not have universal import for our metaphysical understanding. Thus, a wider range of perspectives will help mitigate this potential criticism, although it is still of course not inconceivable.

In each of the passages presented, the term "information" should be understood precisely as each specific author intended it to be. In the subsequent analysis, concepts of information, form, structure, and other key concepts will be attributed to a particular author if and when required for the sake of clarity. Each author will be denoted by a two-letter subscript (e.g., "concept$_{XZ}$"). For example, for Carl von Weizsäcker, we use the two-letter code "WZ" for his name, so his concept of information, outside the particular subsection discussing his work, is denoted as information$_{WZ}$ (or I_{WZ} for short). Likewise, Turek's concept of information is denoted as information$_{TR}$ (or I_{TR}).

Note: What follows is not a detailed picture of the metaphysics of information being presented by each specific writer. Many aspects that these authors discussed have been omitted, with only those fragments that pertain to this study's topic being presented. However, these selections were made under the understanding that they could be presented outside the context of the larger work while preserving the author's intended meaning.

In addition, numbers in brackets (e.g., " (1)"",(2)", etc.) are used to refer to particular fragments in the quotes from an author's work, with these quotes being supplied in the footnotes.

3.1.1 Between the mind, nature, and language

Carl von Weizsäcker (1971),[59] in his work *Die Einheit der Natur*, [60] explores several facets of the concept of information. In fragments (1) and (2),[61] he seeks the "*objective character of information*", with "*objective*" meaning something that is "*independent of a human subject*" or "*independent of the physical carrier*" (e.g., a sheet of paper, a telegram, etc.). In short, "*objective*" means that something that is common across physical carriers exists independently of them. He claims that information reduced to language, which is the most common meaning associated with information, is insufficient to explain what information is. Instead, von Weizsäcker understands "language" as a general means of communication between human agents rather than the written or spoken form of any particular language.

In fragment (3), von Weizsäcker states that information is not a thought (i.e. a product of consciousness or the mind), nor is it a material object (i.e. it is not concrete). What is more, information is not a telegram or a collection of letters (i.e. ink blots on paper). He says information is not a message that can be understood as "*information about some facts in reports, in papers, telegrams*." In other words, it is not a message conveying particular facts. For von Weizsäcker, information is something that is common among different physical objects.

In fragment (4), von Weizsäcker states that information is fundamental to nature, and it has no meaning or intentionality like consciousness does. He says that information is some third "thing" that is independent of consciousness and matter (i.e. the physical world). Von Weizsäcker therefore fashions a puzzle here: If information is not physical (i.e. it is independent of matter) and not related to consciousness (i.e. is independent of the mind), then what is it? He does not tell us. He later claims that information must have meaning, but meaning is always associated with some sort of intellect—whether human, animal, or artificial—and a conscious agent.[62] So, if information is not material, and if it is separated from the

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[59] *Carl von Weizsäcker was a German physicist and philosopher. Weizsäcker made important theoretical discoveries regarding energy production in stars from nuclear fusion processes. He also did influential theoretical work on planetary formation in the early Solar System.* (Carl Friedrich von Weizsäcker 2019).

[60] Note that the page numbers refer to the Polish edition of Carl von Weizsäcker's 1971 book *Die Einheit der Natur*, Munchen: Verlag, Berlin. Polish edition, 1978, PIW, Warszawa.

[61] " (1)… *information is not a material thing or a content of consciousness. These two interpretations fall apart facing the objective character of information*. (2)…*information is what is common between two different paper telegrams, one written by the sender and one received by the receiver*.(3) *Information is not our momentary state of consciousness*. (4) … *information should be conceptualized as a third thing, independent of matter and consciousness*. (5) [Information]… *is Platonic form, or Aristotelian eidos, interpreted within the XXth century idiom*" (ibid., p.79).

[62] What is meaning, how it arises, and whether a conscious biological agent is needed to be present for meaning to be created are questions without a good answer. Here we make the certain assumption that nature by itself is meaningless, with meaning being created by, and for, an agent interacting with nature. Such

consciousness as the source of meaning, yet it has meaning, where is this meaning located? What is it? It seems that von Weizsäcker faces the same dilemma that was indicated by Paul Davies, namely that of abstract versus concrete information.

In fragment (5), von Weizsäcker observes that information has the characteristics of Platonist *Form* or Aristotelian *eidos*, but these notions must be rendered in a modern conceptual framework to be properly understood. Many researchers, as indeed von Weizsäcker does, point to similarities in the ancient concepts of *Form* and *eidos* as early intuitions about information acting as a forming factor in nature, but they stress that these ancient terms must be reinterpreted within the context of our current knowledge of nature. In other words, they cannot just be adopted "as is" for our metaphysical debate. The open question is therefore what should we adopt from the old concepts and what should we leave out? Thus, von Weizsäcker's statement that information is like *"Platonic form, or Aristotelian eidos, interpreted within the XX century idiom*" is not entirely clear or satisfying.

In fragment (6),[63] von Weizsäcker returns to the (original) Latin meaning of information, where *informare* means to form or give form. Information, in this context, possesses causal power in that it is responsible for the shape/form of objects (i.e. information gives shape). However, the terms "shape" and "form" do not correspond to an object's external three-dimensional geometric configuration but rather to its *eidos*(i.e. what that object is). This distinction is not entirely obvious, because the *eidos* of something is related to its geometric shape, yet they are not the same. What is more, *eidos* itself has several other interpretations beyond geometry. Unfortunately, von Weizsäcker is not clear about what he precisely means by "*eidos*." In fragment (7), he posits that information cannot be understood in isolation from matter–energy, and it should be connected with matter–consciousness. How exactly this complex of matter, consciousness, and information should be brought about, as well as what it is in relation to modern physics and contemporary concepts of matter and energy, is not explained. For von Weizsäcker, the matter–consciousness–information complex is an obscure concept, so it remains for the reader. It seems that consciousness would need to be transcendental like Descartes' *res cogitans* rather than something empirical. As von Weizsäcker observes, the terms "matter–consciousness" and

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an agent must have a certain level of complexity in its cognitive system to create meaning. Precisely what level of complexity is needed here is discussed in Chapter Five.

63 (6) *The origins of the word 'information' point us in the proper direction. In the Latin dictionary, the basic meaning of informare is to shape, form, or as a metaphor, form a thought, image. Informare is something of (an act of)imposing form on matter or pressing matter into form*. (7) *We need to, however, remind ourselves that information may be understood only in conjunction with the matter-energy pair, not with matter-consciousness. If we would be looking to place information in the mind, we could not be speaking about empirical consciousness but transcendental. However, the concept of transcendental consciousness would only obscure the problem* (ibid., p. 80).

“transcendental” in this context are rather obtuse in that they do not explain much. However, even if it is somewhat confused, this claim would suggest that information does not depend on the mind for existence. Later on, however, there are passages in which von Weizsäcker seems to claim the opposite.

In fragment (8),[64] von Weizsäcker assumes an intuitive understanding of the terms “form”, “shape”, and “structure” and does not try to provide any formal definitions. Thus, we accept these intuitions at face value and deduce their meaning from the context. Indeed, the terms need to be taken literally without implying any deeper theory or connection to some metaphysical or physical theory, simply because this is not intimated by the author. We need to keep this in mind and not assume that that von Weizsäcker seeks to revive Platonic ontology and Aristotelian helomorphism in their original forms, because he has already cautioned against these interpretations. Indeed, he made it clear in fragment (5) that such ancient concepts need to be reinterpreted in a new language, although he did not indicate what this new language maybe. This note of caution from von Weizsäcker is not really such a revelation, however, because no sane person would take the Ancient Greeks so literarily.

So, what else can we learn about information from von Weizsäcker? Information is comprehended by the senses, but it is not the specific physical form that one perceives, such as the particular shape of a letter of the alphabet. Information is something different, and it comes from the immediate sensual form of an object or phenomenon. Moreover, information is intentional in the sense that a thought is an intentional act. For von Weizsäcker, this means that every thought has meaning. In the modern interpretation of thought, thoughts are intentional and directed toward some object, which is somewhat equivalent to having meaning (Searle 1983). Thus, for von Weizsäcker, information depends upon consciousness, yet it is separated from it. This claim seems rather strange.

In fragment (9), von Weizsäcker posits that information is an abstraction of the form/shape of thought. Information is carried in a shape/form that can be sensed (e.g., sound waves, electric impulses, etc.), yet it is not the medium itself (i.e. not the sound waves or electrical impulses). Information is what these objects or phenomena convey, in some way, and it is common among the different physical carriers. However, if information is common among different physical carriers, what is it? Where is it? Von Weizsäcker’s claim only makes sense if we assume that information is something extra-physical and (von Weizsäcker

[64] (8)*In the following sections without detailed definitions of terms, I will consider information as form, structure, or shape. This form may be a form of artifacts or phenomena apprehended through senses: printing ink on paper, chalk on a blackboard, sound waves in the air, electric current impulse in a conduit, etc. It is never identified with a geometric form as the printed telegram or an acoustic communication of a telephone operator contains the same information.* (9) *It belongs to the higher form of abstraction (but I do not define it). It may be perceived, or comprehended by people. But it is not an act of thinking but the content of this act. It is a thought in the sense in which one can say that two people have the same thought* (ibid., p.80).

ends his discussion on this note) subsists in the mind in some form, or that information has an independent existence like in Popper's third world. Any of the three options brings significant metaphysical and ontological consequences. One may argue that it is a shadow of Descartes' dualism (the mind–body separation), which is quite a common problem in the study of information, because literal Cartesian dualism is difficult to maintain in the light of the modern philosophy of cognition and neuroscience (e.g., Robinson 2017).

In the following fragments, von Weizsäcker argues against the concept of information as an objective, meaningless element of nature. This discussion introduces certain incoherence, because information cannot be *form* or *eidos*, even in von Weizsäcker's reduced version of these notions, and at the same time mind-dependent, as he claims in previous fragments. In fragments (10) and (11),[65] von Weizsäcker clearly identifies information with an (en) coding (an intentional representation of thought) and certain intentional processes (e.g., creating "*a series of electrical impulses in computers*"*).* He does not consider the form/shape of natural phenomena or objects that do not convey thought as information. He also admits that the division between information-carrying form (i.e. a linguistic form carrying information as some sort of language) and a form that is not information (i.e. not a linguistic form) is fluid but nevertheless required and real. The term "fluid" in von Weizsäcker text means relative.

We may ask what this is relative to and how? What would it mean to have two entities with a fluid boundary between them? How could we say that one is this and another is that? All these questions arise from von Weizsäcker's ambiguity about information. Von Weizsäcker's concept of language is based on a series of intentional signs/forms but abstracted from their particular realizations. This may indicate some kind of proto-language, but it is not a language that anyone may speak. Is it therefore the language of thought? Or is it thought itself? Von Weizsäcker is unclear here. For von Weizsäcker, language, of sorts, seems to be critical in conceptualizing information. This is generally always the case when the concept of information is relative to cognitive agents. Von Weizsäcker seems to express the concern that the conductor Kent Nagano put in the following statement: "*Without language there is nothing; without language there is no thinking, no consciousness, no human existence*" (Nagano 2019, p. 36).We agree with the claim that language is fundamental to humanity and human culture, but Nagano's statement needs revising: Nagano's "nothing" is not "nothing" as in "no existence" (i.e. an ontological nothing) but rather the absence of the thought and consciousness that typifies human existence. Nagano therefore

[65] (10) "*In no case is information any form or structure, even defined at a high level of abstraction. Two things are needed here: linguistic character and univocal meaning. What does it mean for information to have a linguistic character?* (11) *The language is a series of electrical impulses in computers, or a sequence of letters, but it is not the form of stars or plants, or shapes of artifacts, or a cake or a cutlet. The boundary between the linguistic and non-linguistic forms is not clearly defined but necessary for this discussion*" (ibid., p.81).

forgets about nature, as did von Weizsäcker. While this omission is not surprising for an orchestra conductor (Nagano), it is for professional physicist like von Weizsäcker. Music may not exist regardless of whether we are here or not, but nature does not.

In fragment (12),[66] information is defined in the process of communication. Von Weizsäcker claims that for a shape/form to be information there must be a communicator (i.e. a sender) and at least a potential receiver. Language here is understood as the means of communication. Von Weizsäcker clearly refers to the Shannon–Weaver–Hartley theory of communication and the model of communication (i.e. sender, channel, message, and receiver) in general (e.g., Cherry 1978, Pierce 1961). As explained in fragments (13) and (14), this is why for von Weizsäcker there is no "genetic information" in DNA, because you cannot identify a human or other subject as the sender or receiver of such a "genetic language." Of course, this view comes from the early seventies of the 20th century. These days, we have no problem in assigning an informational interpretation to DNA. For examples of this, see the works of Yockey (1999, 2005), Barbieri (2016), Cartwright et al. (2016), Gonzales et al. (2016), Koonin (2016), Roederer (2016), Walker et. al. (2016), Wills (2016), and Davies (2019).

Von Weizsäcker's view of information in the context of the communication process is clearly a literal interpretation of Shannon's communication model (or indeed any generic communication model) (Cherry, op.cit.).Von Weizsäcker tries to reinterpret this model by adding the dimension of meaning, but as we know, the Shannon–Weaver–Hartley information concept explicitly focuses on structure (i.e. the statistical structure of a language) to the exclusion of meaning. The Shannon–Hartley–Weaver information entropy was presented as an objective measure of some probabilistic structure denoted as a signal or more precisely a message, which is a signal with finite boundaries. We also know that this is an incorrect interpretation of the Shannon-Weaver-Hartley model, because the whole statistical model underlying the theory was founded on the probabilistic model of a language, namely English in the original case. In other words, it was based on meaning, because languages are by nature designed to be meaningful.

In the Shannon–Weaver–Hartley model, there is also the problem of the assumptions behind the underlying probability model. One assumption in this model is the statistical independence of the

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[66] (12) *"We can explain the linguistic character of information without the term 'language.' We can use the notion of 'communication. 'Information is a form used to communicate. 'Used to' must be understood as the possibility rather than the actual act; unread books contain information.* (13) *The concept of communication reminds us that language is not about the isolated function of the mind, Cartesian res cogitans, but in a large part it is a communication between two persons*. (14) *A set of chromosomes contains information determining the phenotype of an organism. Even the letters in which this information is written have been identified. However, there is no person that communicates and a person that would understand the communication here* (ibid. 82).

modeled probability space. Such an assumption seems to contradict the inherent features of any language, because the elements of language always have highly correlated structures, with uncorrelated linguistic-like utterances being a sort of gibberish or cipher. Shannon's model, however, assumed no such correlation. Later attempts to reinterpret the Shannon–Weaver–Hartley formula for information content in terms of thermodynamic entropy have led only to confusion (e.g., Pierce 1961). Despite syntactical similarities between Gibb's formula for thermodynamic entropy and Shannon's formula for measuring information, these two varieties of entropy are not the same phenomena, so conclusions about one of them do not necessarily translate to the other.[67] These problems are discussed further in Chapter Five.

Von Weizsäcker adopts a very narrow understanding of communication as an exchange (of information) between human agents. He does not consider machine-to-machine (M2M)[68] communication or communication between artificial agents or biological forms. It is therefore a purely anthropomorphic perspective, and such a perspective will clearly result in anthropomorphic information. Maybe this is a sign of the times when von Weizsäcker was writing his book (1970), when information technology was in its early stages. Von Weizsäcker's perspective, which was rather common in the 1970s, obviously evolved, as we can see when reading research from later decades. Von Weizsäcker is unable to disassociate the notion of information from language and its narrow definition as a human communication tool. Yet, in the following sentences, he cannot resist the attraction of the idea of meaning-free information.

In fragment (15),[69] von Weizsäcker considers the concept of information to be similar to ontological information in this study, so it is information existing objectively without meaning and "*without reference to language or communication.*" He even identifies it with measurable structures. However, in fragment (16), he states that he cannot accept the concept of meaningless information. The critical remark comes in fragment (17), where von Weizsäcker insists that structures cannot just exist and be information. He

[67] To make this more obvious, we could say that two phenomena, even if they can be quantified by the same mathematical structure (e.g., a linear equation), are not necessarily similar or the same.

[68] "*Machine–to-Machine (M2M) communication is a form of data communication that involves one or more entities that do not necessarily require human interaction or intervention in the process of communication. M2M is also named as Machine Type Communication (MTC) in 3GPP*" ("White Paper on M2M" 2019). In fact, M2M covers many variants of communication, including Man-to-Machine and Machine-to-Man (communication between a human operated device and a machine). See, for example, Pandey (2016), Pawan et al. (2016, pp. 83-105), Zanini (2017), and Galetić et al. (2019).

[69] (15) "*You may also define information without reference to language or communication. In this case, information exists in nature objectively. These are measurable collections of structures and we only talk about existent things.* (16) *However, we may postulate that it is precisely our linguistic ability that allows us to extract from existent things information structures.* (17) *How it is difficult to distinguish these two points of view is seen as an attempt to define information extra-linguistically. If we denote as information any form that can be described by enumerating a finite number of yes-or-no decisions, this seemingly objective information becomes a linguistic form* (von Weizsäcker, op. cit., p.82)

claims one needs a language to bestow the concept of information on physical structure: "*it is exactly our linguistic ability that allows us to extract from 'existent things' information structures.*" Thus, for him, a structure is an enumerable, measurable, perceivable element or aspect of nature, and if it is measurable, it must be in some sense "visible" or available for sensual introspection. However, he also sees (as expressed in the earlier claims) structure as *eidos* (i.e. the essence of a thing), and *eidos* is not perceived by the senses but rather intuited or rationalized (i.e. we need *eidos* to have objects). So, how can a structure be *eidos* and yet be measurable? Would this imply that a measurable structure is just an expression/representation of *eidos*? It seems that information is either a sensible structure or it is *eidos*—it cannot be both, because how can the external shape be the cause of itself? In other words, how can it have the causal power of *informare* (i.e. shape-giving) if it is conceived as a perceivable structure? All structures are notoriously difficult to define at the fundamental level, which is why modern structural realism often skirts the question of what a structure is and tries to get away with some domain-specific definitions. By locking himself in a definition of structure as an enumerable, sensory object, von Weizsäcker loses an opportunity to free himself from anthropomorphism and the assumption that measurement is a quintessentially human domain. The point posited in fragment (17)("*How it is difficult to distinguish these two…*") is exactly what is addressed in this present study by differentiating ontological and epistemic concepts of information (i.e. concrete information and information as meaning), but von Weizsäcker does not admit this is a possibility.

Henceforth, the concept of information developed by von Weizsäcker is denoted as information$_{\mathrm{WZ}}$ or I_{WZ}.

3.1.2 Form, structure, and information

Krzysztof Turek,[70] for his part, introduces the notion of information as a physical phenomenon without meaning. In addition, Turek's information is not related to any communication system or process but rather expressed in the internal/hidden structure (or form) of things. These terms will be explained in detail, because Turek provides specific, narrow definitions that differ from the meanings usually associated with them.[71]

[70] Krzysztof Turek was a physicist and a philosopher of science and an adjunct professor at the University of Science and Technology, Cracow, Poland. He obtained his doctorate in philosophy at The Pontifical University of John Paul II, Cracow, Poland.
[71] Turek's writings, which are in Polish, have been translated by the author.

In fragment (1),[72] Turek's interpretation for the meaning of the Latin word "*informare*" goes beyond the usual readings of this term, such as by Carl von Weizsäcker. Turek points out that this Latin word suggests that (a) information is a causal factor in shaping things (objects) (i.e. "*giving form, shape*" and "*creating form*") and that (b) the shape, in this case, is the internal form of the thing.

In fragment (2), [73] Turek explains that the meaning for the internal shape of an object, which is attributed to information, can be found in the concept of what he calls *hylemorphism*, a sort of form–matter composite. Indeed, the word "composite "may be a better choice than hylemorphism for denoting Turek's proposed concept, because Turek's form–matter composite has a very narrow interpretation when compared to Aristotelian hylemorphism.[74] As such, it does not carry all the baggage that comes with Aristotelian metaphysics. It should therefore be interpreted strictly according to Turek's explanation rather than Aristotle's. Turek explicitly states, *"based on my analysis, I can conclude that information may be considered a new concept only if we consider anew the narrowly understood Aristotelian concept of form*" (ibid., p. 39).

So, what is form and what is matter in Turek's form–matter composite? Form for Turek is an element that shapes formless matter. It imposes upon matter its external contours or shape, as well as its internal configuration. In fragment (3), Turek restates the position of realism, where reality exists independently of us and our conceptual schemes, linguistic practices, perceptions, and beliefs, while our thoughts

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72 (1) "*The term information or to inform has an origin in the Latin terms for 'information' and 'inform'. Information denotes an image, a visual representation, and outline; 'informo' is a verb that can be translated as 'giving form, shape', 'creating form', and figuratively speaking, educating or teaching. The prefix 'in' is translated as 'inside. 'in' and 'form' together have a special meaning that can be translated as 'internal shape' or 'internal composition.' To explain this 'internal shape' or 'internal composition,' we need to consult the Aristotelian theory of matter and form*" (Turek 1978, p.32).

73 (2) "*Form means shape or outline and is opposed by the term 'content.' In a scholastic philosophy (i.e. Aristotelian), form is an element of reality that shapes the shapeless chaos-matter. It is similar to the concept that shapes our thoughts (a concept gives shape to a thought).* (3) *If we assume epistemic realism, we admit that there is a one-to-one correspondence between concepts in the mind and the forms of things*. (4)*The universe appears to us as being composed of individual, separate things. Let us take a collection of identical balls. We perceive them not as one ball but as a collection of individual elements, each being a separate ball. Despite the fact that each one of them is a different element of a collection, we conceive of them under the same concept of 'a ball', which corresponds to their (common) form. To explain the existence of many individuals of the same genus (having the same form), we have to introduce another element, a prime matter. The role of this prime matter is to impose individuality on forms. Form shapes matter, matter imposes individuality on form in representatives of the same genus. There is no precedence for matter first, form second, or vice versa; this relationship may be considered figuratively as interaction: Matter or form cannot exist separately; they always constitute indivisible wholes. Balls are identical in form but different in matter, which is why we can perceive them as individuals" (*ibid., p.32).

74 Aristotelian hylemorphism clearly has several acute problems that exclude it as a potential model for information, at least when following the original too closely.

accurately reflect the external world.[75] Without this, the whole discussion would be meaningless, and we could not talk about the world outside of us as having any independent properties. As we will see, this position creates some tensions in Turek's philosophy, because later in his writings, he suggests some kind of mind–matter separation, implying the dual nature of reality (i.e. mind and matter).

In fragment (4), the role of form and matter in the form–matter composite is illustrated through the example of a collection of identical billiard balls. We have a collection of individual objects with the same form, external shape, and internal constitution (i.e. a billiard ball). We implicitly assume that these balls are made out of the same "matter" and have exactly the same shape. Matter, however, imposes individuality on each ball, making them unique. This individualization includes occupying an exclusive location in space, because no two balls can be in the same place at the same time. The form (i.e. a billiard ball) shapes matter into individual instances of the same genus. There is no priority between form and matter, and they cannot exist separately. In the example, the balls may seem like identical objects because of their shared form, but they are individual objects due to matter.[76]

Turek relates the concept of form to the concept of structure in fragment (5).[77] An abstract structure is a system with a given number of collections (or sets),[78] as well as relations between elements of those collections. An abstract structure can be exemplified by a DNA polymer, which is a highly organized complex of interconnected units of molecules that form complexes at multiple levels of organization, from the atomic to the molecular level. This is in fact a structure of structures, a structure whose elements are other structures.[79] The concept of a structure is contained within the concept of a form, meaning that

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[75] This claim is obviously a shorthanded complex epistemic claim that we have, within the limits of our sensory and cognitive systems, contact with the world as it is rather than its image, reflection, or other facsimile. Our senses and our minds have evolved to relay to us the state of what is out there, so we can survive (e.g., Searle 1998).

[76] It is an open question as to whether a location in space is a sufficient criterion for individuation. See, for example, Ladyman (2015).

[77] (5) "*The abstract structure is a configuration with a given number of sets and their relations. For example, DNA structure is defined by the configuration of nucleotides A, G, C, U. In these sets, we have defined 64 relations of three elements, defined as amino-acids, (i.e. AAC, CAA, etc.). Over amino-acids, we define the relations denoted as proteins. The DNA proteins are elements of another relation: genes. We should also note that nucleotides are relations defined over atoms. Thus, we have in this case structures of structures* (ibid., p.32).

[78] Strictly speaking, it would be a mistake to equate collections with sets, because sets come with certain implied properties, while collections do not have such restrictions.

[79] This example comes close to the following interpretation of the Aristotelian form–matter composite: *"In one understanding of matter, it is the counterpart of form—the stuff that gets informed—so that whenever there is a form, there must also be some matter that serves as its subject. In this conception, there will often be hierarchies of matter, with the most basic stuff, prime matter, at the bottom, and various form–matter composites at higher levels, which may themselves be conceived of as the matter for some further form. Wood, for example, is a form–matter composite that can itself serve as the matter for a bed."* (Pasnau 2015). This common-sense interpretation of hylemorphism comes from medieval times, but it was controversial even then.

every structure is a form, but not every form is necessarily a structure. This is what Turek explains in fragments (5) and (6).[80]Forms and structures may be involved in three relationships: (a) forms reducible to structures, (b) forms containing structures, and (c) forms without structures. In fragment(8), Turek explains that the concepts of form, structure, and information are closely related, but they are not the same, as we can see in Turek's definition of information as "*a certain subset of sets of forms reducible to structure*."

Turek defines three types of forms in fragments (9), (10), and (11).[81] Forms may or may not contain structures, and the differentiation between forms containing structures and forms that are reducible to structures defines the boundary between reductionist and non-reductionist theories.[82] By claiming that every form is reducible to structure, we assume that every structure can be represented in a formal language (i.e. described by some symbolic system), so we ultimately claim that everything is reducible to the language of logic and mathematics. In other words, we assert that the logico-mathematical

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[80] (6) "*The concept of a structure is contained in the concept of a form. This means that every structure is a form, but not that every form must be a structure. In the simplest case, a form is a structure and as such can be expressed in the formalisms of mathematics and logic.* (7) *Thus, we will differentiate three types of forms: (a) forms containing structures; (b) forms reducible to structures; (c) forms without structures. This differentiation is important if we assume that each existence is characterized by a certain form*. (8) *In this context, a question about the essence of information requires the precise description of the form that corresponds to this concept [of information]. I will be attempting to demonstrate that the concept of information means a certain subset of sets of forms reducible to structure*" (ibid., p.34).

[81] (9) "*Forms reducible to structures are investigated by the natural sciences and may be described by logic and mathematics or other formalism*." In this case, it may be asserted that "*form is an internal material content of the material being, as well as its internal and external configuration*" (Turek 1981). "*Examples of such structure-forms are seen in concepts of classical mechanics, expressed: ((P,Re), s, f, m, g, E_1,...E_r)*." The concept of a structure of natural sciences was taken from Wojcicki (1974, p.96) when referring to Turek (1978). "*Elements of the set P are material points. In a set Re of real numbers, we differentiate a certain interval T, whose elements are time intervals (moments in time). The relations s, f, m, and g defined over the sets P and Re, are basic, non-definable relations and denote notions of location, the force with which a point acts on another material point at a given moment, the mass of a material point, and the external forces acting on material points. E_i denotes the mathematical relations defined by the theory of classical mechanics. The statement that classical mechanics describes in approximation a certain part of reality is equivalent to the statement that the structure of classical mechanics is 'similar' to the form of this part of reality* (ibid., p.34). (10) *Forms that do not contain structures cannot be identified. They can be denoted only by simple (indefinable) concepts. When we consider Aristotelian prime matter, we think about it as being internally shaped by the form without structure. Thus, we need to have a way of referring to, denoting, something that is not recognizable to the senses, touching only the material world, a sea of structures delimited by prime matter* (ibid., p.37). (11) *Forms containing structures but not reducible to structures are forms with (containing) structures to which they are not equivalent. One form that is unreducible to a structure is the mind. Some aspects of this form have structures that are an object of specific sciences, such as biology, psychology, etc. The nonstructural parts of the mind are indicated by philosophy, art, and music, among others. Denying the unstructured part leads to a reductionist, mechanical, or computerized model of the mind* (ibid., p.36).

[82]"*Achievements of physical sciences appear to demonstrate that nature (its non-living aspects) is shaped by forms reducible to structures. One may, however, oppose this view and claim that forms of material (i.e. non-living entities) cannot be reduced to structures, just as we cannot reduce living beings to form–structures. This is a non-reductionist thesis*" (ibid., p.36).

representation is complete with respect to the universe. Forms without structures, meanwhile, are mental in nature. We can only describe them as simple, non-definable concepts taken to the limits. This claim obviously incurs some kind of mind–body dualism. While Turek can certainly posit the dual nature of reality, this puts him on a collision course with most of the contemporary philosophies of the mind and cognitive theories that claim that a purely physical description of nature is complete. While Turek's claim of dualism makes his proposal difficult to accept as a whole, it does not invalidate his concept of information. As we have seen already, and we will continue to see in other work, the act of balancing two aspects of information (i.e. abstract and concrete) pervades the philosophy of information (e.g., von Weizsäcker 1971, Floridi 2013, Davies 2016).

Turek defines information in fragment (12)[83] using the concepts of substance and form. In Turek's view, substance is not necessarily the Aristotelian substance but rather an individual complex of form and matter. Turek's substance can therefore be anything that can be differentiated as a form–matter composite, so it includes artifacts and natural objects. Example substances offered by Turek include spoken or written language, a magnetic tape, a computer punch card, a chromosome, a man, a computer, and a natural object. All these entities are concrete and belong to some genus. Turek writes "*if a certain substance S1 is formed by the finite structure I or its fragment, and the structure S2 can be formed by a structure I, I is called information*" (Turek, op. cit., p.4). In other words, a substance S1 is constituted/formed by the finite structure I (i.e. it has a finite number of elements), so if a substance S2 can also be potentially formed by structure I, we refer to structure I as "information" Thus, information is one of three enumerated types of form (i.e. a, b, or c, see quotation(7)) that can be either imposed on matter (prime matter) or found in substance (form–matter composite).The former is of type (a) (see above),while the latter is of type (b). Information can also be both realized and potential. In the case where the form has a structure (i.e. type (a) and maybe type (b)), information may be represented by logical and mathematical formalisms. Information must be, or is, what is potentially realizable or what has been realized in substance, as it is understood above. Structures that are infinite and conceptual (i.e. mental concepts) or structures that express categories or genera are not information in the sense set down by Turek. The nature of such abstract structures differs from the nature of structures as it is understood in this study. There is no further explanation in Turek's work about what these abstract structures could be, although some similarities with Davies' real–abstract dilemma for information come to mind.

[83] (12) "*I will use the concept of substance to denote a complex of matter and form shaping it. If we have a substance S1 that is formed by an individual structure I with a countable number of elements, and we have a substance S2 that can be formed by a structure I, then we will denote structure I as information*" (ibid., p.34).

Interpretations of information, like those in Shannon's theory of communication or information in a epistemic or linguistic context, derive from the concept of form in type (a).The substance here is understood as a complex/unification/fusion/oneness of matter and form. Information in this view is a species of structure. In Turek's view, there are abstract structures that resemble functions (i.e. relations/mappings between sets) and embodied/physical structures that are objects of scientific research. These embodied structures are formed by the elements of reality, namely objects and relations. This definition of structure should not be taken as an ultimate definition but instead limited to just what Turek understands as a structure.

So, what is the argument for the existence of such forms/information and their physical objectivity? This is what Turek claims:

> *We perceive the world as a world of individual things* [Note: this view of course may not hold on the level of QM]. *The pile of identical balls is not one ball but a set of identical elements, and each of them is a different ball. The elements of this set are different but identical in their form. To explain the existence of many individual objects/entities of the same type/form, we need to introduce the element of prime matter. This prime matter is responsible for the individuation of forms (i.e. in the same species, form shapes matter, and matter bestows individuality). (ibid., p.2)*

Thus, summarizing Turek's work, we may say that in the world of things (i.e. the universe), shapes are due to form and individuation is due to prime matter. Form realized in a physical medium is structure in the sense explained above, and this structure is information, so all elements of nature contain information as a structuring element. This is an epistemically neutral element of nature. This means that this element exists not because we perceive it, or because someone else perceives it, but because nature is this way. When reading Turek's work, the terms "information", "form", and "structure" must be interpreted as Turek's idioms. Alternative interpretations will distort the argument, so they should not be used with the principle of charity in mind,[84] because this would lead to bad philosophy.

The concept of information developed by Turek will henceforth be denoted as information_{TR} or I_{TR}.

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[84] The principle of charity, as it is used in this context, is not the principle governing the Red Cross, for example, although this may accidentally be the case. Instead, "*The principle of charity governs the interpretation of the beliefs and utterances of others. It urges charitable interpretation, meaning interpretation that maximizes the truth or rationality of what others think and say*" (Feldman 1998). See also Woodhouse (1994).

3.1.3 Between the physical and the abstract

Stefan Mynarski (1981),[85] in *Elements of system theory and cybernetics*, states that the term "information" without any qualifiers can denote quite dissimilar concepts, both real and abstract. In fragment (1),[86] he says that two kinds of information can be differentiated, information related to a physical object (i.e. anything physical) and information without a physical reference. In the former case, we have what he calls "real information", while in the latter case, we have "abstract information."

Fragment (2)[87] describes "abstract information" as being related to events or phenomena that do not exist as physical entities, so such information is created by the mind. We may say that it is a thought, assuming that thoughts are the content of the mind. Abstract information, as a creation of the mind, bears a strong resemblance to epistemic information as it is defined in this work, although with the restriction that epistemic information is information about any phenomenon, whether it exists or not and not necessarily in the past or future. (These restrictions are imposed by Mynarski.) We are unsure how Mynarski interprets the verb "exist "in fragments (1) and (2), but it cannot carry the same meaning for "real" (physical) and "abstract" information. A charitable reading of the text suggests that Mynarski is aware of the nuances for the existence of real and abstract entities, because he differentiates them into the physical and the abstract. However, he does not qualify the verb "exist." We focus here on "real information", information that exists in physical things or is connected with physical phenomena, as described in fragment (1).

Mynarski begins with a claim in fragment (3)[88] that information, or real information, is fundamental, although this term is not clearly explained by Mynarski. He further explains his concept of information in fragments (4), (5), and (6).[89] Information in this sense (i.e. fundamental) is related to the organization of a system, to its structure (4). The degree of "structural complexity" is inversely related to the system's

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85 Stefan Mynarski was an expert in marketing and cybernetics working at the Cracow University of Economics. He developed the concept of information as an element of the physical world, one that is responsible for form and organization. ("Stefan Mynarski" 2013).

86 (1) "*Information may exist in relation to the specific physical object or phenomena or independently of them. In the former case, we talk about real information, in the latter one, we talk about abstract information*" (ibid., p.140).

87 (2) "*Abstract information is related to objects and events that did not happen or have not happened yet. Thus, as such, it may exist by itself, independently of the existence of mater–energy composites (physical objects) and their matter–energy dependencies. Abstract information is a creation of a mind and is related to the problem of [en]coding*" (ibid., p.141).

88 (3) "*Information is not fully definable because of its elementary, fundamental character*" (ibid., p.138).

89 (4)"*…from the perspective of information systems, information is a measure of organization of these systems or a measure of the degree of their undefinability.* (5) *Information perceived this way is related to the constitution of a system and its orderliness.* (6) *Information related to the system constitution and internal organization is denoted as structural information*" (ibid., p.139).

undefinability. In other words, the more structure/organization a system possesses, the less that remains unknown about the system (i.e. it can be more precisely defined). Mynarski denotes information as it is conceptualized in fragments (3), (4), (5), and (6) as "structural information." This is a measure of a system's organization and consequently its undefinability or definability, depending on which way one views it. Mynarski does not explain what kind of a measure information is, such as probabilistic, deterministic, and so on. We may only guess from the later chapters of the book that Mynarski attempts to connect his concept of "real information as a measure" or his "structural information" with the concepts for measuring the amount of information that were defined by Shannon and Hartley. Alternatively, maybe we could interpret the "measurability of information" as simply being quantifiable.[90] However, every system, even a completely unorganized one, can be quantified (see, for example, Chaitin's measure of algorithmic complexity). Thus, the term "definability", if it means "quantifiability" requires some explanation, but one is not offered by Mynarski.

Furthermore, Mynarski discusses how real information (i.e. information in physical things, as defined in fragment (1)) relates to fundamental concepts of physics. He states in fragment (7)[91] that information is the third constitutive element of nature, with the first two being matter and energy. Structural/real information defines the *positioning/configuration* of elements in the organization of matter–energy systems. While the matter–energy balance is constant, the structure is not, so it changes, and this change of structure is equivalent to a change in information, as he claims in fragment (8).

In fragment (9), Mynarski states that any physical system may be conceptualized along the three dimensions of matter, energy, and information. Matter provides mass, substance, and phase. Energy is the

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[90] The term "measure" may have philosophical and mathematical interpretations. Finkelstein defines it as *"a symbol assigned empirically, objectively to attributes of objects and events of the real world in such a way as to represent them, or to describe them"* (Finkelstein 2005). In a stricter sense, a measure is a function that assigns a non-negative number to a subset of a set X under certain properties. The Shannon–Hartley measure of information is defined under the axioms of Kolmogorov Probability Theory and is therefore a probability measure (Hájek 2012).

[91] (7) "*Structural information is regarded on par with matter and energy as a third element of every system, because it defines its structure and its structure depends on it (i.e. the positioning/configuration of matter-energy in the system).* (8) *Because matter-energy is preserved (cannot be destroyed), it cannot be changed in any other way but only by changing its positioning/ configuration. But this represents a change of structure, or information* (ibid., p.139*).* (9) *Real information together with matter-energy is a concrete component of every system. Every system, process or phenomenon may be described in one of three perspective/dimension: material, energy, and information. In the material perspective, we define a specific physical substance (mass) occupying a defined space and having a certain physical form/phase. In the energy perspective, we define the movement/change of matter, which may be kinetic (in movement) or potential (configuration of elementary particles). In the informational perspective, we define a degree of organization of matter-energy, or in the other words, we describe a specific system*" (ibid., p.140).

ability of matter to change,[92] while information is the degree of organization, or to put it differently, it is the capacity of a system to yield to rational description.[93] Thus, physical things in Mynarski's metaphysics have three components/dimensions, each being equally important. In the modern view, the distinction between matter, energy, and information would be blended into matter–energy and information, suggesting that physical things are energy–matter phenomena that are shaped by information. Such an interpretation conforms, at least at face value, to the original ancient meaning of information as "*informare*" or giving shape. The concepts of matter and energy in Mynarski's work are not explained further, so it appears that he does not use them in the strict physical sense, because this would require further elaboration, but rather in the popular interpretations of the terms. (Mynarski was not a physicist.) Furthermore, Mynarski proposes in fragment (10)[94] that we may also look at the concepts of matter, energy, and information in three dimensions: matter–energy, matter–information, and energy–information. The first dimension defines the thermodynamic properties of the system and energy changes. The second dimension defines the properties that are dependent on the organization of the system's components, while the third dimension defines the capacity of the system to transfer/exchange/change information or communicate it. Only in these pair wise combinations do these three dimensions provide a complete description of the properties of a physical system. Of course, this is just Mynarski's view and not a theory of physics.

Mynarski states in fragments (12) and (13)[95] that information (i.e. real information) is the most important of these three dimensions, because it introduces coherence, structure, and order into reality, although the three elements of physical reality—matter, energy, and information—are mutually dependent (12).

[92] This definition of energy is rather simplistic, so it needs to be taken not as a strict definition but rather as a simplification of it. However, the inaccuracy of this definition does not affect the understanding of information.

[93] One may wonder whether an irrational description is possible. Would this mean it is incoherent? It seems that any description must already have some rationality in it. Thus, the term rationality must be further qualified to avoid ambiguity, but such an explanation is not offered by Mynarski.

[94] (10) "*Also, these two dimensions define the properties of a system. In the matter-energy dimension, we define the thermodynamic properties of the system related to the change of thermal energy into work or work into thermal energy. In the matter-information dimension, we define system properties related to the configuration and relationship between the different parts of the system. And in the energy-information dimension, we define properties of the system related to information transmission. Only in the three dimensions of matter-energy-information can we talk about control*" (ibid., p.140).

[95] (11) "*Information is therefore the most important ingredient in any system, as it introduces order and organization. Its close relation to energy assures the connectivity in the system, which is a guarantee of not only control but also of the system's coherence. Information without energy is blind and capable of creating chaos and disorder only* (ibid., p.140). (12) *Thus, it may be concluded that matter (mass) depends on energy, and energy on information, regarding their mutual interactions. But the dependency also works in the other direction, as energy cannot exist without matter and information without energy if we talk about their transmission or displacement. Thus, the mutual relationship of these three elements is the foundation of existence itself*" (ibid, p.141).

Mynarski concludes that these three elements are the foundations of reality or even, as he states, existence. One may argue, however, about the precise meaning of the claim that "*energy cannot exist without matter.*" One may ponder what Mynarski means here, seeing as how matter and energy are quantifiably equivalent in modern physics. Mynarski's suggested relationship between information and energy (i.e. that information cannot exist without energy) has also been indicated by other researchers, such as Landauer (1996) and Ladyman et al. (2007), even if the nature of such a co-existence is not entirely clear or without controversy. These dependencies have been explored further through Landauer's (1996) principle and the research on Maxwell's demon. See, for example, Landauer (1996), Bennett (2003), Lutz (2012), Ladyman et al. (2007), Moore (2012), and Hong et al. (2016).

The claim about information and energy does not concern some causal relation between energy and information. It only stipulates the existence of some sort of dependency between energy and information. The connection between matter, energy, and information, in Mynarski's study, is intuitive observation rather than an empirically confirmed fact, because he does not propose any adequate physical theory or experimental observations in support of this thesis. (Note that Landauer published his findings more than a decade later.) Thus, it is safer to regard these intuitions as merely plausible conjecture, at least in the context of Mynarski's study. However, such connections have resurfaced in several works (see Chapter Two on intuitions) in the form of the entropy of physical systems and information as its quantification, as well as in Landauer's ideas about the physical nature of information. Thus, Mynarski's intuitions, while not grounded in a solid physical study, may not be completely off the mark.[96]

The concept of information developed by Mynarski is henceforth denoted as information$_{MN}$ or I_{MN}.

3.1.4 Information in and about things

John Collier,[97] in his paper "Intrinsic Information" (Collier 1990), introduces two concepts of information: information-in-things (IiT), which is intrinsic information or information$_{INT}$ and denotes the structure/information embedded in physical things, and cognitive information (CT) or information$_{CT}$, which denotes information gleaned by a cognitive agent. Collier states in fragment (1)[98] that

[96] It often happens in science that intuitions predate the mathematical or formal expressions of phenomena. This was the case with Newton's theory of universal gravitation. It was first conceptualized as an intuition by Hooke, although Newton never acknowledged his debt to him. Two views of "gravitational forces" existed in Newton's times: Descartes theory of vortices and Hooke's concept of gravitation as attraction between masses. Initially, Newton preferred Descartes' solution, but Hooke's intuition ultimately won (Guicciardini, 2018). It may therefore be a similar story with Mynarski's view of information.

[97] John Collier received his Ph.D. in the Philosophy of Science from the University of Western Ontario in 1984. Currently, he is a professor in the philosophy program at the University of KwaZulu-Natal ("John Collier" 2018).

[98] (1) "*Physical things have properties that give them a definite structure and causal capabilities. If information is an intrinsic property of physical objects, then it seems likely that it is contained in their physical structure.*"

information$_{INT}$ is non-intentional (i.e. not about something),[99] but it is a (partial) cause of cognitive information. (Alternatively, maybe we should describe it as a primary source?) There is no direct relation (i.e. a one-to-one mapping) between information$_{INT}$ and information$_{CT}$. The emergence or creation of cognitive information is a complex process that is not completely understood. This process involves the combination of sensory information, background information, and other factors. (Note that this creates the problem of how the cognitive agent creates the meaning.) The emergence or creation of cognitive information is not discussed further in this study. Collier attributes causal powers to information$_{INT}$, but only in relation to information$_{CT}$ rather than with respect to nature. Collier argues that nature has a structure or organization, so we may say that natural objects are structural. However, he is not clear whether these structures are information itself or the results of information. Maybe the effect of information on things should be understood in the same sense as energy, which is not seen not as energy itself but rather through changes in the physical state of objects?

In fragment (2),[100] Collier justifies his claim of a causal factor existing behind information$_{CT}$ by stipulating that information$_{CT}$ (i.e. information "assimilated" by a cognitive agent) must (see fragment (3)) correlate with the outside world to be reasonably predictable and regular. Collier states that the notion of information is not related to cognitive gains, because it is more general than the notion associated with cognition. In other words, informatio$_{nCT}$ is a subspecies of information$_{INT}$. Furthermore, Collier observes in fragment (4)[101] that external objects (i.e. nature) must have a property that is a source of information for cognitive agents. This property is communicable, and it is foundational for cognitive information. For Collier, information$_{CT}$ denotes information that is derived from an interpretation of information$_{INT}$ by the cognitive agent. Information$_{CT}$ therefore corresponds to our concept of epistemic information in this work.

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[99] "*Intentionality is that feature of the mind by which mental states are directed at, or are about, or refer to, or aim at, states of affairs in the world*" (Searle 1998, p.64).

[100] (2) "*The world must contain either information itself, or else something that when properly connected to our cognitive processes is converted into information. This something is transmitted by physical and biological means; received information at the cognitive level must interface in a law-like manner with the transmissions. I am going to stipulate that what is transmitted is information, irrespective of whether there is a cognitive receiver.* (3) *This notion of information is more general than the common one, containing it as a species. It might be less confusing to use a new term for this broader notion, but technical usage has already extended information to the non-intentional realm*" (ibid., p.2).

[101] (4) "*…there must be some property of objects (in the world) that allow us to have information about them. This property must be causally based and communicable to us, as well as being commensurate with information in the vulgar sense*" (ibid., p.1).

In fragment (5),[102] Collier posits that the (primary) [103]source of cognitive information is the external world (i.e. information$_{INT}$). Information$_{CT}$ is therefore constructed from outside stimuli by a cognitive system/agent, so this agent creates epistemic or semantic information. Thus, information$_{CT}$ must have causal sources in the physical constituency of the world (6);[104] otherwise information$_{CT}$ would represent phantasms, illusions, or mirages. By creating information$_{CT}$, the mind imposes meaning upon the otherwise epistemically neutral information$_{INT}$.

But how is meaning derived from epistemically neutral stimuli by a cognitive system? One answer would be to say that no meaning is conveyed in the neural stimuli. Another answer would claim that information$_{INT}$ must be somehow isomorphic to information$_{CT}$, because these two information modes are highly correlated, although the latter one is "augmented" by meaning.[105] The precise notion of what he means by "isomorphic "here is not explained by Collier. Indeed, the creation of meaning is a problem for the theory of meaning, so it falls outside the scope of this study. The problem of meaning and the question of its *loci* (i.e. where it is seated) is part of an ongoing discussion between externalists and internalists.[106] However, it seems that Collier's claim that the substrate of information$_{CT}$ is physical, and that this substrate exists in physical things regardless of the presence of any cognitive system, is impervious to these discussions on the creation of meaning.

The concept of information developed by Collier is henceforth denoted as information$_{CL}$ or I$_{CL}$.

3.1.5 The universe is information

Tom Stonier (1990)[107] conceptualizes information as the third fundamental element of nature, with matter and energy being the first two. In fragment (1),[108] Stonier claims that information, together with matter

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102 (5) "*There is something 'out there in the world' that can be transmitted to intelligent beings who can understand the information it contains, and pass it around among themselves…Either this something is pre-existing meaningful information or else it can be converted by cognition into meaningful information*" (ibid.,p.5).
103 The term "primary source" means that cognitive information is "blended" with the content of the mind and mind-specific processes, which are components that may, in principle, differ between individuals.
104 (6) "*There are reasons to suppose the concept of information can be usefully extended to the non-intentional world. First, cognitive systems are physical (and also biological). This is not analytic, but it is a "deep" fact about our world. Whatever allows meaningful information at the cognitive level is constructed from physical resources. Physical reality constrains the way cognitive systems can work, including how they can process and interpret information*" (ibid., p.2).
105 The meaning assigned to sensory stimuli is agent dependent. For a trained ear, a noise in the forest can represent the calling of an elk, but to an untrained ear, it is just a noise. Ambiguous imagery like the rabbit–duck illusion is a good example of how the mind imposes meaning on otherwise meaningless optical stimuli (Myers 2003).
106 This is part of a larger discussion about where meaning is located, such as whether it is external or internal to the cognitive system.
107 "*Tom Stonier was a biologist, philosopher, information theorist, educator and pacifist. His scientific studies centered on information to provide a plausible explanation to the evolutionist concepts of Pierre Teilhard de*

and energy, is a part of the universe. However, information is not immediately visible, or at least observable, in the same way that matter and energy are. Stonier adopts the term "internal structure" to express the role of information in nature, using this term to state that while the visible shapes/forms of objects and phenomena reflect the existence of information, they are not what information really is. That is why when we talk about information, we usually do not consider the external three-dimensional structure of things (i.e. the visible shape). Information is therefore not the shape of the letters printed on a telegram or the notes in a musical score but rather something behind them. Stonier says that information is "*more subtle"* than what is obvious to the senses.

In fragment (2),[109] Stonier takes the "*text-book case*" of a falling tree in the forest to demonstrate how the anthropocentric perspective on nature limits our understanding of natural phenomena, including information. In this case, the word "Anthropomorphic" refers to seeing information as being dependent upon the (re)actions of a human agent. The lesson to take from the example of the falling tree is that if we limit our concept of information to the human perspective, we forget its real "nature." In other words, we forget that we left something out from the phenomena, namely its physical nature.

In fragment (3),[110] Stonier points out that as energy, which is the fundamental element of reality, has different forms of appearance or realization, so does information. Thus, anthropomorphic information is just one realization of information, a mode under which it appears to us. This is a significant claim, because it goes against all the epistemic definitions of information that prevail in the current discourse, namely that information is something that has some meaning to a human observer (or, more generally, any cognitive agent). Information has different physical realizations and different physical carriers, as Stonier explains in fragment (4).[111] Thus, one cannot assume that information is the external shape of the

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Chardin. He drafted the principle of the transformation of a primordial energetic soup (big bang) towards a pure informational state (the de Chardin's Omega point). ("Tom Stonier" 2019).

108 (1) "*Matter and energy comprise the surface structure of the universe. The surface structure of the universe is readily perceivable to our senses. The internal structure is more subtle. It is organized in a manner that is no so obvious: it consists not only of matter and energy, but of information as well. Matter and energy is what we interface with physically. Information is more subtle. We propose that "information" is as much a part of the physical universe as is matter and energy*" (ibid., p.2).

109 (2*) "If a tree falls, and there is no one to hear it, does it produce the sound? The answer is no if that sound exists only if it causes vibrations in a human eardrum. The answer is yes if one defines sound as patterns of compressed air produced by the crushing tree. The former interpretation is egocentric and obstructs any intelligent analysis of the world outside*" (ibid., p.8).

110 (3) "*Just as there exist different forms of energy—mechanical, chemical, electrical, heat, sound, light, nuclear, etc.—so do there exist different forms of information. Human information represents only one form of information*" (ibid., p.9).

111 (4) "*Information may be propagated as patterns of light, pulses of chemical substances, pulses of compressed air, pulses of radio waves, pulses of electrons. Information handling in the present generation of computers is*

physical carrier (see also the note in (1)). These "external forms" differ depending on the carrier media. Stonier posits that the diversity of carriers used in the communication of information demonstrates that information has physical realization, so it is a property of nature (or the universe) in the sense that everything that exists contains information. We just have problems recognizing information as a property of nature, preferring instead to focus exclusively on our own perspective (5).[112]

So, what is information for Stonier? He proposes several definitions in fragment (6).[113] What is more, he says information is a part of the universe, so this is "physical information" (7). There is also the information of an interpreter (i.e. cognitive agent interpreting physical information) or interpreted information. The difference between physical and interpreted information lies in the meaning added to the physical information. Physical information has no meaning and exists independently/objectively with an independent reality. Information equated with meaning therefore exists for some agent, and it is "*physical information interpreted*", as Stonier states in fragment (8). Meaning is not information but rather an aspect of information, according to Stonier.

Thus, according to Stonier, we have two types of information: (a) physical information existing independently without meaning and (b) information with meaning, at least for someone, or in other words, interpreted information. For Stonier, it is generally a human agent or other living system that does the interpretation, although again we do not have a fine differentiation here for what forms of living systems (e.g., animals, plants, bacteria, etc.) perform interpretation and thus add meaning to physical information. It seems that these more subtle divisions came to light later around the transition from the 20th to the 21st century, because artificial agents, tree lovers, and animal activists were not yet common at the time. Stonier's division of information clearly separates ontological and epistemic information, as also proposed in this current work. Stonier goes further by declaring: "*Information exists. It does not need to be perceived to exist. It does not need to be understood to exist. It requires no intelligence to interpret*

digital. In the human nervous system, there are dozens of neurotransmitters and other related substances which can enhance or inhibit nerve impulses. The nature of the information inside people's heads must be different from the one contained inside the computer" (ibid. pp.10-11).

112 (5) "*Perhaps part of the problem of recognizing and accepting the idea that information has physical reality and constitutes an intrinsic property of the universe stems from the fact that we ourselves are so deeply embedded in the processing and transmitting of it*" (ibid., p.12).

113 (6) "*Information as used in this book is a property of the universe—it is a part of its internal structure.* (G5) *In contrast to physical information, there exists human information which includes the information created, interpreted or transmitted by human beings. We define human information as that which is perceived, created, or transmitted, without making a judgment as to its accuracy or reliability.* (8) *If information has an independent reality, meaning does not. Meaning involves the interpretation of information in relation to some context…we must not confuse the detection and/or interpretation of information with information itself*" (ibid., pp. 17-18).

this. It does not have to have meaning to exist. It exists. Without this insight, it becomes impossible either to understand the physical universe or to try to develop a general theory of information" (ibid., p.24).

Stonier also provides an interesting definition of meaning by stating, *"the phenomenon we call meaning involves a gradient of relationships between physical information and mental interpretations*." Of course, limiting meaning to "mental interpretations" inevitably excludes artificial and natural agents as interpreters of information. "Meaning", as it is understood in this study, does not have such limitations, so it is more general than Stonier's concept of meaning. The term *"a gradient of relationships between physical information and mental interpretations"* hints at meaning having different quantifiable (as they can be ordered by a gradient) realizations for different agents, not just from agent to agent of the same species but across species. Such an interpretation would confirm our current understanding of meaning in that it is very subjective. Stonier uses the predicates "real", "latent", and "potential" to enumerate the different modes in which information can be conceived (see fragment (9)).[114] Stonier emphasizes that these terms denote the same thing, however, so they are not different types of information. They are just different modes in which that information can be perceived. In other words, "information" is the same under all these denotations, but they show different aspects of information that may be mistaken for information itself.[115]

In fragment (10),[116] Stonier observes that there is an opportunity to define a different concept of information if we are careful about the details of the conceptual context. This statement points to the reason behind different perceptions of the nature of information, many of which often conflict. The difference stems from the confusion between what exists and what is transferred, interpreted, or processed. It seems there is also a philosophical problem here: We resist attributing some physical, intrinsic capacities or role, even a causal role, to information, but this position brings us closer, as some would think, to Aristotle's *morphe* and *hylemorphism*, which has generally been judged as not being philosophically viable. However, this may not hold true anymore,[117] at least for some aspects of this

[114] (9) "'*Real' information … is… interpreted in this book as meaningful information, i.e. the information than can be conveyed to a receptor. 'Latent' or 'potential' information will be considered as real information, as real as the energy contained by an object or a system that cannot be observed. That is, the heat contained by such a system exists whether we observe it or not*" (ibid., p.25).
[115] One cannot help but recall the parable of the blind men and the elephant (Shah 1974).
[116] (10) "*It becomes impossible to develop a general theory of information as long as we confuse various aspects of information with its transfer, processing, or interpretation. This book assumes that there exists a dichotomy between (a) the information intrinsically contained by a system, and (b) the information which may be conveyed by the system to some receptor*" (ibid., p.25).
[117] See, for example, Marmodoro (2013), Austin (2017), or Rea (2014). Also: "*Aristotle famously held that objects are comprised of matter and form. That is the central doctrine of hylomorphism (sometimes rendered as 'hylemorphism'—hyle, matter; morphe, form), and the view has become a live topic of inquiry today.*

concept. As we saw with the works of Turek and Mynarski, Aristotle's *morphe* and *hylemorphism* may be impossible to defend, yet alone define, in its original formulation, but more restrictive modern interpretations may be formulated in a more acceptable way.

Fragment (11)[118] contains several interesting claims. The first is that chemical processes or physical processes (i.e. processes in inorganic matter) are, in general, information processes or processes manipulating information. The second claim is that the same can be said about organic processes (i.e. those which involve organic matter), so there are no material differences between these two types (inorganic and organic) processes. The obvious conclusion is therefore that natural processes are information processes in the sense that they manipulate information that is encoded in a physical structure. This information is perceived as patterns or organization. Alternatively, we may say that every physical object has some structure that encodes information. For Stonier, these "patterns of organization" are not information but rather encodings or expressions of information. We evidently see here an idea that would later reemerge as pancomputationalism, which is still a difficult pill to swallow for some because it requires a redefinition of what computing is.

In fragment (12),[119] Stonier formulates "the heart of the concept of information." He links information with organization, but information is more than just a static organization—it has causal powers to "*organize or maintain an organized state of a system.*" Energy is seen as the capacity to perform work, although this is a greatly simplified description of energy, so information is the capacity to create and maintain order. In fragment (13), Stonier states that order is the opposite of randomness, but it is not clear what Stonier means here. Even seemingly random phenomena exhibit structure and can be quantified (e.g., Chaitin's measure of complexity or even Shannon's and other related measures for random

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Contemporary proponents of the doctrine include Jeffrey Brower, Kit Fine, David Hershenov, Mark Johnston, Kathrin Koslicki, Anna Marmodoro, Michael Rea, and Patrick Toner, among others. In the wake of these contemporary hylomorphic theories, the doctrine has seen application to various topics within mainstream analytic metaphysics" (Bailey &Wilkins 2018).

118 (11) "*The information which is processed by the solution of potassium permanganate interacting with a crystal of manganese dioxide—or by the human cell interacting with a strand of DNA—is the organizational pattern of the carrier of information, the MnO_2 or the DNA. That is, in each and every instance, the information is physically encoded as patterns of organization*" (Stonier, op.cit., p.25).

119 (12) "*Any physical system which exhibits organization contains information. The definition of the term 'information' becomes analogous to the physicist's definition of the term energy; energy is defined as the capacity to perform work. Information is defined as the capacity to organize a system or to maintain it in an organized state.* (13) *Organization is a reflection of order. A structure or system may be said to be organized if it exhibits order. Order is non-random arrangement of the parts or the structure or system. Randomness is the opposite of order.* (14) *Organization and information are, by definition, closely interlinked. However, they are different: one cannot have a shadow without light, but a shadow and light are not the same. A shadow is the manifestation of light interacting with an opaque object. Likewise, organization is the manifestation of information interacting with matter and energy*" (ibid. pp.25-26).

phenomena). Stonier's randomness must refer to the lack of any visible (i.e. recognizable) organization. In fragment (14), Stonier states that information and order are not the same, demonstrating that he is not equating information with order or structure. He uses here the analogy of light and shadow to convey that organization is a "manifestation" of information. In other words, it is the result of information interacting with matter and energy, much like how a shadow is a result of light interacting with an object rather than just the light itself. This critical claim about the interaction between matter, energy, and information is not explained further, however. We may only guess that Stonier's view is that information can be perceived as organization and structure, but it is not identical to these phenomena.

Fragments (15), (16), (17), and (18)[120] concern information as an abstract concept, but with the addition of physical realization, as indicated in fragment (17). Information is therefore not a concept that can be reduced to physical phenomena, like a rainbow, for example. It is more like energy, although it is not clear in what way, so this is more of an intuition. Stonier brings up the comparison between energy and information many times. Energy, before it was defined as a phenomenon in its own right, had been disguised in several concepts, such as mass, force, heat, radiation, and work. Only in the process of understanding the nature of heat, mass, and work did the concept of energy finally emerge. The case is similar for information, which has been obfuscated by several concepts, such as form, shape, organization, and *morphe*. Only later was a common, unifying concept of information developed. In fragment (18), Stonier observes that to quantify these different notions, a new concept was needed: information. Just as energy was abstracted from concepts like mass, force, heat, work, and other energy-related phenomena, information was abstracted from concepts like form, shape, organization, and *morphe*. Only in this form could we start quantifying it and assign a number to it. However, we need to be careful not to fall into the trap of believing that if we can measure something, we know it. Associating

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[120] (15) "*It is important to emphasize the conceptual necessity for an abstract term such as 'information.' Information is a quantity which may be altered from one form to another. Information is a quantity which may be transferred from one system to another. This is not true, at least to the same degree, for the more concrete terms 'order,' 'organization,' 'patterns,' or 'structure.'*(16) *Information, like energy, is an abstract quantity. What the present work proposes is more than that, that information, like energy, also possesses a physical reality.* (17) *To be more precise, heat (involving uncorrelated photons in a crystal or randomly moving molecules in a gas) is the product of the interaction between matter and pure energy. Structure is the product of the interaction between matter and pure information. Information may be considered as the more abstract quantity, which, when added to matter, manifests itself as structure (organization). Such a definition leads to a different conceptualization of information from that of the communication engineers. Such a definition also differs from the standard dictionary definition, which defines information as, for example: knowledge, news or what is told.* (18) *To the argument that what we are really talking about is 'patterns' and 'organization,' the answer is that 'information' is a more abstract generalization which one needs in order to measure it by some universal measure such as 'bits.' It becomes as difficult to measure quantitatively a pattern or a structure in term of bits without the aid of the abstract concept 'information,' as it is to measure in joules the output by a lamp without the more abstract concept 'energ*y'" (ibid., pp.28-29).

information with numbers—such as in the cases of Shannon and Hartley, Fisher, and Chaitin, as well as Burgin (2003, 2005), who, as we will see later, lists about 32 mathematical formulas for information—does not clarify the essence of information. On the contrary, we may say these quantifications have rather blindsided us, acting as a red herring of sorts.

In fragment (15), we see some incongruence emerging in Stonier's description of information. He claims that information may be converted from one physical form to another, but this is only true if we assign meaning to information. In our view, what is common between different carriers is meaning rather than information, at least if information is conceived as structure. If we see information purely in terms of physical form, there is no connection between, for example, a music sheet with Chopin's nocturnes and a recording of the same music on compact disc, because their physical structures are radically different. These physical carriers embody different structures, so they contain different information in the sense of organization. Their similarity, however, lies in the meaning assigned to these structures by a cognitive agent, so recognizing this similarity requires the presence of the mind. (To be more accurate, we would have to refer to the presence of some sort of information processing system.) Thus, what links two or more different physical structures—such as a music sheet, a pattern of air pressure waves, patterns of light pulses in an optical cable, magnetic patterns on a tape, the groves on a vinyl record, or the pit patterns on a compact disc—is simply the potential for these structures to be interpreted in the same way. Nothing intrinsic in the structures themselves makes them similar. For example, there is no intrinsic similarity between waves of air pressure conveying a sound and a digital recording of 0s and 1s or a music score written on a sheet and the grooves on an LP. The transfer of structures and organization in physical objects therefore needs to be mediated by the meaning in someone's mind.

One may ponder what the best word for information is, such as form, structure, organization, pattern, order, and so on. Stonier's use of these terms is not consistent. He may think that these words are synonymous or that none of them alone is adequate to define information, so they should all be used together. However, it seems that "structure" is not the right word after all. It implies, or may imply, the existence of something concrete and tangible, a sort of scaffold. Information does not seem to be like that, though. Terms like structure, organization, and pattern refer more to expressions of information or some factor imposing order or organization. Thus, it seems that the most fitting term for information, at least in Stonier's sense of it, is "order" or "organization." This conveys the causal role (formative power) of information and its effects on matter–energy in a way that other terms do not.

We henceforth denote the concept of information developed by Stonier as information_{ST}

3.1.6 Information is the mathematics of the heavens

For Michał Heller,[121] his view of information has resulted from studies into the fundamental structures of the cosmos (i.e. the universe), related mathematical models, and the properties of nature (i.e. physical phenomena here on Earth). The first fragment (1)[122] comes from Heller's book *The Introduction to the Philosophy of Science* (Heller 2009). In a series of observations, Heller outlines his vision of information in nature. Heller posits that the laws of nature may be interpreted as information, or at least as providing information, and that this is a complementary view to the scientific structuralism. What he means by "complementary" here is not clear, but it may be interpreted as stating that there is no structural–information dichotomy in his view of nature, meaning that structure and information are both characteristics of nature. In fragment (2), Heller, when interpreting Shannon's theory of communication, claims that an increase in the information content of a structure is inversely proportional to the structure's degrees of freedom.[123] Heller observes that the laws of nature impose certain constraints on nature's structures, so in a way, they control what can and cannot be, so not everything is possible in physics.[124] What is possible is therefore just the limited, although very large, number of combinations for the fundamental elements, being constrained by physical laws. The presence of quantum or discrete building blocks therefore makes the universe possible. This view is also reflected in the models of the universe found in combinatorial ontologies, ancient atomism, or the ontologies of Leibnitz and Laplace.

121 "*Michał Kazimierz Heller is a Polish professor of philosophy at the Pontifical University of John Paul II in Kraków, Poland, and an adjunct member of the Vatican Observatory staff. In 2008, Heller was awarded the Templeton Prize for his extensive philosophical and scientific probing of 'big questions.' Heller also founded the Copernicus Center for Interdisciplinary Studies in Cracow."* ("Michał Heller" 2018).

122 (1) *"Informational interpretation of laws of nature may be seen as a complement rather than a competing option to the scientific structuralism.* (2) *According to the modern theory of information, the increase in information content arises in transition from a set (of larger number of degrees of freedom) to a more limited set (i.e. the information content of a set of all letters will increase for a set of letters expressing some sentence).* (3) *Thus, information increases when the number of degrees of freedom decreases.* (4) *Limited sets (sets with constraints imposed on them) are nothing but certain structures, and every structure has certain information. The more restrictions a given structure possesses, the more information it contains.* (5) *As the world is a certain structure, it contains information, or this structure-world encodes information. This information is decoded by science and formulated as laws of nature*" (Heller op cit., pp. 62-63).

123 The degrees of freedom are the number of independent variables (dimensions) that a system may be characterized or exist in.

124 An interesting interpretation of the relation between the laws of nature and the organization of the natural world is suggested by Laughlin. He writes that "*At the most fundamental level, the laws of physics are laid out in plain sight for everyone to see. Yet you cannot generally predict things with these equations […] however, there are collective principles of organization encrypted into these equations*" (Laughlin 2008, p.36). Thus, you could say that the laws of physics define the principles of organization or that information is expressed through the laws of physics. It is, however, a very farfetched conjecture.

The laws of nature, for Heller, act like information (see fragments (3) and (4)), and they determine or constrain what is possible. The more constrained or complex (and at the same time, less likely to exist) structures are, the more information they contain, according to Shannon's law. So, do these structures code information (see fragment [5]) or express information? Is Heller suggesting here that the laws of nature are information, or is he saying that they express information? This resembles the problem of the chicken and the egg, but we do not get an answer to this in Heller's writings[125].

This interpretation of nature, information, structures, and natural laws is further discussed in Heller's article titled "Science and Imagination" (Heller 1995). In fragment (6),[126] Heller perceives structures and the laws of nature as information. This information (as natural laws) is partially decoded and expressed in scientific laws. These scientific laws represent a fragment (or an aspect) of cosmic structures, and they are clearly much less complex than these natural structures really are. However, Heller does not explain in what sense the laws of nature are structures.

In fragments (9) and (10), Heller states that while the laws of nature and structures are not isomorphic, they act in concert with nature, implying a sort of interdependency. In other words, the laws of nature are the results of nature's properties to some degree, although to what degree we are unsure. The point of this remark is to convey that laws and natural structures are not the same but somewhat interdependent. Heller refers to this similarity between nature and abstract mathematical structures as "harmony." Harmony, as proposed by Heller, is an intriguing property of abstract models of the cosmos. According to Heller, the mathematical models of nature are highly simplified (when compared to the complexity of nature) and formalized, so they have a high level of abstraction. They are therefore not of the same "nature" as physical entities. So, how are they able to reflect some of nature's properties, often quite accurately? One may be tempted to see Platonic forms in these abstractions and nature as their realization. Such a view would certainly explain this strange harmony. This would be the position of modern or mathematical Platonism, which by the way has little to do with the ontology of Plato (e.g., Linnebo 2018).

Additional explanations of the concepts of nature, structure, information, and form can be found in Heller's paper titled "Evolution of the concept of mass" (Heller 1987, pp. 152-169). In fragments (11)

[125] See the similar comments on the priority of laws of nature and nature's organization expressed Laughlin (Laughlin 2006, pp. xi-xvi).

[126] (6) "*The modern theoretical physics suggests that the world does not possess structure but is a structure.* (7) *This structure contains encoded information or is information.* (8) *Science decodes its fragments by fitting mathematical structures to the structures of cosmos.* (9) *The decoded fragments of information are denoted as scientific theories or models of nature.* (10) *The mathematical structures of our theories and the structure of cosmos are not isomorphic but there is a strange resonance, a harmony between them. Because of this resonance–harmony, theories that are grossly simplified in comparison to the structures of cosmos harmonize with the world, reproducing some of its (structural) properties* (Heller 1995, p.170).

and (12),[127] Heller posits that information can be thought of as a foundational element of nature instead of matter. In particular, modern physics models the universe through mathematical formulas, which are shapes/structures without content. In this view, is information expressed through "empty" mathematical structures, or are these structures information? Heller does not address this problem.

In fragments (13) and (14), Heller suggests that even if there is something beyond these "Platonic" structures, modern science is unable to detect it. Such a statement approaches the position of epistemic structuralism (i.e. adopting the mathematical version of structuralism), which claims that the structures of nature are mathematical structures, and nothing else (i.e. ontology) can be known about them.

In fragment (15), Heller observes that this concept of information is not the same as the concept of information that arises from the Shannon's Theory of Communication (ToC). The ToC would perceive the structure as encoding something rather than as the "stuff of the universe." Thus, the concept of information in the ToC is inadequate for expressing anything beyond the concept of a number for information. In fact, Shannon's ToC does not define information, as some have come to mistakenly believe, but rather its measure. To put it more precisely, the function defined by Shannon is a measure of information, with the elementary unit of information being a digital bit (i.e. 0 or 1). Thus, Shannon's measure of information does not define information any more than the definition of a kilogram defines what mass is. It just quantifies a certain property of a physical phenomenon under certain assumptions. Such a reading of the ToC will be less prone to misinterpretation and possibly closer to Shannon's original intentions.

The concept of information developed by Heller is henceforth denoted as information$_{HL}$ or I_{HL}.

[127] (11) "*As one must have some image of the world, the image of matter as foundational 'stuff' must be substituted with another one. The image of the world not as material composite but as a pure form would correspond much better with the findings of modern physics.* (12) *All models of the cosmos constructed by modern physics are abstract mathematical models. They do not have anything else but shape and structure (i.e. they are purely formal schema).* (13) *Even if the real world contains something beyond the form, the modern methods of physics cannot detect it; this something that slips through the net of mathematical-empirical methods.* (14) *In this sense, the world of physics is a pure form.* (15) *The same concept can be expressed as follows: if we define information as the constraint on degrees of freedom (possibilities), each law of physics is information as it limits the possibilities of nature.* (16) *One may think that the "stuff" of the universe is nothing else but information. But the current understanding of information is purely formal (Shannon–Hartley theory of information).Thus, information is reduced here to structure, not to what this structure is filled with. In this view, the structure of the world is an information code, or encoded information, and the role of science is to decipher this code*" (ibid., p.30).

3.1.7 The universe computes

Gordana Dodig Crnkovic[128] discusses the nature of information in the context of ontology (i.e. what exists) and computing. In fragment (1),[129] Dodig Crnkovic claims that information has an objective presence, so it is not an intentional object (i.e. an object of thought) but instead represents objective ontology (i.e. fundamental ontology). Dodig Crnkovic's ontology is not an ontology of computer objects—such as virtual ontology, an ontology of knowledge systems or computer games, or such like—but rather an ontology responding to the general question of "What is?"

In fragments (2)[130] and (3),[131] Dodig Crnkovic conceptualizes nature as a complex of patterns (or structures) and natural processes, which are transformations of, or interactions among, these structures/patterns. By recognizing natural structures/patterns as information—and she denotes these natural uninterpreted (meaning not assimilated by a cognitive agent) patterns as "proto-information" or "potential information"—the whole of nature appears to be formed on, or by, information or, more accurately, proto-information. It follows that natural processes are computations in the sense that they process/transform or act on information ("proto-information") or structures that are information. Thus, from this perspective, computation is information processing, but not in the narrow sense of the UTM (and therefore the Church-Turing thesis), where information is a series of signs and computing involves UTM artifacts performing syntactic-informed operations on these signs. Instead, it occupies a more generalized sense where information is a structure/organization and computing involves general transformations of these structures. In other words, they are structural transformations rather than symbolic operations.

Dodig Crnkovic states that information is part of the fabric of the universe in the sense that information forms the structures/patterns that in turn form nature.[132] It is not clear whether information is a structure

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128 "*Gordana Dodig Crnkovic is Professor in Computer Science at Mälardalen University and Associate Professor at Chalmers University of Technology. She holds PhD degrees in Physics and Computer Science. Her current research is in Morphological computing and the connection between computation, information and cognition via interacting agents on different levels of organization - from physics to biology and cognition*" ("Gordana Dodig Crnkovic" 2018).

129 (1) "*Understanding patterns as information, one may infer that information is a fundamental ontological category*" (Dodig Crnkovic 2012, p.1).

130 (2) "*[Information] is a fabric of reality and reality consists of informational structures organized on different levels of abstraction/resolution*" (Dodig Crnkovic 2013a, p.6).

131 (3) "*Information is what constitutes the structure of the universe, at any given moment*" (Dodig Crnkovic 2008, p.2).

132 The term "fabric" is frequently used in discussions about structural realism. It was used in David Deutsch's book *Fabric of Reality* (Deutsch 1998) and Brian Greene's book *The Fabric of the Cosmos* (Greene 2004) in the sense of being the "foundational stuff" of physical reality. In both books, the term "fabric" refers to the basic

qua structure or exists in structures, as well as what these structures are (see fragment [4]).[133]So, what structures does Dodig Crnkovic have in mind? Are these structures perceivable or are they the structures of mathematical models of nature or other deep structures of some sort? In the absence of clear definitions, we are left with the difficult task of supplying an interpretation ourselves, namely that Dodig Crnkovic's natural structures are proto-information or potential information.

Fragments (5)[134] and (6) [135] bring important clarifications. Fragment (5) states that proto-information is, or may become, information for a cognitive agent. Thus, proto-information is potentially information about the world when it is received and processed by a cognitive agent. In fragment (6), we encounter the condition that proto-information is always embedded in a matter–energy entity. This means that there is no information without a physical embodiment (i.e. a physical carrier). This condition therefore excludes any non-physical concepts of information, such as a thought or other abstract Platonic-like form. For Dodig Crnkovic, information, as opposed to "knowledge of the world as information", is clearly physical, and it exists at the foundations of reality (i.e. the fabric of the universe) and at the foundations of information for a cognitive agent.

Dodig Crnkovic extends the concept of information beyond ontological and structural claims and makes information a part of the world view of pancomputationalism, natural computing, morphological computing, or info-computationalism.[136] In fragments (7), (8), and (9),[137] she provides another perspective on information, namely that information (organization) is as fundamental to nature as change is. The claim that nature is structural and constantly in flux is thus "translated" to the claim that structures that form/constitute nature are actually information that undergo constant changes. This notion of "constant changes" may be seen as a Heraclitan flux or as it is in modern language computations. Computation, in this view, is the information/structure flux. We may therefore ask: Is this *information rhei* rather than *panta rhei*? This new perspective changes our current conceptualization of computing, which his mostly

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aspects of nature or the physical world of time, space, quantum mechanics, and symmetry, to list just a few concepts associated with this term by Deutsch and Greene. We will retain this interpretation for this term.

133 (4) "*nature [is] informational structure—a succession of levels of organization of information*" (Dodig Crnkovic 2012, p.5).

134 (5) "*[proto-information]becomes information for a cognizing agent in a process of interaction through which aspects of the world get uncovered]*" (Dodig Crnkovic 2013b, p.1).

135 (6) "*There is no information without representation, all information is carried by some physical carrier*" (Dodig Crnkovic 2009, p.20).

136 See, for example, Dodig Crnkovic (2009, 2011, 2012a) for a summary of claims and references.

137 (7) "*The ontologically fundamental entities of the physical reality are information (structures) and computation (change)*" (Dodig Crnkovic 2009, p. 2). (8)"*information and computation are two interrelated and mutually defining phenomena—there is no computation without information (computation understood as information processing) and vice versa, there is no information without computation (information as a result of computation)*" (Dodig Crnkovic 2013b, p.1) (9) "*no matter if data form any symbols; computation is a process of change of the data/structure*" (Dodig Crnkovic 2011,p.305).

regarded as Turing's notion of computing extended (justifiably or not) by the Church–Turing thesis.[138] (Note of course that the Church–Turing thesis is conjecture rather than a physical or metaphysical law.)In the view proposed by Dodig Crnkovic, the Turing computational model is a subset of natural computation, not the other way around, because the former does not represent a generalized concept of computation (Dodig Crnkovic 2011, p. 304-306) as is often claimed (e.g., Piccinini 2015, 2017). Indeed, Turing computation is at most a generalized concept for computation on symbolic (i.e. human-constructed) structures. Natural computations are therefore much richer than what the Turing computational model would permit. In this view (i.e. computation as information/structure flux), all processes in nature are computations on information. In other words, computation is understood as information processing, where changes and transformations are applied to structures that are information. The Church-Turing thesis was extended by Wolfram to cover this concept.[139]

In fragment (9), Dodig Crnkovic redefines computing from Turing's symbol-processing to information/structure change.[140] But is Dodig Crnkovic's view of computing an intuition, or is it a well-justified claim? We do not have a definite answer to this question, but we have several possible answers, just as we have several variants of pancomputationalism. The ideas of pancomputationalism, natural computing, morphological computing, and info-computationalism worlds are not without controversies, even if they sound plausible.[141] These claims are difficult to swallow because they change a certain established paradigm, an entrenched way of seeing things. Pancomputationalism and natural computing, in some versions, carry heavy metaphysical claims that are difficult to substantiate, although can we ever substantiate such deep metaphysical claims? When interpreting Dodig Crnkovic's words, one may, however, reject or dispute the concept of natural computing or pancomputationalism but retain the concept of information as a structure of nature and the flux/changes in nature as information changing, because the concept of pancomputationalism depends upon the latter claim, but the opposite is not true.

The concept of information developed by Gordana Dodig Crnkovic is henceforth denoted as information$_{DC}$.

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[138] "*The Church-Turing thesis (formerly commonly known simply as Church's thesis) says that any real-world computation can be translated into an equivalent computation involving a Turing machine. In Church's original formulation, the thesis says that real-world calculation can be done using lambda calculus, which is equivalent to using general recursive functions*" ("Church-Turing Thesis" 2018).

[139] "*The Church-Turing thesis has been extended to a proposition about the processes in the natural world by Stephen Wolfram in his principle of computational equivalence , which also claims that there are only a small number of intermediate levels of computing power before a system is universal and that most natural systems are universal*" ("Church-Turing Thesis" 2018).

[140] See, for example, the claims of soft computing in Nakajima et al. (2015).

[141] See, for example, the references in ("Pancomputationalism" 2019), Piglucci (2013), or Copeland (2017).

3.1.8 Information is in everything

Cesar Hidalgo (2015),[142] in his book *why Information Grows: The Evolution of Order, from Atoms to Economics*, sets out in fragment (1) the framework for his view of information.[143] He posits that "*the world is made out of matter, energy and information*" without explanation other than to state that everything in the world (i.e. matter and energy) in addition to occupying space–time has some form or shape, which is synonymous with information for Hidalgo. Thus, from this viewpoint, information is one of the three essential components of the universe in the energy–matter–information triad. This information is responsible for the organization/shape of matter–energy. The physical world (i.e. what exists objectively in reality) is characterized by order, the arrangements of things, structure, or the organization of matter–energy at all scales, from the sub-atomic to the cosmic. This idea is expanded further in fragments (2), (3), and (4),[144] where Hidalgo observes that the universe is full of—or as he puts it, "pregnant with"—information. Visible structures are not information, although they do manifest in the presence of information. In other words, information should not be equated with the visible structure of something, and this thought has come up many times in this study. Information is order, an organization of things or objects. The order in things also characterizes man-made artifacts, from a pen to the Large Hadron Collider (LHC).[145] Indeed, the type of order/organization defines what something is. This seems to echo, albeit rather distantly, the ancient concepts of form or *eidos*. Form and *eidos* are replaced by Hidalgo with information, making form or *eidos* less mysterious and quantifiable. Information as order or arrangement in things is intrinsic to making those things what they are,[146] so for Hidalgo, the fundamental concept of information is the order or arrangement of things.[147]

In fragment (5), Hidalgo clearly states that information is separate from meaning. Although information can be interpreted as a message with meaning, [148]it can also be regarded as a source of the message in the

[142] "*Cesar Hidalgo is the MIT Associate Professor and the leader of the Macro Connections group at the MIT. He has a degree in statistical physics and he is also an expert on Networks and Complex Systems*" ("Cesar Hidalgo" 2015).

[143] (1) "*The universe is made of energy, matter, and information*" (Hidalgo 2015, p.15).

[144] (2) "*[The world) is pregnant with information… it is … a neatly organized collection of structures, shapes, colors, and correlations. Such ordered structures are manifestations of information*" (ibid. 17).

[145] (3) "*Information is physical; information is always physically embodied; information is physical order; information is inherent in all the physical objects we produce – because they embody physical order*" (ibid., p.19).

[146] (4) "*Order means physical order—the way in which parts of the system are arranged. By definition, physical order is information. Physical order is what differentiates the Bugatti [an expensive car brand] before the crash from the wreck that was left after the crash*" (ibid. 196).

[147] An arrangement of things is meant to represent how things are combined into the whole (i.e. it is the structure of things).

[148] (5)"*information is meaningless; information is not about something, it is physical order embedded in objects; information and meaning refer to concepts that are fundamentally different; what travels through electromagnetic waves is information not meaning; meaning emerges when a message reaches a life form or a*

right circumstances. However, meaning is not a defining characteristic of information, because information with meaning (i.e. epistemic information in this work) only emerges when information encounters a cognitive agent, whether artificial or natural, because the agent creates meaning. Information as it is understood by Hidalgo as the organization of things is epistemically neutral, so it has no intrinsic meaning.

We can derive meaning from some natural phenomena because information as order is always present everywhere.(Indeed, this universal capacity of the human mind has been understood and abused by diviners, shamans, and seers seeking to derive meaning from bones, tea leaves, sheep's entrails, and so on.) We can even see epistemic information where there is none, such as in TV shows, the popular press, or social media posts. From this position, the claims that information surrounds us and that we are information-processing systems can be easily comprehended. All man-made artifacts are also filled with information as order, such as cars, tables, radios, and so on. Indeed, because nature is full of information, everything in nature embodies order (although the origins may differ), and physical order is information.

Meaning is the interpretation of a quality, a sort of property, attributed to a physical phenomenon or an artifact by a cognitive agent. It is fundamentally different from the *"physical order that carries the message* " (ibid., p.16). Similar observations were made by Boltzmann, Shannon, and Schrödinger. What is left after separating meaning from physical phenomena is physical order. Boltzmann, Shannon, and Schrödinger, each in their own way, denoted this "physical order" as information. Such information is independent (i.e. it exists independently) from a human perspective, so it is not relative to the human agent perceiving it—it is objective in this sense. Information as physical order can be destroyed or created, but it is not equivalent to thermodynamic entropy, as some have claimed.

The concept of information as the physical order of a system—as was conceptualized by Boltzmann for gases, Shannon for communication messages (although only through analogy), and Schrödinger for DNA—can be generalized to any physical order of nature. The preceding section gives several additional examples of such generalizations. This order of nature is embodied in natural structures, and it expresses the order or organization of natural and man-made things. Hidalgo claims that no concept other than information could embody the existence of order, form, or observable structures (i.e. those that can be detected, quantified, abstracted, simulated, partially recreated, and described) at all levels of nature, from

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machine with the ability to process information; meaning is derived from context and prior knowledge; biological forms of communication (such as DNA) are there whether we know how to decode them or not. They are a characteristic of information-rich states, not of who is observing them. Meaningless forms of order are what information truly is" (ibid., pp. 15-16, 23).

atoms to galaxies. (This is what "the scale-independence of information" means for him.)In Hidalgo's view, people, as cognitive agents, "read" this order and generate epistemic information.[149]

In fragments (6)[150] and (7),[151] Hidalgo attributes additional properties to information, making a series of statements about information and entropy. In Hidalgo's view, information is not in any way equivalent to entropy (ibid. pp.17-19). Information embodies the concept of order, which is opposite to entropy. The similarity between information and entropy has unfortunately arisen from the Shannon–Hartley formula for the amount of information (information entropy) and the syntactic similarity of this formula to the Boltzmann (Gibbs's formulation of entropy) formula for the entropy of ideal gas. This syntactic similarity has led to one of the most frequently repeated misconceptions about the nature of information. Of course, as we discuss later, there is absolutely nothing wrong with using Shannon's formula as a measure of information and attributing to this measure the properties derived from this model. Shannon's formula provides a measure of information because we decided what it measures, and we denote this as information. However, the properties of Shannon's formula can hardly be attributed to the general concept of information.

In fragments (8) and (9), Hidalgo postulates that physical processes are in fact computations, because in these processes, information as an organization of matter undergoes changes. In this view, computations bestow upon matter "*an ability to compute*." This changes the concept of what computing is, from the symbolic algorithmic/procedural operations performed by a UTM to computing as a physical process operating on structures as information, much like we discussed in several previous cases. Again, this claim leads to some variant of pancomputationalism.

The concept of information developed by Cesary Hidalgo is henceforth denoted as information$_{\mathrm{HD}}$.

3.1.9 From Chopin to information

In their paper titled "What does it mean to understand and what does it mean specifically to understand information", Jacek Jadacki[152] and Anna Brożek[153] (2005) postulate the existence of information as "*a*

[149] The process of creating epistemic information is the subject of epistemology and not discussed at length here.

[150] (6) "*Information is scale independent and can be destroyed—the endurance of information is not guaranteed*" (ibid., p.33).

[151] (7) "*Entropy and information are not the same thing, entropy refers to the average of physical states, information (Shannon) to a particular messag*e. (8)*Information is the opposite of entropy, as it involves uncommon and highly correlated configuration. Physical processes are information processing or computing in the generalized sense.* (9)*The ability of matter to process information or the ability of matter to compute*" (ibid., p.35).

[152] A professor of philosophy at the Warsaw University (1974-2016) who specializes in semiotics and the history of Polish philosophy.

certain internal state of [the] object."[154] To formulate this concept of information, Jadacki and Brożek question what "kind" of information, in the common dictionary understanding of the term, may be associated with perceptions of music.[155] All forms of information that are comprehended by an agent can be denoted as *anthropomorphic information* (ibid., p.152). The concepts of such information are highly intuitive and imprecise, and in order to treat information as a scientific concept, its definition must be more specific (ibid., p.152). The authors begin by defining information in the anthropomorphic sense. Through a series of eliminations and reductions in the elements of this initial definition, they come to the conclusion that information exists independently of the mind, so it is essentially a state of things or a state in things that may potentially or not be an object of cognition. This obviously implies that information, in this sense, exists independently of whether someone is perceiving it or not. Below is a summary of Jadacki and Brożek's argument.

The first part of the argument, denoted as Argument AI, defines anthropomorphic information as follows:

If	
(a) x in time period t sends sentence Z to y	[sender]
(b) y during t senses sentence Z communicated to y by x	[receiver]
(c) Z claims p	[meaning]
(d) Z is true	[obtains]
(e) p obtains	[reality]
(f) y in the period t understands Z and learns(c)	[comprehension]
(g) y before did not know p	[novelty]
then	
(h) x communicated to y in t INFORMATION that is p	
(i) y obtained in t from x INFORMTION that is p and	
(j) y just after t knew p	
and	
(k) the reason for (j) is (a)	

This argument is not novel, being just a kind of formalization of the standard communication model elaborated by Shannon, Cherry, and other researchers. The assumptions (c), (d), (e), and (g) are usually implicit in these models. Jadacki and Brożek add the condition that the sentence Z must be true, which is not necessarily a requirement for a communication exchange. Information, at least in the sense of

153 A professor of philosophy at the Warsaw University who specializes in semiotics, the history of Polish philosophy, and logic. Anna Brożek is also a concert pianist.
154 The discussion about information by Jadacki and Brożek originated in some way from listening to Prelude in *E-minor* (op. 28) by Frederic Chopin.
"By listening to a musical composition, one can learn different things. One could say that in this composition reside different types of information. This sense of information we will denote as anthropomorphic" (Jadacki & Brożek 2005, p.152).

anthropomorphic information, may be false after all. The communication process by itself is not a guarantee of knowledge.[156]

Jadacki and Brożek define anthropomorphic information as having seven attributes—namely sender, receiver, meaning, veracity, actuality, comprehension, and novelty—and in general outlines, it is a communication model. In more detail, these are:

- The *sender* and *receiver* denote the agents originating and receiving the information.
- The *meaning*, *veracity*, *actuality*, *comprehension*, and *novelty* are attributes of the sentence being transmitted and later comprehended by the *receiver*.
- The *sentence* is the carrier of the *anthropomorphic* information.
- In addition, the *meaning* and *veracity* attributes imply that the sentence reflects some true state of affairs, while the sentence must be understood by the receiver (*comprehension*) and be previously unknown to him or her (*novelty*).

The definition of information does not change if the sender is eliminated (ibid., p.153) from the definition, because "*anthropomorphic information without [a sender] would still be anthropomorphic information.*" They also question whether "*information can be present in the absence of a sentence? It seems that it can. Every musical performance is an event, without a single sentence qua sentence. But we may safely claim that every person in the audience got some information… . The list of different information one can apprehend during the performance of any musical composition can be multiplied ad infinitum. But instead of listing them, we will create a new definition of information that will subsume this concept*" (ibid., p.153).

The definition of information may therefore be even further reduced by eliminating the sentence, which is understood here as the carrier of information. This is what happens during a musical performance, where the audience listens to the same composition, but each listener may receive different information. The audience may learn about the performer, glean information about the structure of the musical piece, decide whether the performance was correct, have memories of some past events evoked, or receive information in some other way. A concept of information that would subsume all these possible types of "information" would need to exclude a sender and a sentence as the carrier of information.

156 We define knowledge to be a justified, true belief (JTB). The Gettier problem is not the issue here. Despite the fact that the Gettier problem has been recognized as a landmark case in epistemology, the case has serious problems in my view, because no serious agent seeking truth not for philosophical gains but as a survival factor (think about a spy agency as an epitome of truth seeking agent) would accepts the claims formulated by Gettier as being true. Only under a very narrow interpretation of the JTB does the Gettier problem have any power. It is more of an exercise in logic for philosophers than a real case. See also the work of Ichikawa et al. (2018).

Jadacki and Brożek state that argument AI may be reconstructed without a sender. This new argument (Argument AII) has the following form:

If	
(b) y during t senses sentence Z communicated to y by x	[receiver]
(c) Z claims p	[meaning]
(d) Z is true	[obtains]
(e) p obtains	[reality]
(f) y in period t understands Z and learns that(c)	[comprehension]
(g) y before did not know p	[novelty]
then	
(h) x communicated to y in t INFORMATION that is p	
(i) y obtained in t from x INFORMATION that is p	
(j) y just after t knew that p	
and	
(k*) the reason for (j) is (b)	

Arguments AI and AII still associate the carrier sentence Z with "information." Thus, information obtained in this communication process depends upon the understanding of Z, yet Z may be interpreted in many ways. It seems that information, however, is something common to the multitude of possible interpretations.[157]

The proposed abstraction/reduction process leading to the generalized concept of information leaves out the *sender*, *receiver*, *meaning*, and *veracity*, and it leaves *actuality*, *comprehension*, and *novelty*. Information defined only with these attributes has no specific meaning, and it can only be interpreted by a cognitive agent. Thus, such information may be understood as carrying the variety of anthropomorphic information that is associated with a musical performance. Information, as it is defined above, is a raw material for semantic interpretation, because it may have different meanings.

We could again reconstruct the definition of information without the sender or the sentence. This (Argument AIII) takes the following form:

If	
(e) p obtains	[reality]
(f*) y in period t perceives that (c)	[comprehension]
(g) y before did not know p	[novelty]
then	
(h) x communicated to y in t INFORMATION that is p	
(i) y obtained in t from x INFORMATION that is p and	
(j) y just after t knew p	
and	

[157]"*To obtain a concept of information that would include all the listed examples of information, one must carry out further abstraction and construct the concept of information without [sender] and [sentence] attributes*" (ibid., p.154).

(k**) the reason for (j) is (f*)

Jadacki and Brożek conclude that in argument AIII, any object with some state (i.e. a physical state) has information that may potentially be recognized by a cognitive agent (1).[158] The concept of information as semantic or *anthropomorphic* information can be generalized to cover all possible interpretations of it, and this generalized concept denotes the structure of physical phenomena that contain that structure. The structure of an object can be denoted as its state, but information as the state of an object exists whether it is being observed or not. Of course, it can potentially be received or decoded, but authors do not clarify the meaning of terms like "*state of an object*", "*be in a state*", or "*contains a certain state*." However, these could be interpreted as referring to a "physical state" or "physical structure" through the analogy of the musical composition, which is the main subject of the discussion, being carried through the state of the physical media (i.e. the air).

One may certainly ask whether, for Jadacki and Brożek, a musical composition "is the physical state" of the carrier (e.g., sound waves, digital media, music sheets, etc.) or something else. The answer to this question lies in the statement that "music is in the object" rather than that music is the object. This claim would indicate that music exists as something beyond the physical realm. However, we do not get any explanation about what this "beyond" could possibly be, and this comment seems more poetic than factual.

The concept of information developed by Jadacki and Brożek is henceforth denoted as information$_{JB}$.

3.1.10 Evolution, us, and information

Thomas Nagel,[159] in his book *Mind and Cosmos* (Nagel 2012), argues that the existence of information with ontological properties is rooted in the concept of evolution.[160] If we assume the validity of evolution and evolutionary principles (i.e. organisms evolve under environmental pressure to maximize their odds

[158] (1) "*As one can see, after the proposed modification of the concept of information, in principle, every object that contains a certain state, or that is in a certain state, contains information as a possible object of cognition*" (ibid., p.155).

[159] "*Thomas Nagel is an American philosopher and University Professor of Philosophy and Law Emeritus at New York University, where he taught from 1980 to 2016. His main areas of philosophical interest are philosophy of mind, political philosophy and ethics*" ("Thomas Nagel" 2018).

[160] Close links, or even an organic dependency, between the mind or its structure (i.e. thoughts) and the environment has been indicated by many researchers including, for example, Antonio Damassio in his book *Descartes' Error* (2003). As will be discussed later, the mind and any other living organism are information-processing systems created by, and geared toward, information from the environment with the explicit objective of surviving.

of survival),[161] as most do, the claim that the world order is our creation leads to a contradiction and denial of scientific realism and evolution (ibid., p. 86).

In fragments (1) and (2),[162] Nagel argues that the rationality, intelligibility, or order pervading nature is not a human creation or invention, thus arguing against the Kantian philosophy of knowledge (ibid.). This order is a property of nature, and it long predates humans. In fragment (2), this all-pervading order/rationality is the factor that enables all sciences to emerge as sciences and allows us to investigate order in the world. Science assumes a priori that the world is ordered in some way; otherwise the efforts of scientists would be doomed to fail before they began.

In fragments (3)[163] and (4), [164] Nagel observes that the world is intelligible, so it can be partially explained by the universal laws of physics.[165] The order in the natural world is a result of the laws of the physical universe, so these laws create order in Nagel's view. Physical laws explain why the universe is ordered, organized, and intelligible. This view does not equate to physical reductionism, however, because some aspects of the universe are not reducible to the pure laws of physics, such as biology. We, and all living things, are products of evolution. The pervading order and "rationality" in nature is, in a way, a foundation for the reasoning behind the theory of evolution. Evolution could not take place in an absolutely random universe, because environmental pressure must be persistent and predictable to some extent for organisms to adapt to it. The rationality of nature is a foundation or a condition, *sine qua none*, of rational scientific methods. Scientific methods in turn "discover" rationality in nature, much like how we may refer to the discovery of America or other places and phenomena that already existed long before their discovery. However, the primacy (i.e. the order of appearance of rationality) belongs to nature, and we, with our rational minds, are its creations, so we are the order from the order.

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[161] See, for example, Alzohairy (2009), who states, *"Darwin's Theory of Evolution is the widely held notion that all life is related and has descended from a common ancestor: the birds and the bananas, the fishes and the flowers—all related. Darwin's general theory presumes the development of life from non-life and stresses a purely naturalistic (undirected) descent with modification. That is, complex creatures evolve from more simplistic ancestors naturally over time. In a nutshell, as random genetic mutations occur within an organism's genetic code, the beneficial mutations are preserved because they aid survival—a process known as 'natural selection.' These beneficial mutations are passed on to the next generation. Over time, beneficial mutations accumulate and the result is an entirely different organism (not just a variation of the original, but an entirely different creature.*"

[162] (A9) "*Science is driven by the assumption that the world is intelligible. That is, the world in which we find ourselves, and about which experience gives us some information, can be not only described but understood*. (B9) "*Without the assumptions of an intelligible underlying order, which long antedates the scientific revolution, discoveries [of sciences] could not have been made*" (ibid., p.16).

[163] (3) *"[the intelligibility of the world] could be subsumed by universal, mathematical laws governing the spatiotemporal order*" (ibid., p.14).

[164] (4) *"the natural order is intelligible, namely, through physical law—everything that exists and everything that happens can in principle be explained by the laws that are 'given by' the physical universe*" (ibid., p.18).

[165] Here, Nagel guards himself with "the world… explained partially…" against materialist monism or strong reductionism.

In fragments (5),[166] (6),[167] and (7),[168] Nagel states that our perceptual functions are products of evolution: They give us a more or less accurate, or objective and reliable, account of the world (auth. otherwise we would not be able to survive, never mind evolve). The information that we get from the world is from the world and about the world. Information from nature therefore shapes us and our knowledge, which is intimately bound with the universe, binding us with the universe in the process. We are not separate minds looking at a spectacle—we are an intrinsically integrated part of the game. The causal objects (including rationality or the order/form of things) of our thoughts exist in nature. However, as reasonable beings, we can go beyond the practical truths of sensory perception. We can abstract, generalize, and synthesize, so we create integrals, differentials, moments, unicorns, centaurs, griffins, and other things that do not exist in nature. Translating this into our concepts of information, we say that nature has inherent order, and this order shaped us and our senses to perceive this order. Indeed, evolution cannot deceive its creations, because that would achieve nothing. We perceive this order because we have evolved to do this, but we also reshape the received information. This is how epistemic information, or knowledge about the world, "emerges."

Our concepts and knowledge (i.e. information about the world that is called epistemic information in this study) reflect the world. They do not have to do this by definition, but we have evolved to reflect this order, so we are reflections of it. Otherwise, we would not be here. Even "here" would not be here.

In fragments (8),[169] (9),[170] and (10),[171] Nagel provides an argument for why he thinks an anti-realist is wrong and why evolution is a proof against this anti-realist. The argument goes like this: There is a world

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[166] (5) "*[auth. as creatures of evolution,] our bodies and central systems are part of the physical world, composed of the same elements as everything else*" (ibid., p.36).

[167] (6) "*Conscious subjects and their mental lives are inescapable components of reality not describable by the physical sciences*" (ibid., p.41).

[168] (7) "*the basic forms of perceptual, emotional, and consciousness we share with other animals. These mental functions do put us into a complex relation with the world around us, but they seem in principle susceptible to an evolutionary explanation…if such experiences can be added to the evolutionary menu, their roles in enabling creatures to navigate the world, avoid dangers, find nourishment and shelter and reproduce all make them potentially adaptive and therefore candidates for natural selection. Perception and desire have to meet certain standards of accuracy to enable creatures to survive in the world: they have to be able to respond similarly to things that are familiar and differently to things that are different, to avoid what is harmful, and to pursue what is beneficial*" (ibid., p.73).

[169] (8) "*Thought and reasoning are correct or incorrect in virtue of something independent of the thinker's beliefs*" (ibid., p.72).

[170] (9) "*there is no real, judgment-independent physical word and the world is all but human construction… [an antirealist position] would mean that evolutionary theory is inconsistent with scientific realism and cannot be understood realistically would be an excessively strong result. There would be something strange to the point of incoherence about taking scientific naturalism as the ground for antirealism about natural science*" (ibid., p.75).

[171](10) "*if I think of myself as the product of Darwinian natural selection, I am justified in believing the evidence of my senses for the most part, because it is consistent with the hypothesis that an accurate representation of the world around me results from senses shaped by evolution to serve that function… [and] the reliability of my*

out there that is objective and is independent of our beliefs. Nagel repeats here the argument that our senses reflect the world out there and its structure or organization, just as they have evolved to do so. This in fact is the principle of evolution. Nagel observes that our perceptual, mental, and reasoning capacities are together representing the world out there for evolutionary reasons. (Of course, we cannot talk about evolution as an intentional act or even as having *telos*.)

The statement in fragment (11)[172] clearly evokes the original concept of information (as in *informare*) as shaping the mind or maybe the archaic and simplistic Aristotelian idea of "*a ring imprinting its shape in the wax*."[173] One should also not take this claim to be an endorsement of Hume's view of the mind. The mind plays an active role in interpreting the perceptual "feed", but as the mind is also a product of evolution, the interpretation it imposes on this feed generally reflects the world outside, at least if cognitive function has not been disrupted, such as by hallucinogens, to the extent that the whole perceptual feed can be barely comprehended, let alone related to the world.

In fragment (12),[174] we get another look at the causal powers of information. For several researchers mentioned in this study, information may have causal powers at the fundamental level forming the universe (i.e. ideas similar to Plato's forms and Aristotle's substantial forms). In Nagel's view, information lies at the root of evolution and its causality. For Nagel, if we believe in physical laws, we need to accept information as "*something about the world that eventually gave rise to rational beings."* The question is then whether *"informare*" denotes the shaping of nature or the shaping of the mind or both? Alternatively, are the mind and nature of the same kind, in a way where the mind is not apart from nature but rather a part of it?

Nagel does not agree that materialist reduction (physics) explains everything in the world, including the mind and consciousness, as stated in fragment (13).[175] The mind and consciousness are part of the physical world, however, so they ultimately have to be explained by it. Whether materialism offers a full explanation of the world, including the mind and consciousness, is beside the point here. What is

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logical thought processes is consistent with the hypothesis that evolution has selected them for accuracy" (ibid., p.80).

172 (11) "*Perception connects us with the truth only indirectly. When I see the three, I see it because it is there, but not just because it is there. Perception is not a form of insight: I do not grasp the presence of the three immediately. Rather, I am aware of it because the three causes a mental effect in me in virtue of the character of my visual system, which we may suppose has been shaped by natural selection to react in this way to light reflected from physical objects. Having such a system, together with other perceptual and motivational dispositions, enables me to survive in the world*" (ibid., p.82).

173 Aristotle (Aristotle 2001), DA 424b1-b3. DM 450a31–2.

174 (12) "*if we believe in natural order, then something about the world that eventually gave rise to rational beings must explain this possibility*" (ibid.,p.82).

175 (13) *"materialism is incomplete, even as a theory of the physical world, since the physical world includes conscious organisms among its most striking occupants*" (ibid., p. 45). See also the same on p.44 and p.32.

important is that we, and all other animal life, are an integral part of the universe, and our minds are reflections of its underlying order, not anything else, at least under normal conditions.[176]

We will henceforth denote the information conceptualized by Nagel[177]as information$_{TN}$.

3.2 Chapter summary

In Chapter Three, we analyzed how concepts similar to our notion of ontological information are presented in the existing research literature. We analyzed the research of a cosmologist (Michał Heller 1987, 2014), physicists (Carl von Weizsäcker 1970, Krzysztof Turek 1978, Tom Stonier 1990), philosophers (John Collier 1989, Thomas Nagel 2012), computer scientists with philosophical leanings (Mynarski 1981, Jadacki 2005), a philosopher and concert pianist (Anna Brożek2005), a computer scientist and philosopher (Gordana Dodig Crnkovic 2012), and a computer expert in Big Data (Cesary Hidalgo 2015). Von Weizsäcker's information is a mixture of concrete and abstract concepts, but what is important is the admission that information itself cannot be just a thought. It must be something in nature. He fails, however, to tell us exactly what he means by this. Summarizing Turek's work, we may say that in the world of things (i.e. the universe); shapes are due to the factor of form, while individuation is due to prime matter. Form is realized in physical medium as structure in the sense explained earlier, and this structure is information, with all elements of nature containing information as a structuring element. This is an epistemically neutral element of nature, meaning that it exists not because we or someone else perceive it but simply because nature is this way. Mynarski, meanwhile, bases his idea of information in cybernetics conceived not just as the science of systems but as a general paradigm of nature. Thus, for Mynarski, information is as much a part of nature as energy and matter are. However, Mynarski's information still depends in some way upon a system to recognize it as information. Collier, meanwhile, recognizes two kinds of information, namely information with meaning and information without meaning, with the latter being an intrinsic property of nature. According to Stonier, we have two types of information: (a) physical information existing independently without meaning and (b) information with meaning, which is information for someone or information interpreted. Information of type (a) forms the fabric of the universe. Heller, meanwhile, identifies information with "hidden" structures of the universe.

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[176] One may argue the term "normal" here, but it would be detraction from the goal of this study and a rather bad example of philosophy. For example, knowing how philosophy goes, we could end up concluding that there are no "normal" conditions or that the term is too nebulous to be defined precisely, despite it being used quite successfully in everyday language.
[177] For a similar conceptualization of nature, evolution, and the development of cognitive abilities in living matter, see, for example, Rudy Rucker, who observes that "*Mathematics consists of concepts imposed on us from without. Just as our bodies have evolved in response to objective conditions imposed by the environment, our ideas have evolved in response to certain other fundamental features of reality*" (Rucker 1987, p.14). Now, is Rucker saying that mathematics is a fundamental feature of reality or that the idea of mathematics (which we created) reflects a fundamental feature of reality?

Next, Dodig Crnkovic sees one form of information, namely physical information expressed in natural structures. According to her, the constant changes in these structures represent a form of natural computation. Hidalgo, meanwhile, claims that information is the form of natural objects and artifacts. Thus, according to him, everything around us contains information. Next, Jadacki and Brożek claim that information is the physical structures of natural phenomena existing independently of our presence. According to Nagel, though, structure is a feature of nature that has been driving the evolution of organisms and the mind. This natural information is, in his view, primarily the causal order for information created by the mind.

In all these studies, information is recognized as being an organizational factor in nature, one that is objective, all pervading, and fundamental, and without this, the concept of nature (and of rational nature) would not be possible. The authors rarely find a special term for it, however. They refer to it as information with specific properties or information with certain utilitarian functions or operational significance.

4 Ontological Information: Synthesis

We now ask: What kind of information emerges from the previous studies? Is our claim for the existence of ontological information justified? Are the four intuited properties of ontological information (see Chapter One) are confirmed in the studies? Which properties can we ultimately assign to this information? How many are there: all four, just three, or do we need to add more? Could the concept of ontological information add any clarity to the already numerous and confused conceptualizations for information, or is this just another red herring? Should we, as is often suggested, just adopt Shannon's theory of communication (ToC) as the overall framework for discussing information in general? Alternatively, is the ToC just another take on the problem, something that is operationally useful (even very useful) but conceptually and metaphysically deficient? Finally, does ontological information (the concept of it) help us to resolve any of the conceptual difficulties of information, such as the concrete–abstract dichotomy that has been indicated by many authors?

The existing studies do not directly answer these questions, because their ideas about information do not share exactly the same set of features, and despite their many similarities, they are not quite aligned. Among their several commonalities, the studies agree that there is information as a natural phenomenon, so it is without meaning, unrelated to knowledge, independent of a cognitive agent for its existence, and unrelated to a communication process, but it is connected with the properties of the universe or maybe one of these properties itself. Several authors indicate the tension between the concept of information as an abstract object of thought (i.e. the most common view of information) and information as a concrete, physical thing (i.e. information as it is understood in this study). Are solution to this tension would also resolve the nature of information, as some writers claim. In many studies ranging from cosmology to the foundations of life, the concept of information and entropy (thermodynamics) are very closely related, even to the extent that both are seen as almost equivalent in a numerical sense or even in a conceptual sense, but this claim is disputable. Moreover, every author confirms that information is closely related to the organization of nature, so information is a structure of sorts. Some authors also point to its causal efficacy. This claim should not surprise anyone, because causal efficacy will be a natural property of information if it is indeed a natural phenomenon. The information these studies describe can be quantified, and it is often conceptualized as part of a matter–energy–information complex. Some propose that this "complex" is a new kind of hylemorphism, while some talk about a similar concept but drop the Aristotelian reference. What the authors exactly state in support of these conjectures is detailed in the following sections.

4.1 Ontological information: What did we learn?

4.1.1 Intuitions and ontological information

The concepts of information emerging from the works of Edmund Kowalczyk, Keith Devlin, Frank Wilczek, John Barrow, Sean Carroll, Richard Sole and Santiago Elena, Carlo Rovelli, Charles Seife, John Polkinghore, and Paul Davies can be summarized in eight observations: (1) Information is a natural phenomenon, without meaning and unrelated to knowledge but connected with the properties of the universe (i.e. nature). (2) In several studies, we see the tension between the abstract (mental) concept of information and information as something concrete and physical. (3) In any discussion of information as a natural phenomenon, entropy (thermodynamics) plays a prominent role. (4) The term information is usually not clearly defined but rather described through its properties. (5) Despite the diverse views, there are several commonalities in their descriptions of information in nature. (6) Information is closely related to the organization of nature or its structure. (7) Information in nature can be quantified.(8) Information in nature is often conceptualized within the triad of matter, energy, and information.

Observation (1) states that information is a natural phenomenon, without meaning and unrelated to knowledge but connected with the properties of the universe (i.e. nature), and this figures prominently in the research. Devlin claims that information is "*a basic property of the universe, alongside matter and energy*" (Devlin, op.cit., p.2). Barrow, meanwhile, sees information as a major measurable property of the universe, claiming that "*the maximum information content is determined by the surface area of the volume, just as for a black hole*" (Barrow, op.cit., p.179). Next, Carroll claims that information, which he calls microscopic information, *"refers to a complete specification of the exact state of a physical system*" (Carroll, op. cit., p.34). Thus, if this information is actually the state of the physical system (i.e. in both the classical and quantum context), it is a property of the universe and mind-independent. Rovelli indicates that information is a well-established concept in many areas of physics, and this is a physical rather than psychological concept (i.e. ontological rather than epistemic). He states that it is *"mentioned in the foundations of thermodynamics, the science of heat, the foundation of quantum mechanics and in other areas besides, with the word quite often used very imprecisely*" (Rovelli, op.cit., p.209). He repeats the same idea by stating that "*a set of atoms can have information in the technical sense*" (ibid., p.213) and that *"the concept of information can be useful also to the mysterious aspects of quantum mechanics*." Furthermore, he says that "*information in this sense—a correlation between states of systems—is ubiquitous throughout the universe*" (ibid., pp. 261-267). Finally, Rovelli states that *"it should be clear that the notion of information plays the central role in our attempts to understand the world*" (ibid., p.226). Rovelli's observations clearly position information in the physical world rather than in the realm of the mind. Seife claims that information *"is a physical entity, a property of objects akin to energy or work or mass*" (Seife, op.cit., p.56). Davies also stresses the role of information as a physical concept unrelated to knowledge, saying that *"information clearly plays a physical role in the world, not least in biology"* (Davies, op.cit., p. 35). The authors describing this concept of information take care not to make too many specific claims, but it seems to be the exact properties of this information they are cautious about rather than its existence. Indeed, they all agree that this information is "out there" in nature as a part of it. In the sense that these author's use the term "information" (i.e. as a natural phenomenon), it has explanatory value in fundamental physics (e.g., a unification of physical laws, the maximum information content of a volume, a specification for the state of a physical system, a fundamental explanation in QM, and the fundamental laws of physics).

Observation (2) points out that there is a perceived tension between the abstract (mental) concept of information and information as a concrete, physical thing. This tension is expressed by Davies in stating that "*the idea of information derives originally from the realm of human discourse. Used in this sense, it is a purely abstract concept. On the other hand, information clearly plays a physical role in the world, not least in biology. The challenge to science is to figure out how to couple abstract information to the concrete world of physical objects*" (Davies, op. cit., p.35). Davies forgets, however, to add that one thing cannot be both abstract and concrete at the same time and in the same way. (This problem is discussed further in Chapter Five.)This dichotomy is so critical that Davies even claims that this abstract–concrete split is one of the greatest challenges that science and philosophy faces. We may say that the view of information as an abstract thing (i.e. as knowledge or related to the mind's operations) is more rooted in tradition, so it is more widely accepted. Information as an element of the natural realm, meanwhile, is more a case of a forgotten idea. The original concept of information as an ordering/organization in nature has existed in some form since the early days of human thought (e.g., Tao, *eidos*, Form, *morphe*). In this tradition, information is bound with what exists, and no information is in a nonexistent state, so information implies existence and existence implies information.[178] Schrödinger's view is that existence,

[178] We may claim that facts require information in the sense that information is ontologically fundamental. Thus, negative facts, being unrepresented by specific information, are purely abstract concepts. As Barker and Jago state, *"Negative facts get a bad press. One reason for this is that it is not clear what negative facts are. We provide a theory of negative facts in which they are no stranger than positive atomic facts. We show that none of the usual arguments hold water against this account. Negative facts exist in the usual sense of existence and conform to an acceptable Eleatic principle. Furthermore, there are good reasons to want them around, including their roles in causation, chance-making and truth-making, and in constituting holes and edges*" (Barker & Jago 2011). In the sense of information, negative facts are an abstract construct rather than a concrete entity. Thus, they would not exist in the same way as positive facts (see also the discussion of Rosenberg (1972)). Can the concept of information add anything to the discussion about negative facts and the Eleatic principle?

at least in terms of life, depends on information (Schrödinger 1944). The modern tradition of seeing information as something apart from nature, as something existing in the mind, probably has Kantian and Cartesian roots, but it has certainly been cemented in the age of information processing with the abstraction of information into digital formats. This split between abstract and concrete information is seen throughout the presented studies and studies in the following section. This will be discussed later in the study, when we will conclude that in the case of abstract and concrete information, we are dealing with two ontologically different concepts, and we posit that this is apparent and thus resolves this tension.

Observation (3) claims that in any discussion about information as a natural phenomenon, entropy (thermodynamics) usually plays a prominent role. Kevin Devlin observes that "*information would be an intrinsic measure of the structure and order in parts or all of the universe, being closely related to entropy*" (Devlin, op. cit., p.2). John Barrow, meanwhile, states that *"It is possible to relate the notion of entropy, which is a measure of disorder, to the more general and fruitful notions of 'information'*" (Barrow, op. cit., p.179). Furthermore, he says that *"the maximum information content within a bounding surface area corresponds to the information or entropy*" (Barrow, op.cit., p.188). Carlo Rovelli links information with thermodynamics and the science of heat, thus forging an implicit connection between information and entropy in the claim that *"information is mentioned in the foundations of thermodynamics, the science of heat*" (Rovelli, op.cit., p.209). What is more, Rovelli observes that "*today, physicists commonly accept the idea that information can be used as a conceptual tool to throw light on the nature of heat*" (Rovelli, op.cit., pp. 261-267), which confirms the previous statements in some sense. Next, Frank Wilczek claims that "*entropy has close connection to information*" (Wilczek, op. cit., p.402), but he does not supply a better explanation of this close connection. Putting aside mathematical formulations and interpretations, it seems that the concept of information entropy—due to Shannon's Theory of Communication and the term "entropy of information", which he coined—is seen as being almost synonymous with organization (or disorganization) and order (or its inverse) in nature. As such, the concept of information entropy plays a role in linking ideas of information to the concepts of fundamental physics, chemistry, biology (see the theories of life, viral theories, or genetics), and metaphysics. This information in nature exists without the presence of the mind, communication, or a message from someone to another. It is just a feature of nature. Thus, it may be that information entropy has become a concept that has allowed us to find or discover similarities across these diverse conceptual domains of metaphysics, computing, physics, cosmology, and biology despite the different meanings that entropy has in each of these domains. Moreover, we cannot forget Schrödinger's work on entropy and the origins of life (Schrödinger 2004). The capacity of nature to create local complexes with a high level of information content, which in Schrödinger's language is called negentropy or negative entropy, works against the Second Law of Thermodynamics,[179] but it is at the origin of life according to him. Schrödinger's book was originally published in 1944,[180] and it does not mention the term "information." On reading the book now, however, one gets the impression that this concept was somehow forgotten by the author. (Tom Stonier made this connection easily but only 30 years later.) This may have partially been the case, but it seems that the actual reason for this "omission" was the fact that the link between entropy and information had not yet been recognized, or rather popularized, yet. In Schrödinger's work, entropy plays the role of the concept of information in that is a function of, or an indicator of, the degree of organization for a physical system.

Note: See the comments on entropy and information in Chapter Five, because while the analogies between entropy and information may be useful, they may be also misleading if made without qualifications.

Observation (4) states that the term "information" is usually not clearly defined in the sense that we do not get a formal definition in the form of "information is..." or "by information, we understand this and that… ." In most of the reviewed studies so far, the term "information" is explained only through an extended description, sometimes over several paragraphs. It is often not attempted, on the part of the authors, to denote the information that they are talking about with a single term, such as "natural information", "objective information", "physical information", or some other concise phrase. Devlin explicitly states that "*man can recognize and manipulate 'information' but is unable to give precise definition as to what exactly it is being recognized and manipulated*" (Devlin, op. cit., p.2). Barrow, meanwhile, connects "information" with entropy, saying that "*It is possible to relate the notion of entropy, which is a measure of disorder, to the more general and fruitful notions of 'information'*" (Barrow, op.cit., p. 179). In this view, information would be some kind of generalized measure of disorder, but this is just our interpretation of Barrow's text. Rovelli, for his part, realizes that multiple, often conflicting, concepts are associated with information and hence the lack of a precise definition, saying that "*We tend to use the word 'information' in multiple, often incompatible, ways*" (Rovelli, op.cit., p.2009). Further confirming this claim, he says, *"The term 'information' here requires caution, because scientists use the same word to mean different things in different contexts*" (Rovelli, op.cit., p.213). Rovelli probably gives the most precise definition of information as "*the white ball in my hand has information about the fact that the ball is in my hand. We are dealing with physical facts, not mental notions. Information in this senses—a correlation between states of systems—is ubiquitous throughout the*

[179] This is Schrödinger's so-called paradox, which seems to be nonexistent for open systems (i.e. a biosphere is an open system).

[180] Since 1944 (the original publication date), Schrödinger's book "What is Life?" has been published in at least 24 editions in English alone.

universe (Rovelli, op.cit., pp. 261-267). However, Rovelli's definition is in no way the ultimate concept of information. Seife claims that information is "*a physical entity, a property of objects akin to energy or work or mass*" (Seife, op.cit., p.56). This claim differs from what Rovelli says while still perceiving information as belonging to the physical realm.

The lack of a clear definition is unsurprising, given that information may have several, often contradictory, meanings. One would therefore assume that when writing about information, to avoid confusion, the authors would say something like this: "The concept of information I am talking about is…and it is denoted as…" Instead, we need to perceive this explanation implicitly and mine out its meaning from the text. Such interpretations are always prone to misinterpretation, however, because we may incorrectly guess an author's intentions. Thus, the studies cited in the discussion have been denoted as "intuitions "rather than "definitions." Such a positioning of these studies relieves both the authors and ourselves of some pressure, because intuitions do not have to be completely accurate.

Observation (5) claims that several commonalities exist among the descriptions of information in the reviewed studies despite the apparent lack of convergence from their authors. While different characteristics are attributed to the concept of information, studies show strong similarities in their descriptions of information. In almost all of these studies, information is explicitly positioned as a property of physical systems, and it is closely connected o the organization of the physical world, so information is physical or has a physical presence. Devlin claims that information is "*a basic property of the universe*" (Devlin, op.cit., p.2). Barrow, meanwhile, claims that "*information is a new fundamental principle governing the maximum information content of the volume of space*" (Barrow, op.cit., p.188). Next, Carroll claims that information is "*the complete specification of the state of the system*" (Carroll, op.cit., 34). Rovelli, meanwhile, states that information as "*a correlation between states of systems is ubiquitous throughout the universe*" (Rovelli, op.cit., p.224). Seife, meanwhile, states that information *"is a physical entity, a property of objects akin to energy or work or mass*" (Seife, op. cit., p.56). For his part, John Polkinghore states that *there is a need to introduce a third fundamental concept of a pattern-forming character that will embrace these emergent properties of holistic order. Information may be a suitable word for it*" (Polkinghore, op.cit., p. 96). The point to observe here concerns how all these authors talk about information in terms of an organization of nature or physical systems, and this organization exists regardless of the presence or not of any cognitive system. This "information" is natural, physical, and mind-independent, and it is devoid of meaning.

Observation (6) claims that information in nature is closely related to the organization of nature, its structure or form**.** Information, in its different names (e.g., structure, order, form), is synonymous with organization in most of the reviewed studies. Devlin claims that "*information would be an intrinsic measure of the structure and order in parts or all of the universe*" (Devlin, op.cit., p.2). Barrow, meanwhile, states that *"It is possible to relate the notion of entropy, which is a measure of disorder, to the more general and fruitful notions of 'information.' We can think of the entropy of a large object like a black hole as being equal to the number of different ways in which its most elementary constituents can be rearranged in order to give the same large-scale state*" (Barrow, op.cit., p. 179). In Barrow's view, information is closely related to (i.e. it is a measure, function, or expression of) the order of the constituent elements of the black hole. For Carroll, meanwhile, information is related to the order of the universe, as envisioned by Laplace. As Carroll states, *"The Laplacian world-view is based on patterns, not on nature and purposes*" (Carroll, op.cit., p.34). Polkinghore, as already quoted a few times in fragments, says that "*there is a need to introduce a third fundamental concept of a pattern-forming character that will embrace these emergent properties of holistic order. Information may be a suitable word for it*" (Polkinghore, op.cit., p. 96).

Observation (7) claims that information in nature can be quantified, meaning that information is a measurable property of nature, just like mass and energy are. As information can be quantified, it can be isolated as an entity with its own characteristics. Moreover, as it can be quantified, this also means that it can be used for some operational gain. This is the point that the authors make. Devlin talks about information being a measure as follows: "*information would be an intrinsic measure of the structure and order in parts or all of the universe*" (Devlin, op.cit., p. 2). T he conclusion that if something can be measured, it can be quantified seems self-evident. Barrows, meanwhile, by comparing entropy with information, implicitly admits that information is quantifiable, like in *"the notion of entropy, which is a measure of disorder, to the more general and fruitful notions of 'information'* (Barrow, op.cit., p.179). He also talks about "*the maximum information content within a bounding surface area corresponds to the information or entropy*" (Barrow, op.cit., p.188). If information has a maximum, it must be a quantifiable phenomenon that can be expressed as a number. Sole and Elena imply that information is a critical quantifiable factor in deciding the course of evolution (i.e. whether evolution will occur or not). They claim that "*mutation imposes a limit on the amount of information (in terms of genome length,*υ*) that is consistent with stable information*" (Sole & Elena, op.cit., p. 45).

Observation (8) claims that information in nature is often conceptualized within a matter–energy–information complex. Matter, energy, and information are what physical reality is at the fundamental level. The precise manner in how this unification is accomplished is a matter of speculation, however. This unification of form and matter has a long tradition in notions like *eidos*, Form, hylemorphism, and *morphe*, both in the ancient Greek and modern versions of such concepts. The unification of information and matter is expressed in many ways by the different authors. Devlin states that "*information should be regarded as (or maybe is) a basic property of the universe, alongside matter and energy (and being ultimately interconvertible with them)*" (Devlin, op.cit., p.2). Wilczek suggests that *"There are two unifications in fundamental physics that I think would be most desirable, but where existing ideas are less mature. One is the unification of our description of matter and information*" (Wilczek, op.cit., p. 402), indicating a close link between matter and information. Seife, meanwhile, claims that "*information…transcends the medium it is stored in. It is a physical entity, a property of objects akin to energy or work or mass*" (Seife, op.cit., p.56). Next, Polkinghore states that "*in addition to traditional descriptions in terms of matter and energy, there is a need to introduce a third fundamental concept of a pattern-forming character that will embrace these emergent properties of holistic order. Information may be a suitable word for it*" (Polkinghore, op.cit., p.26). Furthermore, in the same paragraph, he observes that "*Just as relativity theory has integrated matter and energy into a single account, so one might hope for an eventual discovery that would integrate the triad: matter-energy-information*" (ibid., p.26). We do not get any new sort of hylemorphism or other new theory from these writers. They only point to the close relation between the fundamental physical concepts of energy, matter, and information, but the nature of this relation remains unknown.

We now move from the intuitions to the more detailed studies of information and analyze which properties the authors of these studies attribute to it.

4.1.2 Claims about ontological information

The concept of information that emerges from the writings of Heller, von Weizsäcker, Turek, Stonier, Collier, Nagel, Mynarski, Jadacki and Brożek, Dodig Crnkovic, and Hidalgo can be summarized in 11 statements: (1) the notion of information associated with knowledge does not completely cover the concept of information. (2) Information is a physical/natural phenomenon. (3) Information as a physical/natural phenomenon has no meaning. (4) The meaning of information is derived by the mind of a cognitive agent rather than being intrinsic to information as a physical/natural phenomenon. (5) The role of information in nature may be conceptualized through the matter–energy–information complex. (6) Information as a physical/natural phenomena is fundamental to nature, so whatever exists physically must contain information. (7) Information as a physical/natural phenomenon is expressed in structures/form and the organization of things. (8) Information as a physical/natural phenomenon cannot be reduced to what we conceptualize as structures. (9) Information as a physical/natural phenomenon is responsible for the internal organization of nature's objects and artifacts. (10) Natural processes are information processes that we may call a form of computing. (11) Quantifications of information provide a measure of sensible structures that reflect the presence of information, but such quantifications are not information itself. Now, let us examine how these claims are justified.

(1) Information as knowledge does not completely cover the concept of information

Information, in most lexicons and dictionaries (e.g., "Information – Merriam-Webster" 2019, "Information – CED" 2019, "Information – OED" 2019, "Information – Collins ED" 2019, "Information – Macmillan" 2019), as well as in common parlance ("Information" 2018),[181] is most often associated with knowledge, the transfer of knowledge, communication, and the reception of knowledge, with these involving facts or news about something. This is how information is interpreted in the works of Bar-Hillel and Carnap (1953), Brooks (1980), Buckland (1991), Devlin (1991), Losee (1998), Sveiby (1998), Dretske (1999), Casagrande (1999), Burgin (2003), Lenski (2010), Floridi (2013), and Vernon (2014), to list but a few authors. However, information as knowledge, news, a fact, a message, does not exhaust the meaning associated with this concept. The reviewed studies show how information may be conceptualized as a purely natural phenomenon. For example, Carl von Weizsäcker writes that "*information is not a material thing or a content of consciousness. These two interpretations fall apart facing the objective character of information*", and he states that "*information is what is common between two different paper telegrams, one written by the sender and one received by the receiver*" (von Weizsäcker, op.cit., p.79).Von Weizsäcker therefore seeks the "*objective character of information*", where objective means that it is independent of a human subject or physical carrier (e.g., a sheet of paper, telegram, etc.) or that it is common across different physical carriers/embodiments. Information reduced to language (the most common meaning of information), he claims, is not sufficient to explain what information is. "Language" is understood by von Weizsäcker as a general means of communication between human agents, but not necessarily the written or spoken word in any particular language. He proposes that "*information should be conceptualized as a third thing, independent of matter and consciousness*" (ibid., p.79). In this view, information is fundamental to nature. It has no meaning or intentionality like consciousness has. Von Weizsäcker views of information face some problems, however. In his exposure of information, he claims that information must have meaning, yet if information is not consciousness, as he says, it cannot have meaning, as meaning arises in a conscious agent, such as a human or other intelligent system. As we indicated earlier, this incoherence was not resolved by von Weizsäcker.

[181] We regard Wikipedia entries as representing the popular meaning of concepts rather than their scientific renditions. Thus, researching the use of the term "information" in the popular, non-scientific context seems appropriate for establishing the use of this term outside of the domains of philosophy and science.

For Turek, information is related to shape, form, or the internal shape of things rather than to a message, news, or knowledge. He writes that:

> *the term information or to inform has an origin in the Latin term "information" and "inform." Information denotes an image, a visual representation, an outline; "inform" is a verb that can be translated as "giving form, shape "and "creating form, "as well as, figuratively speaking, "to educate or teach." The prefix "in" is translated as "inside", the terms "in" and "form" together have a special meaning that can be translated as "internal shape" or "internal composition." To explain the "internal shape" or "internal composition", we need to consult the Aristotelian theory of matter and form. (Turek, op.cit., p.32)*

Turek's analysis of the Latin term *informare* goes beyond the usual and rather superficial readings of this term by such as von Weizsäcker and others. Turek points out that the Latin word suggests two important things:

(1) Information is a causal factor in shaping things (e.g., *"giving form, shape"* and *"creating form"*); and

(2) The shape, in this case, is the internal form of a thing. The explanation of this term ("the internal form of a thing") must be sought for in Aristotelian hylemorphism.

The rest of Turek's paper is an elaboration of this concept.

Stefan Mynarski states that "*information may exist in relation to the specific physical object or phenomena or independently of them. In the former case, we talk about real information; in the latter one, we talk about abstract information*" (Mynarski, op.cit., p.140).Thus, two kinds of information can be differentiated: information related to a physical object and information without a physical reference. In the former case, we have real information, while in the latter case, we have abstract information. As Mynarski claims, *"abstract information is related to objects and events that did not happen or have not happened yet. Thus, as such, it may exist by itself, independently of the existence of mater–energy composites (physical objects) and their matter–energy dependencies. Abstract information is a creation of a mind and is related to the problem of coding* [or encoding]" (Mynarski, op.cit., p.32). Therefore, "abstract information" is a creation of the mind and related to events or phenomena that do not (or may not) exist as physical entities. Being a creation of the mind, abstract information bears a strong resemblance to epistemic information as it is defined in this study, albeit with the qualification that epistemic information can be "information" about any phenomenon, whether it exists or not. We are not sure how Mynarski interprets the verb "exist" in the cited fragments, but it cannot have the same meaning for "real" (physical, concrete) and "abstract" (a creation of the mind) information. A charitable reading of the text would suggest that Mynarski was aware of these nuances in the existence of real and abstract entities, as he differentiated them into physical and abstract. We focus on Mynarski's term "real information" for information existing in physical things or connected with physical phenomena.

Collier admits that two meanings are usually associated with information. He states that "*the world must contain either information itself or else something that when properly connected to our cognitive processes is converted into information. This something is transmitted by physical and biological means; received information at the cognitive level must interface in a law-like manner with the transmissions. I am going to stipulate that what is transmitted is information, irrespective of whether there is a cognitive receiver*" (Collier, op. cit., p.2). He adds that "*this notion of information is more general than the common one, containing it as a species. It might be less confusing to use a new term for this broader notion, but technical usage has already extended information to the non-intentional realm*" (Collier, op. cit., p.2). Collier justifies this claim about the existence of causal factor behind information by stipulating that information that is "assimilated" by a cognitive agent must correlate with the outside world to be reasonably predictable and regular. Collier also claims that the notion of information as not related to cognitive gains is more general than the one that is associated with cognition, or in other words, "cognitive" information is just a subcategory of a more general form of information.

Stonier, likewise, states, *"Just as exist different forms of energy—mechanical, chemical, electrical, heat, sound, light, nuclear, etc.—so do there exist different forms of information. Human information represents only one form of information*" (Stonier, op. cit., p. 9). Furthermore, he claims that *"information may be propagated as patterns of light, pulses of chemical substances, pulses of compressed air, pulses of radio waves, pulses of electrons. Information handling in the present generation of computers is digital. In the human nervous system, there are dozens of neurotransmitters and other related substances which can enhance or inhibit nerve impulses. The nature of the information inside people's heads must be different from the one contained inside the computer*" (ibid., pp.10-11). He also states that "*perhaps part of the problem of recognizing and accepting the idea that information has physical reality and constitutes an intrinsic property of the universe stems from the fact that we ourselves are so deeply embedded in the processing and transmitting of it*" (ibid., p.12). Energy, a fundamental element of reality, has different forms of appearance or realization, so it is information, and human information is just one form of this. This is a significant claim, because it goes against most of the definitions of information that currently prevail, where information is something that has some meaning to a human observer. Information has different physical realizations and carriers, so one cannot regard the external shape of a physical carrier as information. These external forms differ depending upon the carrying medium. In the same fragment, Stonier posits that the diversity of carriers used in the communication of information demonstrates that information has physical realization and that it is a property of nature, and we just have a problem realizing this, preferring instead to focus exclusively on our perspective and asking what value "it" has for us.

For Nagel, the reason and order we perceive in nature is not a direct reflection of our minds, as postulated by Kant,[182] but of the organization existing independently in nature. He states that *"science is driven by the assumption that the world is intelligible. That is, the world in which we find ourselves, and about which experience gives us some information, can be not only described but understood*" (Nagel, op. cit., p.16), adding that "*without the assumptions of an intelligible underlying order, which long antedates the scientific revolution, discoveries (of sciences) could not have been made*." Furthermore, Nagel claims that *"thought and reasoning are correct or incorrect in virtue of something independent of the thinker's beliefs*" (ibid., p. 72). Nagel argues for the existence of a rationality (i.e. intelligibility, order) pervading nature that is not a human creation or invention. (Note how Nagel argues against the Kantian philosophy of knowledge.)[183] The rationality, intelligibility, or order that pervades nature is therefore a property of nature, one that long predates humans. This all-pervading order/rationality is what enables all sciences to emerge. Finally, he states that "*if we believe in natural order, then something about the world that eventually gave rise to rational beings must explain this possibility*" (ibid., p. 82), suggesting another reference to the causal power of information. For several researchers, information may have causal power at the fundamental level, at the forming of the universe. In Nagel's view, information lies at the root of evolution and its causality. For Nagel, if we believe in physical laws, we need to accept information as "*something about the world that eventually gave rise to rational beings.*" Thus, information interpreted as knowledge about something is a reflection of a more primary, mind-independent aspect of nature. It is an order or structure of nature to which we attribute the concept of information.

Dodig Crnkovic expresses a similar idea, stating that "[*proto-information*] *becomes information for a cognizing agent in a process of interaction through which aspects of the world get uncovered*" (Dodig Crnkovic 2013b, p.1). Thus, this proto-information, or information embedded in nature, is, or may become, information for a cognitive agent, so proto-information is potential information about the world when received by an agent.

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[182] Greatly simplifying it, we could say that Kant's transcendental argument is the claim that while there must be an external source for our knowledge of the objects in nature, the mind imposes upon the senses its own interpretation (i.e. pure forms of perception), and this is what we perceive (McCormick 2019).

[183] We talk here about the Kantian thesis that the "thing-in-itself" (or in Kant's German, *Ding an sich*) is not knowable, and the mind imposes its structure on our perception of nature, so pure categories of understanding are found a priori (before experience) in the mind. Thus, we cannot deduct from observation that nature is structural or something else.

Hidalgo states that "*information is not about something; it is physical order embedded in objects; information and meaning refer to concepts that are fundamentally different*" (Hidalgo, op.cit., pp.15-16). Hidalgo clearly indicates that information is separate from meaning, although it can be interpreted and regarded as a message, but this is not the defining characteristic of information. Information with meaning emerges when information encounters a cognitive agent, whether artificial or natural. In other words, the agent creates meaning. The order of, or in, nature that is understood here as information is epistemically neutral, so it has no intrinsic meaning, but it may represent meaning for someone. Information-as-order or order-as-information is always and everywhere. That is why we humans can derive meaning from any natural phenomena, and this universal property of nature has been understood and abused by diviners, shamans, seers, and such like, as we have pointed out several times already. In this view, claims like "information is all around us" and "we are information processing systems", which are often found in the popular press and popularized science books, can be explained and understood (apart from the recognized fact that we are de facto information processing biological systems).

(2) Information is a physical/natural phenomenon

What does it mean when we claim that information is a physical phenomenon? It means that information is an aspect of physical reality, so it can be measured, quantified, and observed because it has a physical existence. Information is not some form of "spooky" fluid or, in the language of von Weizsäcker, some "transcendental" entity. It belongs clearly to the physical universe. Von Weizsäcker claims that information has physical expression and characteristics and belongs to the world of physical phenomena, so information is "*not our momentary state of consciousness*" (von Weizsäcker, op.cit., p. 79) and can only be understood "*in conjunction with the matter-energy pair*" (ibid., p.80). Mynarski, meanwhile, claims that "*Real information together with matter-energy is a concrete component of every system*" (Mynarski, op.cit., p.140), so it is a part of physical systems. Collier, for his part, observes that "*Physical things have properties that give them a definite structure and causal capabilities. If information is an intrinsic property of physical objects then it seems likely that it is contained in their physical structure*" (Collier, op. cit., p.1). Thus, information is a part of the physical world, the world of real objects. Likewise, Tom Stonier claims that "*'information' is as much a part of the physical universe as is matter and energy*" (Stonier, op. cit., p.2). He further states that "*information has physical reality and constitutes an intrinsic property of the universe*" (ibid., p.12). Heller, meanwhile, postulates that "*information as informational interpretations of the laws of nature may be seen as a complement rather than a competing option to the scientific structuralism*" (Heller 2009, pp.62-63). Thus, information is a part par excellence of physical reality, so it must be physical. For Dodig Crnkovic, "*information is a fundamental ontological category*" (Dodig Crnkovic 2012, p.1) and "*all information is carrier by some* *physical*" (Dodig Crnkovic 2009, p.20). In addition, *"the ontologically fundamental entities of the physical reality are information*" (ibid., p.2). Thus, if information is ontologically fundamental, then it must be a part of the real world and therefore physical. For Hidalgo, *"information is physical; information is always physically embodied; information is physical order*" (Hidalgo, op.cit., p. 19). Furthermore, *"information is inherent in all the physical objects we produce, because they embody physical order*" (ibid., p.196). Hidalgo has little doubt that information has a physical presence, yet Hidalgo's work does not explain to us what information is .It only establishes the fact that the information is part of the physical world and that as a physical phenomenon, it can be studied through the methods of the physical sciences.

(3) Information as a natural/physical phenomenon has no meaning

This claim is somewhat related to the previous one in stating that information has no intrinsic meaning because information and meaning are two separate concepts. Meaning is attributed to information, because information as a natural/physical phenomenon is meaningless. Information just exists, much like the physical world is out there regardless of whether there is a cognitive agent to see it or not. Von Weizsäcker is not entirely sure about the relation of meaning to information. On the one hand, he claims that meaning "*is not an act of thinking but the content of this act*" (von Weizsäcker, op.cit., p.80), implying that meaning is created through the act of thinking rather than existing as a property of information. On the other hand, though, he claims that *"in no case is information any form or structure, even defined at a high level of abstraction. Two things are needed here: linguistic character and univocal meaning*" (von Weizsäcker, op.cit., p.81). Von Weizsäcker has in mind some kind of an abstract language, which we may interpret as some form of regularity or symbolism. However, what is a language and what is not seems unclear to him, because he states that "*the boundary between the linguistic and non-linguistic forms is not clearly defined*" (von Weizsäcker, op.cit., p.81). It appears that von Weizsäcker cannot free himself from the anthropomorphic perspective on information, making his view of information somewhat incoherent. Stonier, meanwhile, observes that "*If information has an independent reality, meaning does not. Meaning involves the interpretation of information in relation to some context…we must not confuse the detection and/or interpretation of information with information itself*" (Stonier, op.cit., pp. 17-18). Hidalgo clearly states that "*information is meaningless; information is not about something; it is physical order embedded in objects; information and meaning refer to concepts that are fundamentally different*" (Hidalgo, op.cit., pp. 15-16) and that "*Meaningless forms of order are what information truly is*" (ibid., pp. 15-16). The problem of the relation between meaning and information is discussed further in the following section.

(4) Meaning in information is derived by the mind of a cognitive agent

Meaning is not an intrinsic aspect of information. This means that meaning (in information) is derived from, or added to, physical stimuli (i.e. physical information) by a cognitive agent, [184] implying that information is relative to that agent. How meaning is derived and what we mean by an agent is detailed in Chapter Five. Of course, the fact that meaning is derived from, or added to, physical stimuli, which we denote as physical or ontological information, allows us to say that information carries meaning. Collier observes that "*there must be some property of objects (in the world) that allows us to have information about them. This property must be causally based and communicable to us, as well as being commensurate with information in the vulgar sense*" (Collier, op.cit., p.1). He also writes, *"There is something 'out there in the world' that can be transmitted to intelligent beings that can understand the information it contains and pass it around among themselves. Either this something is pre-existing meaningful information or else it can be converted by cognition into meaningful information*" (Collier, op.cit., p.5).

Thus, information in nature is positioned as having no meaning, but meaning is derived by cognitive faculties from information that exists, in some sense, in nature. Stonier illustrates this with the example of a falling tree: "*If a tree falls, and there is no one to hear it, does it produce the sound? The answer is no if that sound exists only if it causes vibrations is in a human eardrum. The answer is yes if one defines sound as patterns of compressed air produced by the crushing tree. The former interpretation is egocentric and obstructs any intelligent analysis of the world outside*" (Stonier, op.cit., p.5). He also writes: "*If information has an independent reality, meaning does not. Meaning involves the interpretation of information in relation to some context. We must not confuse the detection and/or interpretation of information with information itself*" (Stonier, op.cit., pp.17-18).

Dodig Crnkovic also believes something similar, stating that "*[proto-information] becomes information for a cognizing agent in a process of interaction through which aspects of the world get uncovered*" (Dodig Crnkovic 2013b, p.1). As one may recall, proto-information is the structural aspect of natural phenomena that we call ontological information here. Hidalgo provides probably the clearest statement that information is meaningless, with meaning being derived from information by a cognitive system: "*information and meaning refer to concepts that are fundamentally different; what travels through electromagnetic waves is information not meaning; meaning emerges when a message reaches a life form or a machine with the ability to process information; meaning is derived from context and prior*

[184] The strong similarity between epistemic and ontological information and the perception of color is difficult to escape unnoticed. Color is how we perceive different electromagnetic wavelengths, which are of course colorless. Meaning is, in a sense, how we perceive an epistamically neutral physical stimulus.

knowledge; biological forms of communication (such as DNA) are there whether we know how to decode them or not. They are a characteristic of information-rich states, not of who is observing them" (Hidalgo, op.cit., p. 15-16).

(5) The role of information in nature may be conceptualized as a matter–energy–information complex

Information as an element of nature is conceptualized as a complex in a form resembling that of Aristotelian hylemorphism (i.e. a matter–form compound). Different authors conceptualize this matter–energy–information complex in different ways, but regardless of the specific details, all the cited authors agree that information is responsible for the structure, organization, and shape of things, and this is clearly an acceptance of the compositional nature of existing entities. Von Weizsäcker states that information "*is Platonic form, or Aristotelian eidos, interpreted within the 20th- century idiom*" (von Weizsäcker, op.cit., p.79). What this means is not exactly clear, though. Furthermore, he says, *"Information is something of (an act of) imposing form on matter or pressing matter into form*" (ibid., p.80). In this statement "information" is an action, and "form" is imposed on matter by information, so matter is shaped by form. However, this claim leads to the strange interpretation that we have two separate things, matter and form, and these somehow combine together to give us formed objects or things. This is not very clear, so von Weizsäcker adds, *"We need to, however, remind ourselves that information may be understood only in conjunction with the matter-energy pair*" (ibid., p.80). Turek is more specific. When describing information as the internal shape of things, he observes that "*to explain the 'internal shape' or 'internal composition,' we need to consult the Aristotelian theory of matter and form,* "and he adds that "*Form means shape or outline and is opposed by the term 'content.' For in a scholastic philosophy (i.e. Aristotelian), form is an element of reality that shapes the shapeless chaos-matter*" (Turek, op. cit., p.32). Turek explains the relation between form and matter in the following passage: "*to explain the existence of many individuals of the same genus (having the same form), we have to introduce another element, a prime matter. The role of this prime matter is to impose individuality on forms. Form shapes matter, matter imposes on form individuality in the representatives of the same genus. There is no precedence matter, first form, second, or vice versa; this is a relationship that may be considered figuratively as interaction: matter or form cannot exist separately; they always constitute indivisible wholes. Balls are identical in form but different in matter, which is why we can perceive them as individuals*" (ibid., p.32).

(6) Whatever physically exists contains information

This claim is made without any Aristotelian/Platonic connection (i.e. Form, *eidos, morphe*), so it may be judged as "cleaner" or more palpable for philosophers who prefer to avoid the ancient theories. Mynarski states, *"Real information together with matter–energy is a concrete component of every system*" (Mynarski, op.cit., p.140). Furthermore, we are told that "*Information is therefore the most important ingredient in any system, as it introduces order and organization*" (Mynarski, op.cit., p.140). Collier, meanwhile, observes that "*Physical things have properties that give them a definite structure and causal capabilities. If information is an intrinsic property of physical objects, then it seems likely that it is contained in their physical structure*" (Collier, op.cit., p.64). This implies that if information exists, it must be a part of all physical things, so we assume that when we talk about things, we talk about them having a definite shape or form. This view is also expressed in the study of Stonier, who states that *"any physical system which exhibits organization contains information*" (Stonier, op.cit., pp. 25-26). Similar views are expressed by Heller, who says that "*As the world is a certain structure, it contains information, or this structure-world encodes information* (Heller 2009, pp. 62-63). He also states, *"The modern theoretical physics suggests that the world does not possess structure but is a structure. This structure contains encoded information or is information*" (Heller 1995, p.170).Gordana Dodig Crnkovic holds a similar understanding of information, stating that *"Understanding patterns as information; one may infer that information is a fundamental ontological category*" (Dodig Crnkovic 2012, p.1). She adds that information "*is a fabric of reality and reality consists of informational structures organized on different levels of abstraction/resolution*" (Dodig Crnkovic 2013a, p.6) and that *"information is what constitutes the structure of the universe at any given moment*" (Dodig Crnkovic 2008, p.2). Cesar Hidalgo expresses the same idea, saying that the world **"***is pregnant with information, it is [...] a neatly organized collection of structures, shapes, colors, and correlations. Such ordered structures are manifestations of information*" (Hidalgo, op.cit., p. 17), adding that *"information is inherent in all the physical objects we produce*" (Hidalgo, op.cit., p. 19).

(7) Information is expressed in structures/form and the organization of things

All the cited researchers associate information with some kind of structure, form, or organization, but structure/form/organization and information are not exactly the same (i.e. they are not synonymous).Von Weizsäcker states, *"I will consider information as form, structure, or shape. This form may be a form of artifacts or phenomena apprehended through the senses: printing ink or ink on a paper, chalk on a blackboard, sound waves in the air, electric current impulses in the conduit*" (von Weizsäcker, op.cit., p.80). Furthermore, he writes, *"You may also define information without reference to language or communication. In this case, information exists in nature objectively. These are measurable collections of* *structures, and we only talk about existent things*" (von Weizsäcker, op.cit., p.81). Mynarski makes three claims with regard to this point: i) "*from the perspective of information systems, information is a measure of organization of these systems or a measure of the degree of their undefinability*" (Mynarski, op.cit., p. 139); ii) "*Information perceived this way is related to the constitution of a system and its orderliness*" (Mynarski, op.cit., p. 139); and iii) "*Information relates to the system constitution and internal organization is denoted as structural information*" (Mynarski, op.cit., p. 139). Mynarski further claims that "*Information is therefore the most important ingredient in any system, as it introduces order and organization*" (Mynarski, op.cit., p. 140), so he posits that information is the order and organization of a system. Stonier states, *"Information is defined as the capacity to organize a system or to maintain it in an organized state*" (Stonier, op.cit., pp. 25-26). Furthermore, he claims that *"Organization is a reflection of order. A structure or system may be said to be organized if it exhibits order*" (ibid., pp. 25-26). Stonier also talks about information as the internal structure of the universe when he says that "*Information, as used in this book, is a property of the universe—it is a part of its internal structure* (ibid., pp. 17-18). However, this "internal structure" is not explained further. He states that "*The information which is processed by the solution of potassium permanganate interacting with a crystal of manganese dioxide… is the organizational pattern of the carrier of information. That is, in each and every instance, the information is physically encoded as patterns of organization*" (ibid., p.25). Furthermore, he states, *"Information may be considered as the more abstract quantity, which, when added to matter, manifests itself as structure (organization)*" (ibid., p.28-29).

Heller, meanwhile claims that "*As the world is a certain structure, it contains information or this structure-world encodes information* (Heller 2009, pp.62-63). He also states, "*The modern theoretical physics suggests that the world does not possess structure but is a structure*" (Heller 1995, p.170), adding that "*This structure contains encoded information or is information*" (ibid.). Furthermore, he posits that *"the current understanding of information is purely formal (Shannon-Weaver-Hartley theory of information).Thus, information is reduced here to structure, not to what this structure is filled with. In this view, the structure of the world is an information code or encoded information, and the role of science is to decipher this code*" (Heller 1995, p. 30).This fragment suggests that structure is what information is reduced to in the current theory of information, but it is not information itself. Dodig Crnkovic suggests something similar by saying that *"Understanding patterns as information, one may infer that information is a fundamental ontological category*" (Dodig Crnkovic 2012, p.1). Furthermore, she adds that information "*is a fabric of reality, and reality consists of informational structures organized on different levels of abstraction/resolution* (Dodig Crnkovic 2013a, p.6) and that *"information is what constitutes the structure of the universe at any given moment*" (Dodig Crnkovic 2008, p.2). Finally, she states, "*nature [is] informational structure, a succession of levels of organization of information*" (Dodig Crnkovic 2012, p.5). Dodig Crnkovic unfortunately does not further explain what these structures are, however. Hidalgo, meanwhile, states that the world *"is pregnant with information…it is...a neatly organized collection of structures, shapes, colors, and correlation*" (Hidalgo, op.cit., p. 17). For him, these structures represent the order in how things are arranged, because he claims that *"order means physical order, the way in which parts of the system are arranged. By definition, physical order is information. Physical order is what differentiates the Bugatti before the crash from the wreck that was left after the crash*" (Hidalgo, op.cit., p. 196).[185]

(8) Information is not structure

Information is most often associated with structure, as we concluded above. We have in mind the visible form of an object, and we also see it in quantifications of information where functions assign some number to visible structures. However, information is not the structure that we are quantifying or even the one we can see. We should, and this is one of the conclusions of this study, stop associating information with the concept of a structure without clarifying it further. For example, what kind of structure do we have in mind? What kind of association are we talking about, and how does this structure relate to information? This observation about the nature of information is one that most of the studies agree upon. Von Weizsäcker states that information "*is never identified with a geometric form, as a printed telegram and the acoustic communication of a telephone operator may contain the same information*" (von Weizsäcker, op.cit., p.80). Furthermore, he states, *"In no case is information any form or structure, even defined at a high level of abstraction*" (von Weizsäcker, op.cit., p.81). He adds, however, the restriction that information "*is never identified with a geometric form, as a printed telegram or the acoustic communication of a telephone operator may contain the same information*" (von Weizsäcker, op.cit., p.80). In the following fragment, von Weizsäcker suggests that information is a linguistic form representing structure or form: "*If we denote as information any form that can be described by enumerating a finite number of yes-or-no decisions, this seemingly objective information becomes a linguistic form*" (von Weizsäcker, op.cit., p.80).This is somewhat difficult to accept, because on the one hand, von Weizsäcker denies the existence of objective information. On the other hand, meanwhile, he claims that "*You may also define information without reference to language or communication. In this case, information exists in nature objectively*" (von Weizsäcker, op.cit., p.82). This claim would suggest that there is no difference between the linguistic form, even in such an abstract view, and the objectivity of nature, which is an anthropomorphism that is rather difficult to accept.

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185 *Automobiles Ettore Bugatti was a French car manufacturer of high-performance automobiles. It was founded in 1909 in the then-German city of Molsheim* ('Bugatti' 2018).

Turek, meanwhile, distinguishes between form and structure and associates information with form: "*The concept of a structure is contained in the concept of a form. This means that every structure is a form, but not that every form must be a structure*" (Turek, op.cit., p.34). Structures, for Turek, are objects that can be quantified, as demonstrated by the following fragment: "*Forms reducible to structures are investigated by the natural sciences and may be described by logic and mathematics or other formalisms*" (Turek, op.cit., p. 36).Thus, structures are what can be counted or quantified. He states that information is a specific type of structure by saying, "*I will use the concept of substance to denote a complex of matter and form shaping it. If we have a substance S1 that is formed by an individual structure I with a countable number of elements, and we have a substance S2 that can be formed by a structure I, then we will denote structure I as information*" (Turek, op.cit., p. 34). Turek explains that "*in this context, a question about the essence of information requires a precise description of the form that corresponds to this concept [of information]. I will be attempting to demonstrate that the concept of information means a certain subset of sets of forms reducible to structures*" (Turek, op.cit., p. 34). The term "set" is used by Turek rather loosely, not denoting an axiomatic mathematical structure but rather a collection of things. For Stonier, meanwhile, information is not even organization. He says, *"Organization and information are, by definition, closely interlinked. However, they are different: one cannot have a shadow without light, but a shadow and light are not the same. A shadow is the manifestation of light interacting with an opaque object. Likewise, organization is the manifestation of information interacting with matter and energ*y" (Stonier, op.cit., pp. 25-26). He continues, "*That is, in each and every instance, the information is physically encoded as patterns of organization*" (Stonier, op. cit., p. 25). What is more, while information is related to structure and organization, it is not either of them, as Stonier puts it, *"To the argument that what we are really talking about is 'patterns' and 'organization,' the answer is that 'information' is a more abstract generalization which one needs in order to measure it by some universal measure, such as 'bits.' It becomes as difficult to measure quantitatively a pattern or a structure in terms of bits without the aid off the abstract concept of information*" (Stonier, op.cit., pp.28-29). Finally, Heller admits that information is somehow related to structure, but it is not it: "*the current understanding of information is purely formal (Shannon-Hartley theory of information). Thus, information is reduced here to structure, not to what this structure is filled with. In this view, the structure of the world is an information code or encoded information, and the role of science is to decipher this code*" (Heller 1995, p. 30).

(9) Information is responsible for the internal organization of nature's objects and artifacts

Information is perceived as the cause of the shape of objects and their internal organization. This role is rarely substantiated or compared to the Aristotelian four causes, however, and it is usually rooted in the meaning of the Latin verb "*informare*." Attributing a causal role to information would require substantial, rather speculative analysis. We therefore acknowledge the causal role of information as indicated by many writers, but we do not explore this topic beyond directly citing what these authors claim. That said, the causality of information would be rooted in its physicality if we accept that information is a physical phenomenon. First, von Weizsäcker states, *"The origins of the word 'information 'point us in the proper direction. In the Latin dictionary, the basic meaning of informare is to shape, form, or as a metaphor, form a thought, image. 'Informatio' is something of (an act of) imposing form on matter or pressing matter into form*" (von Weizsäcker, op.cit., p.80). Turek expresses a similar view: "*The term information or to inform has an origin in the Latin term for 'information' and 'inform.' Information denotes an image, a visual representation, outline; 'informo' is a verb that can be translated as 'giving form, shape, 'creating form,' and figuratively speaking, educating or teaching. The prefix 'in' is translated as 'inside,' and 'in' and 'form' together have a special meaning that can be translated as 'internal shape' or 'internal composition'*" (Turek, op.cit., p.32). Furthermore, he states, *"Form means shape or outline and is opposed by the term 'content.' For in a scholastic philosophy (i.e. Aristotelian), form is an element of reality that shapes the shapeless chaos-matter*" (Turek, op.cit., p.32). Turek clearly associates information as form with the formal cause of Aristotle (see Falcon 2018). He confirms this view in this fragment: "*Form shapes matter; matter imposes on form individuality in the representatives of the same genus*" (Turek, op.cit., p.32). Finally, Heller identifies information with the laws of nature, but we are not told what these laws would be. He states, *"Informational interpretation of laws of nature may be seen as a complement rather than a competing option to the scientific structuralism*" (Heller 2009, p.62-63). Thus, from this perspective, the structures of nature are functions of the laws of nature (i.e. information), but such a claim is just conjecture.

(10) Natural processes are information processes that we may regard as computing

Natural processes are information processes that we may regard as a form of computing: This claim would require changing our definition of computing from Turing computation. This is a rather canonical definition of computing, and not everyone would agree to replace it. Hidalgo states, *"Physical processes are information processing or computing in the generalized sense and the ability of matter to process information or the ability of matter to compute*" (Hidalgo, op.cit p. 35). Dodig Crnkovic postulates similar views in several paragraphs: i) "*The ontologically fundamental entities of the physical reality are information (structures) and computation (change)*" (Dodig Crnkovic 2009, p.2); ii) "*information and computation are two interrelated and mutually defining phenomena—there is no computation without information (computation understood as information processing) and vice versa, there is no information without computation (information as a result of computation)*" (Dodig Crnkovic 2013, p.1); and iii) "*no* *matter if the data form any symbols; computation is a process of change of the data/structure*" (Dodig Crnkovic 2011, p. 305). While not explicitly doing so, these statements postulate the following: Any information processing is computing, because computing is information processing. Computing, or information processing, always involves changes in the structures of some physical system, and in the canonical case, this system is a computer. Thus, we may generalize that any changes in physical structures are changes in information, so they are therefore computations. Symbolic computation (the canonical view of computation) is therefore a narrowly understood form of computation or an imposed interpretation for a certain class of physical processes.

(11) Measures of information provide quantifications of sensible structures that reflect information but are not information itself

Quantified models or measures of information (a) quantify tangible structures that are not information itself. Thus, we may say that they measure just (b) the expressions or effects of information. While claim (a) is rather obvious, claim (b) has also been made several times in the preceding analysis. Thus, we may conclude that measures of information provide quantifications of sensible structures that reflect information but are not information itself. Few authors posit this explicitly, however. Heller writes, *"But the current understanding of information is purely formal (Shannon-Hartley theory of information).Thus, information is reduced here to structure not to what this structure is filled with. In this view, the structure of the world is an information code or encoded information, and the role of science is to decipher this code*" (Heller 1995, p. 30).This statement therefore claims that the mathematical model of information provided by Shannon-Weaver-Hartley is a reduction of the concept of information to a specific mathematical function and associated axiomatic structures, as any mathematisation is.[186] Von Weizsäcker, meanwhile, states that quantification changes the character of information: "*If we denote as information any form that can be described by enumerating a finite number of yes-no decisions, this seemingly objective information becomes a linguistic form*" (von Weizsäcker, op.cit., p.82). Associating information with a syntax (language) takes away its objective character, because syntax is a human-imposed interpretation of nature. For his part, Stonier states that "'*information' is a more abstract generalization which one needs in order to measure it by some universal measure, such as 'bits.' It becomes as difficult to measure quantitatively a pattern or a structure in terms of bits*" (Stonier, op.cit., pp. 28–29). In other words, imposing the concept of bits on information, which is what Chaitin and Shannon-Weaver-Hartley proposed, reduces the concept of information to exactly that (i.e. bits or

[186] *Mathematisation is the act of interpreting or expressing something mathematically or the state of being considered or explained mathematically* ("Mathematisation" 2020). See also (Gellert & Jablonka 2008).

symbols). This reduction may make information "quantifiable" but only in a narrow sense (i.e. in the sense of counting bits).

4.2 Properties: How many and which ones?

We now ask how many properties we should assign to information from the features conceptualized in eight intuitions and eleven claims. Initially, it was proposed that I_O has four properties: structural presentation (SR), ontological objectivity (OO), physical embodiment (PE), and epistemic neutrality (EN). Judging what will be a minimally sufficient set of properties is subjective out of necessity, but the process is not entirely unjustified. First, it is based on insights from the reviewed studies, and these studies should support the proposed set of features. Second, the smallest set has to account for what these studies conclude, preferably completely and exhaustively. We will then attempt to develop minimal yet sufficient set of properties. The following sections propose are solution to this challenge.

4.2.1 The Proposed Three Properties

We propose reducing the characteristics of ontological information to just three features and two corollaries. These seem to correlate well, as we will show, with the claims and intuitions from the studies. Moreover, they subsume the four initial properties, somewhat confirming our intuitions about ontological information, which have guided this study. Seeing as there are only three properties rather than eleven like in the claims from the studies, eight like in the intuitions from the investigated fragments, or four like in our introduction, they are more minimal than the other options and therefore more conceptually efficient. The three proposed characteristics are:

- (EN) Information has no meaning: Epistemic Neutrality
- (PE) Information is physical phenomena: Physical Embodiment
- (FN) Information is responsible for the organization of the physical world: Formative nature

With two corollaries:

- (C1) Information is quantifiable.
- (C2) Changes in the organization of physical objects are denoted as computation or information processing.

Why we chose to separate the two corollaries (C1 and C2) from the first three properties will be explained later. Table 2 below lists these properties, together with their characteristics, and correlates them with the claims from the detailed studies.

Claim	Property	Description
(3)Information as a natural/physical phenomenon has no meaning. (4)Meaning in information is derived by the mind of a cognitive agent.	Epistemic Neutrality (EN)	Information has no meaning.
(2)Information is a physical/natural phenomenon. (5)The role of information in nature may be conceptualized as a matter–energy–information complex. (6)Information is fundamental to nature, so whatever exists physically contains information.	Physical Embodiment (PE)	Information is a physical phenomenon.
(7)Information is expressed in structures/form and the organization of things. (8)Information is not structure. (9)Information is responsible for the internal organization of nature's objects and artifacts.	Formative nature (FN)	Information is responsible for the organization of the physical world.
(10)Natural processes are information processes that we may denote as computing.	Corollary C2	Changes in the organization of physical objects are denoted as computation or information processing.
(11)Measures of information provide quantifications of sensible structures that reflect information but are not information itself.	Corollary C1	Information is quantifiable.

Table 2. The three properties and two corollaries of ontological information.

Now, why do we combine claims (3) and (4) into the property of epistemic neutrality (EN); claims (2), (5), and (6) into the property of physical embodiment (PE); and claims (7), (8), and (9) into the formative nature (FN) property?

First, claims (3) "information as a natural/physical phenomena has no meaning" and (4) "meaning in information is derived by the mind of a cognitive agent" both concern the meaning associated with information, with claim (3) declaring that information has no meaning and claim (4) stating that meaning is derived from information. Thus, they refer to the same characteristic of information, namely that value is attributed to information as a natural phenomenon by an agent, because such information has no intrinsic meaning. The claims can therefore be subsumed under one heading: Information has no meaning.

Next, claims (2), (5), and (6) describe how information is encountered in the physical world: (2) "Information is a physical phenomenon"; (5) "information can be conceptualized in a matter–energy–information complex"; and (6) "information is fundamental to nature. The last claim (6) is effectively confirming the claim of the causal closure of the physical world.[187] If ontological information is a part of this world, it must be physical, thus reflecting claim (2). Claim (5) indirectly refers to the same property, as it positions information as part of a complex that constitutes the physical reality of objects, phenomena, and entities. All three claims position information as part of the physical world, so they can again be subsumed under a single heading: Information is a physical phenomenon.

Claims (7) and (8), taken together, express the notion that information is expressed in structure, but it is not structure in itself. Next claim (9) as "information is responsible for the internal organization of nature's objects and artifacts" adds the concept of a causal role for ontological information. Thus, claims (7), (8), and (9) together describe the role of structures and organization in the conceptualization of information, so they can be grouped under a single heading: Information is responsible for the organization of the physical world.

Now, why are claims (10) and (11) singled out as corollaries? Claim (10) states that "natural processes are information processes that we may denote as computing", but this is an interpretation of ontological information, so it does not constitute an essential feature. Next, claim (11) refers to measures of information. Measures are functions assigned to things or phenomena, so they are of secondary import in terms of characterizing something's nature. In other words, they are devised for utilitarian purposes rather

[187] How do we understand the term "causal closure" in the case of ontological information? This is certainly not a strong causal closure (i.e. every event is reducible to pure physical phenomena at the fundamental level; this position assumes the upward only causation) (e.g., Kim 1993, Vincente 2006). Ontological information (organizational structures) emerges on several layers of physical reality, with the properties at each layer not reducible to the lowest layer (which is what strong causal closure requires). In other words, the properties of a layer "i" are not explainable by the properties of the layers i-1, i-2, i-k, etc. (vide biological systems), with the properties of the layers i-1, i-2, i-k impacting the properties of the layers below (i.e. ,the layer i impacts some properties of layers i-1, i-2, i-k, etc.). This requires downward causation, which does not lead to dualism (see Searle 1998, Nagel 2012). However, these complex systems are still physical, and information is part of them. This is what is meant by "causal closure" in the case of ontological information.

than metaphysical ones. Of course, they can be immensely useful, but their explanatory powers are limited. They are descriptions of nature within the confines of a certain symbolic language.

Thus, we claim that ontological information is characterized by epistemic neutrality, physical embodiment, and formative nature. The property of epistemic neutrality (EN) means that information has no meaning, with this being derived by the capacities of a cognitive agent based on information. The property of physical embodiment (PE) means that information is a physical phenomenon, so it may be conceptualized in a matter–energy-information complex (one not directly implying Aristotelian hylemorphism), and it is fundamental to nature (i.e. whatever exists physically contains information). Finally, the property of formative nature (FN) means that information is responsible for the organization of the physical world, so information is expressed through structures/form and the organization of things, but information is not structure itself—it is merely responsible for the internal organization of natural objects and artifacts.

The properties EN, PE, and FN are well expressed in the published studies, as can be seen in the correlation of these properties with the eleven claims. Thus, with these three properties, no characteristic of ontological information from the reviewed studies is lost. The following section discusses how the properties EN, PE, and FN should be understood.

Note that we do not provide a correlation of these three properties with the eight intuitions for two reasons: First, such a comparison would extend the analysis substantially without moving our discussion forward. Second, we can clearly see that these eight intuitions are entirely subsumed by the eleven claims, so any correlation of the three properties with the eight intuitions would be somewhat redundant and not bring any new perspectives to the discussion.

EN: Information has no (intrinsic) meaning

This property states that ontological information has no meaning, which is defined as representing some value for a cognitive agent. From specific ontological information, an agent may derive something (some value) that has significance for that agent's existence or functioning. The same ontological information may result in a different meaning for different agents. Likewise, this information may have no meaning at all to some agents. Jadacki and Brożek give an example that exemplifies this point: An agent is primarily a conscious being that creates meaning for itself, so the difference between the mechanical and biological reception of environmental stimuli leading to the creation of meaning is not very obvious. In this sense, is a robot a conscious being if it senses light and interprets the image? These questions are discussed further in Chapter Five. However, an agent can in principle be any system, whether organic or artificial, if it senses ontological information or the organization of natural phenomena. Natural agents (i.e. biological systems) have been shaped by nature to perceive nature's properties, including organizational properties, but artificial agents are of our own making of course, so in a sense, they also have biological origins. We are therefore creations of nature, not separated from it. Nagel (2012) discusses this idea in detail. We are built to interpret nature, not falsify it, and evolution assumes this, because organisms that fail to correctly perceive the environment will likely not survive. This is also the general idea behind how we build our artificial agents. However, Kant misinterpreted the nature–mind dependency.[188] This is not an excuse for the failings of his philosophy but rather an explanation.

An agent may also create meaning from his/her own resources in the absence of a specific sender or a receiver (i.e. sending a message without a particular destination target, a broadcast message). This may have meaning for that agent but not necessarily anyone else. We hope that the Arecibo message ("Arecibo Message" 2018) has been sent to someone other than ourselves. If there is no one to decode it, however, it is simply cosmic noise, something close to it, or maybe not even this (i.e. it is too weak and too focused). The fact that ontological information is meaningless means that data, which for some researchers are a primary source of epistemic information, are information that has already been interpreted. Consequently, every fact is laden with theory, and there is no theory-free data. We simply impose a certain format and language on nature's processes and then call them data, but we need to recall from Philosophy of Science 101 that there is no theory-free data (Chalmers 1994, p.72, Bird 2002, p.175).[189] As data are interpreted signals, much like meaning, data for one agent may not be data for another. This is the conceptual context where von Weizsäcker got lost when he said there is no information without language, so information for him must have meaning.

The same argument applies to "information" defined by probabilistic (Shannon–Weaver, Hartley, Fisher) and combinatorial measures (Solomonoff–Kolmogorov–Chaitin). The information defined by these formulas is ontological information that has been interpreted within the formal language of probability

[188] Kant assumed that the mind "creates" the reality that we perceive. Kant does not propose (because the concept of evolution was obviously foreign to him) that the mind evolved to represent reality as closely as was needed for a given entity to survive. Kant also did not ask where the mind came from. The conceptual separation between Kant's concept of the mind and its functions and the modern view can only be fully realized after reading modern studies of the brain, the mind, and its role, such as the work of Damasio (2003, 2018). The issue here is not some kind of model of the mind—such as that of Dennett, Fodor, or someone else—but the close, organic relation between the mind and nature. The mind is part of, or is, nature, not something apart from it. The consequences of this are far reaching. If we postulate that the mind is a computer of sorts, and then does the mind being part of nature imply that nature computes much like the mind does? Is the mind not something apart from it? Would we still wonder what it is?

[189] In university curriculum parlance, the 101 number is usually assigned to an introductory course in a given discipline.

calculus or combinatorial algebra. Any interpretation of ontological information is an imposed interpretation (sic), so it is so difficult to talk about information by looking at its quantifications. When we talk about information expressed through some mathematical formula, we talk about the models we are imposing on the phenomenon. Once we remove ourselves from the context, however, we should clearly recognize that a tree falling in the forest creates a physical pattern of air pressure waves, whether we are there to hear it or not. There is no *Music of the Spheres* or *Musica universalis* ("Musica universalis" 2019). However, there is Gustav Holst's *The Planets* in Popper's sense of three worlds. One cannot accept the concept of ontological information while holding on to the concept of information as meaning or knowledge.

The property of epistemic neutrality (EN) implies that I_O exists independently of the mind of any natural or artificial cognitive, biological, or cyber-cognitive system. Several researchers indicate that this is the case for information. Von Weizsäcker differentiates between information that is "understood in a form-matter composite" and information that includes past experience and past and current knowledge. He says that information in the first sense is form or *eidos* (i.e. a form–matter composite) in the sense that it is a source of knowledge. Thus, he differentiates between information as a physical thing and information as a cognitive product, with the first one being the raw material for the second, although von Weizsäcker later obfuscates this difference. Collier, meanwhile, states that IiT (information in things) is a cause and a source of cognitive information (CI), which must be correlated with the outside world. Thus, outside objects must have a property "that allows us to have information about them", so there must be "either pre-existing meaningful information or else it must be converted by cognition into meaningful information." Collier sees information CI as being created from IiT by cognitive systems, because CI is information with meaning, so meaning has been "added" to external information (IiT). Thomas Nagel states that our knowledge, which is denoted as epistemic information in this study, reflects the world. As this is done in a more or less reliable way, the world must be a source of stable information. This information is what we interpret as the "rationality" of the world, its order or nature. Nagel calls it a "natural order" that expresses itself, or finds expression, in the universal laws of the physical realm. Universal laws are expressions of the order, structure, or organization that we denote as ontological information. Nagel concludes that the existence of the independent, ordered world is the source of our knowledge and "*if we believe in natural order, then something about the world that eventually gave rise to rational beings must explain this possibility*." Thus, in Nagel's research, we have two *locis* and types of information: information in the world perceived as its rationality and laws, independent from the mind, and information in the mind that reflects, rather than accurately copies, the rationality of the world. Dodig Crnkovic postulates the existence of proto-information (PrI), which are patterns or structures in, and of, nature. PrI is “interpreted by an agent “, and it becomes information when “a cognitive agent interacts with aspects of the world. ”PrI should be interpreted as ontological information, while “information” in Dodig Crnkovic’s parlance is created by a cognitive agent, so this is (in the view of this study) epistemic information.

Hidalgo, meanwhile, claims that information is physical, and it expresses the embedded physical order or “arrangement of parts.” This information is meaningless, because meaning is different from information. Meaning emerges when physical information encounters a system that can process it. It is the interpretation of physical phenomena or their properties through cognition. (Of course, we may extend the concept of meaning to include biological organisms and artificial systems. Here, meaning denotes roughly the same concept for cognitive systems in that information has some impact on the structure and processes within these systems.) Thus, we distinguish two concepts of information: information that is devoid of meaning and information with meaning. The former information is perceived as the form, the structure in things, or ontological information in the sense of this study. The latter form of information, information with meaning, which is referred to in this study as epistemic information, has partial origins in ontological information, with meaning being added through cognition. The information in things (i.e. ontological information) is physical in the sense of being embedded in, or a part of, the matter–energy complex. Incidentally, the term “complex” denotes“ *a group of obviously related units of which the degree and nature of the relationship is imperfectly known*” or “*a whole made up of complicated or interrelated parts*” (“Complex” 2018), and it is used here to avoid using the difficult term “hylemorphism”, which is loaded with many interpretations.

In fact, a qualified form of “hylemorphism” is used by several authors, such as Turek and von Weizsäcker, to indicate the relation between matter–energy and information. Certainly, the literary interpretation of a complex as a composite of parts, in light how information is conceptualized, is not correct for the matter–energy–information complex. How information is embedded in matter–energy is not resolved in this study, in the studies we have reviewed, or in any other study for that matter, so it remains open.[190] This problem is as old as philosophy itself. It originated with Plato’s Forms and Aristotle’s *eidos*. These two philosophers somewhat charted the course for this discussion over the coming millennia. Meaningful information is an intentional object, a product of cognition. How meaning becomes added to sensory information is an issue for cognitive sciences, and we currently have a limited understanding of how meaning for intentional objects arises in cognitive systems, although some claim

[190] Some studies (e.g., Landauer 1996, Bennett 2003, Moore 2012, Lutz 2012, Hong et al. 2016, Ladyman et al. 2001) point to the Maxwell demon and Landauer's (erasure) principle for the information–energy connection.

we know it all (e.g., Dennett 2017). A simplified, or generalized, concept of meaning in artificial cognitive systems has algorithmic explanations, but this is bound within the concepts of artificial minds, knowledge bases, and Turing machines, so it is of limited import for the philosophy of the mind, much like with formal models that relate to reality. (See what import Tarski's semantic theory of truth has for understanding what truth is.)[191] Some will recognize the Chinese Room problem in the discussion and the ensuing controversies.[192]

PE: Information is a physical phenomenon

The claim that "ontological information is a physical phenomenon" means several things. Ontological information is not an abstract concept in the way that mathematical objects, ideas, or thoughts are abstract. Ontological information does not belong to the Platonic realm of Forms in either the classic or neo-Platonic sense. Ontological information is real, observable, and measurable. Thus, we can claim that information exists much like other physical phenomena exist, because they exhibit the same class of properties. Furthermore, it seems that whatever exists in a physical sense contains information, so there is no physical phenomenon without information. It took time for the concept of information to emerge as a separate, differentiable aspect of reality, much like how the concept of energy as a separate physical phenomenon also took time to be recognized. One may speculate that the concept of energy emerged once we learned how to use it to our benefit. A similar situation may be claimed for information. The concept of information emerged once we learned how to use it, and this process of discovery has coincided with, or been precipitated by, the advent of the computer, an information-processing tool *par excellence*. Through information technology, we learned to see information all around us as this information became accessible for our manipulation. We have also begun to see ourselves as information-processing systems, because we take in information from the environment and produce knowledge. We also know that the homeostasis of our bodies includes "information-stasis."

The claim that information is a physical phenomenon guards us against attributing some nonsensical qualities to information. Von Weizsäcker claims that information should always be understood within the context of a matter–form composite, where information is quantified by measuring the multiplicity of forms that matter–energy can take on. Physical processes are processes of information exchange. Turek, meanwhile, states that information "*is what is realizable in substance*", while Collier observes that

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[191] See, for example, the comments on Tarski's semantic theory of truth by John Searle in his Berkley Lectures on the Philosophy of Language (Searle 2013a). In short, Tarski's theory of truth does not explain the metaphysical meaning of truth but only truth in an artificial language system. We do not learn much about truth in our everyday and metaphysical meanings from Tarski's theory.

[192] To understand the discussion, see, as starting points, the Chinese Room Argument in (Hauser 2018) or Cole (2015).

information is a property of physical objects, one that "*is contained in their physical structure*." Next, Stonier claims that information is embedded in different forms of matter, while Heller claims that mathematical models of nature decode the information that is encoded in natural structures. Dodig-Crnkovic, meanwhile, postulates that information is what constitutes the structure of the universe, so information is always embedded in matter–energy phenomena. In other words, there is no information without a physical representation, so all information is carried by some physical medium. Hidalgo also claims that information is always physically embodied and that information is physical. This information is inherent in all physical objects, because they embody physical order, and physical order is information. One must be careful not to identify information with the organization of things itself, though. If information were a table, it would not be four legs, a tabletop, and whatever other components. It would not even be the arrangement of atoms that form the wood that in turn forms the table (Russell's famous table view (Russell 1959)). Information is the order of things on multiple levels of organization. Without a table, this information would seem not to exist, because we can identify it only when it is in something.

If we attribute some causal power to ontological information, information must be "of this world" to preserve the causal closure of nature. Something other worldly cannot be the cause of things in this world, unless it is some kind of deity, but we will stay away from this solution in this study.

Closely related to the physical nature of information is ontological objectivity (OB). OB postulates that I_O as an entity, exists objectively. Objectivity in this context means that the object exists independently of an observer (i.e. it is mind-independent). This is how physical objects and physical phenomena exist. The existence of physical entities is also the position of scientific realism or conceptual realism in combinatorial ontology (e.g., Brock & Mares 2010, Coccchiarella 1996), so OB claims that information is just like physical objects or physical phenomena and part of the mind-independent reality. Von Weizsäcker claims that information has an "objective character." He claims that because information is related to the combination/composition of elementary particles, all interpretations of the mass–energy complex apply to information as well. Heller, meanwhile, claims that information may be seen as a material of the world, where "material" is used here in the sense of a physical substance that things can be made from ("Material" 2018), with it having synonyms such as substance, stuff, and medium. Dodig Crnkovic, for her part, claims that information is an "ontologically fundamental entity of the physical reality." Hidalgo, meanwhile, observes that what is left after separating meaning from information that is perceived as having meaningful import is a physical phenomenon that can be seen as physical order.

The consequence of information being a physical phenomenon is the concept of physical embodiment (PE). This property means that I_O always exists in a physical carrier and as a physical phenomenon that is subject to the laws of physics. The claim that "I_O is a physical phenomenon" is necessary and obvious if we want to see information as a part of the physical world, and if this is indeed the case, and we presume that it is, this information must be subject to the laws governing the physical realm. However, we are not sure exactly which laws apply (e.g., the law of gravitation, the law of conservation of momentum, the three laws of thermodynamics, the theory of general relativity, or some other yet unknown laws for information).

Some insight into the sort of laws we may be talking about can be gleaned from the concept of pancomputationalism or natural computing, where all natural processes are seen as information processing. Thus, information would be subject to all laws that we think govern the fundamental properties of the physical universe. We obviously do not know all of these, because if we've learned anything over the history of science, it is that what we know today is never the last word (at least this has been our experience so far). The claim that "I_O exists always in a physical carrier" prevents us from conceptualizing information as some unknown esoteric thing or mysterious phenomenon of sorts, but this is not an endorsement of material monism and certainly not material reductionism. There are philosophies of the mind that consider the mind as not reducible to matter while still recognizing that it has a material base[193].

FN: Information as an organizing factor in nature

Ontological information is responsible for the organization of the physical world. Organization is a fairly broad concept that may be, and is, interpreted as structure, order, form, shape, or rationality (if perceived by a cognitive entity). We do not posit that information is structure, although this has been claimed several times. The problem with such a statement is that we do not know precisely what a structure is and what kinds of structure we would associate with information, as well as how this would be achieved. Information is certainly not the visible structure or shape of an object, but we concede that the shape or structure of an object is how information discloses itself or how we sense its presence. Thus, the shape of a tea cup is not information, but information is being expressed in the shape of a tea cup.

If we try to attribute to the concept of structure some domain-specific meaning, such as mathematical structure or the structure of physical laws, information would simply acquire the characteristics of that domain (i.e. information would be a mathematical structure or a physical law). We may risk conjecturing, though, that quantifications of structure, such as Shannon's ToC probabilistic model of the structure of

[193] Despite claims by some researchers to the contrary the nature of consciousness has not been resolved. See e.g., Kandel (2006, pp. 376- 390), Searle (1998, 2002, 2013b, 2015a, 2015b).

the message, are not information but rather "numbers" assigned to the consequences of information interacting with physical media. It seems that quantifications of information quantify the "shapes "rather than the information. We want to avoid these domain-specific information claims, because ontological information is domain-neutral.

If we say that information is a "deep" structure, it becomes even more ambiguous, because we do not know what we mean by these "deep structures." Finally, if information is a structure, why do we not identify ontological information with structure? Or conversely, why do we posit the existence of information separately from the existence of structure? It would therefore be simpler to say that information is structure, and this is where we would end up with structural realism or informational structural realism. Moreover, structures in structural realism are passive, and they do not carry the meaning of "*informare*", namely to shape, or at least nobody in the structural realism literature has attributed such causal power to structures. We also have other terms like *eidos* or Form for the internal shape of things, which is what gives them their individuality, but these ancient terms are loaded with many interpretations and declaring information as Form or *eidos* could not be regarded as progress in understanding of the concept of information. After all, some would say the Greeks knew it long ago. The term organization seems to encompass the meaning of form, the meaning of structure, as well as allowing for the causal interpretation of "*informare*." Thus, we posit that information is a factor responsible for the organization of physical world.

Information is expressed by, is responsible for, is equated with, or is considered a structural property of natural and artificial objects. The structural property of information is attested to by all of the authors we have studied, although as we mentioned, structures are defined in many ways depending on the context and the discourse domain.

We may again ask whether the structural property of information is intrinsic to information, or is it just the way we perceive information or the way that information reveals itself to us? To help answer this question, we may look at energy and work. We often confuse energy with work, claiming that energy is work. The reality is that work is just away in which energy is perceived. We perceive energy as a factor of "work." By analogy, the structural aspect of information is maybe just the way that information reveals itself but not the information itself. Thus, information is "a principle of organization" that is seen, or at least its effects are, as a structure. Von Weizsäcker conceives information as a structure, the shape of a natural object of an artifact, but information is not simply a geometric shape. Information for von Weizsäcker goes beyond shape—it is something common across different substances and objects with different shapes. He gives the example of a message written on a sheet of paper or printed in a telegram.

Information is what we learn about an object from its structure or shape, yet information is responsible for these structures. For Turek, information is a "*subset of forms reducible to structures*." Information may be realized in prime matter (in Turek's view, information is imposed prime matter), or it is inherent in the form–matter composite. This information can also be represented through mathematical formalism. Collier, meanwhile, claims that things have a definite structure. There must be something that gives them this structure, or it is contained within it. He calls this factor "information." Stonier states that all structures have or contain information, and a change in the information content of an object results in a change in its structure. Information may also be encoded indifferent structures, because it is matter-independent. Heller, meanwhile, postulates that the world is a structure, and this structure contains encoded information. Information structures are therefore fundamental to existence. The more complex a structure, the more limitations it has and the more information it contains. Information is expressed in structures, but form would be a formal cause (in an Aristotelian sense). While information is expressed in structures, it is not what fills these structures. Furthermore, Heller claims that structures in nature are beyond the capabilities of modern mathematical–empirical methods. Jadacki and Brożek claim that information is a certain state in the internal structure of an object. Dodig Crnkovic, meanwhile, claims that information forms structures, which in turn form nature. She defines information as structures on different levels of resolution, with successive levels forming the entirety of nature. Furthermore, she states that reality is built of information structures. She does not explain what these information structures are, though, so we must speculate that they are either structures interpreted as information or structures built from information. Hidalgo defines information as structures, the order or arrangement of parts in system, and these structures are manifestations of information. In other words, physical order is structure that expresses information. In Hidalgo's example, order (i.e. the information contained in an object) explains the difference between the car before the crash and the same car after the crash.

Corollaries C1 and C2

We have formulated two corollaries for three characteristics of ontological information: (C1) information is quantifiable, and (C2) changes in the organization of physical objects are denoted as computation or information processing. So, why were these characteristics singled out?

Corollary (C1), namely that information is quantifiable, is supported in almost every study we reviewed. Functions quantifying information are almost foundational for the idea of information, even if they do not represent what information is but rather how it discloses itself. These quantifications are used to measure certain utilitarian aspects of information, such as optimal communication channel coding (Shannon), error recovery, and optimal computer program size (Chaitin), and such like. They play very important roles in a variety of aspects, but they do not explain the nature of what they seek to quantify. This corollary is supported by claim (11) in that measures of information provide quantifications of sensible structures that reflect information but are not information itself.

Corollary C2, meanwhile, states that changes in the organization of physical objects can be denoted as computation, but what does this mean? Computing refers to information processing, and most would agree with this. Computers process information (i.e. they compute). Computing by computers is essentially a form of symbol manipulation with a set of rules. This is the case for a Turing machine, which is our general model for symbolic computing. The information we seek to manipulate is encoded into symbols that we can then manipulate. This is obviously epistemic information or semantic information; however, because a Turing machine interprets symbols that we define in the way we have defined them. In other words, we impose syntax and semantics on the input. Computers, in contrast, do not add their own interpretation or even their own syntax. For example, we may say that the specific form of a specific electromagnetic wave is "0" or "1." We may say that "01000001" is the letter "A" in ASCII or "100" is the number 4, and then we tell the computer what to do with these symbols through a program. In principle, the computer can add "A" to "4" as 01000001+ 100, because this is a valid binary operation. We would be rather unlikely to do this, though, because it would make little sense to us, and consequently computers, to add a number to an ASCII-encoded letter.[194] (One exception might be if you wanted to transform the "A" into an "E", (i.e. move forward four letters through the alphabet), but that would be a specific intention on the part of the human programmer.) To refer to Searle again, computing is in the eyes of the beholder (Searle 2015b).

In contrast, when information is seen as ontological information and this in turn denotes the organization of physical things, the concept of information processing changes. In this case, information processing is a change to the organization of a physical system. Information processing acquires the meaning of computing but not in the sense of symbol manipulation using a strictly defined limited set of rules—it refers more to changes in the organization of a physical media. As specific case of information processing is TM computing (realization of the abstract Turing Machine), but the more generalized sense of computing concerns changes in physical organization or the processing of ontological information. In reality, what computers do is enact controlled changes to the organization of the physical systems underlying them. These computers are in essence (in the sense of a physical artifact) von Neumann-type machines with a TM interpretation superimposed on them.

[194] In some sense, neuromorphic computing models that are potential replacements for current digital computers (i.e. von Neumann's (1945) computer architecture in silicon) provide some proof that nature computes. If neurons compute, then why not extend this idea to cover all biological systems? For references, see, for example, Furber (2016), and Hylton (2018). For the new concept of computing, see also for example Adleman (1998).

However, does this generalized concept of computing trivialize this concept, because it means that everything computes and computers are everywhere, at least in this extended definition of computing? If we are claiming that everything is a digital computer, this is obviously false. It would muddle the concepts of digital computing and general computing rather than clarify them. If we say that information is an organization of physical entities and information processing is the manipulation of organization, however, it logically follows that nature computes, so natural processes in this sense are computing processes but not in a TM sense.

We must highlight that nature is not a computer in the sense of TMs or the von Neumann architecture, even if the latter does also fit into this extended sense of computing. Thus, if we assume that information as organization is a part/aspect of the physical world, physical processes are, in this sense, computing processes. Alternatively, we may say that information processing is computing in this extended sense. Again, however, we must emphasize that this does not claim that nature is a computer, at least in the TM sense. Corollary (C2) is supported by claim (10) in that natural processes are information processes that we may denote as computing.

4.2.2 Two or one property?

Now, how many properties do we need to characterize ontological information? Do we need all three properties? Maybe we can characterize ontological information with just two, or maybe even one, of them? Let us test the possible options. In this exercise, we use the following notation for the properties of ontological information: ontological information is epidemically neutral (P1), ontological information embedded in a physical carrier is physical (i.e. embodied in physical phenomena) (P2), ontological information is formative with respect to nature (P3). These are subject to the following interpretations:

- P1: Ontological information has no meaning. Meaning is defined as representing some value for the cognitive agent. From ontological information, an agent derives something that has some significance for its existence, thus creating meaning.

- P2: Ontological information is not an abstract object in the way that mathematical objects are abstract. Ontological information does not belong to the realm of Forms in either the classical or neo-Platonic sense. Ontological information is real, observable, and measurable. It exists like other physical phenomena exist, and whatever exists in nature contains information. There are no physical phenomena without information, just as there is no physical phenomenon without energy.

- P3: Ontological information is responsible for the organization of the physical world. Organization may be, and is, interpreted as structure, order, form, shape, or rationality (if perceived by a cognitive entity).

We have the following six options with respect to the various selections of properties: (A) P1 and P2; (B) P1 and P3; (C) P2 and P3; (D) P1; (E) P2; and (F) P3.

Option (A) with P1 and P2 would claim that ontological information has no meaning (P1) and is physical in nature (P2). This, however, would omit the critical aspect of ontological information being expressed in structure/organization. All things that are physical in nature have no meaning. For example, the whole of nature—including the cosmos with its stars and galaxies and the smaller things on Earth like the rivers, oceans, and volcanoes—would qualify as ontological information if we would use only these two properties. Thus, a volcano or a star would be information. Thus, accepting only P1 and P2 as characteristics of ontological information would not be a meaningful proposal, so this option is rejected (the whole of nature is characterized this way).

Option (B), P1 and P3, would claim that ontological information has no meaning but has a formative nature. We assume that things in nature have no meaning because they do not. The P1 + P3 option would leave the door open for the status of ontological information, so it could be an abstract notion rather than a strictly physical phenomenon. Thus, the P1+ P3 option would not address the abstract–concrete tension encountered by such as Davies and von Weizsäcker, among others. It would leave the ontological status of information unresolved, so this option is also rejected.

Option (C), P2 and P3, would claim that ontological information is a physical phenomenon with a formative nature. This option maybe a possible candidate for describing ontological information, because the meaningless character of information can be deduced implicitly in that anything objective (existentially and epistemically) is obviously independent of a cognitive agent. Now, as agents are the source of meaning, anything agent–independent must be meaningless. Thus, we could argue that ontological information has the P1property by implication, yet this would mean the critical difference between epistemic and ontological information is not explicitly accounted for, making this variant less accurate than the original.

Options (D), (E), and (F)—namely the individual properties P1, P2, or P3 by themselves—would not designate any specific phenomenon. These descriptions would be of course correct in that they assert nothing that is incorrect, but they would also be incomplete. By way of analogy, we could characterize an electron as a particle with a negative charge. This would be correct, of course, but it would also cover negatively charged ions rather than being limited to a single subatomic particle. Thus, any designation of ontological information with a single property would be correct but incomplete, because it would cover other phenomena. For example, option (D), P1, would claim that ontological information is epistemically neutral, but many things have no meaning to us, so P1 is not specific enough. Likewise, option (E), P2, would claim that ontological information is physical, but so many things are, so phenomena with this property include a variety of things that are very different in many other respects. Again designating ontological information purely with this property would be incomplete. Finally, option (F), P3, would potentially reduce ontological information to structure, such that ontological information is the structure or shape of things. Everything we talk about has some kind of structure of form, though. If we would accept that ontological information is P3, we could discard ontological information as a redundant concept and simply claim that ontological information is just another name for structure.

We may also look differently at the properties of information: Instead of selecting a set of three, two, or one property, we could seek to create a super-property that encompasses all three of the selected properties into one. We assume that the three properties do express the essence of ontological information, so this hypothetical super-property cannot add any new features but only express the meaning of these three. In fact, we may have such a possibility: The single property could be like Plato's Form or could be Aristotelian *eidos*, Platonic Form, or Tao-Te-Ching Tao. These do, in their conceptualization, combine the concept of form/structure, nature, and the independence from any cognition. These proposals, however, have suffered from centuries of critique, and proposing them anew would not change their value. The concepts of Aristotelian *eidos*, Platonic Form, or Tao-Te-Ching Tao are so condensed and abstract that they are incomprehensible, and they are certainly not quantifiable or measurable. Thus, they do not pass the tests for modern scientific reality. For example, could we accept the claim that Shannon's ToC measures the *eidos* of a message? We think not.

Thus, it seems that the three properties P1, P2, and P3, plus the two corollaries, provide the most complete description of ontological information that we have been able to identify. We therefore propose this option as being characteristic of ontological information. Future research may change how we see and conceptualize ontological information, however, because scientific hypothesis, as this indeed is, can never be proven right but only wrong (Chalmers 1994). This conclusion is based on the research and studies undertaken by Kowalczyk (1974), von Weizsäcker (1970),Turek (1978), Mynarski (1981), Heller (1987, 2014), Collier (1989), Stonier (1990), Jadacki and Brożek (2005), Dodig Crnkovic (2012), Hidalgo (2015), Devlin (1991), Wilczek (2015), Carroll (2016), Sole and Elena (2019), Rovelli (2016), Seife (2006), Polkinghorne (2000), and Davies (2019).

4.3 Chapter summary

We have reviewed the research into the nature of information in two parts. In the first part, the studies contain contextual claims, descriptions, and pre-scientific intuitions rather than detailed formal arguments, hence why this section is titled "Intuitions." These "intuitive" claims come from the works of Keith Devlin, Frank Wilczek, John Barrow, Sean Carroll, Richard Sole and Santiago Elena, Carlo Rovelli, Charles Seife, John Polkinghore, and Paul Davies. Eight intuitions were subsequently formulated: (1) Information as a natural phenomenon, without meaning, is not related to knowledge but to the properties of the universe (i.e. nature), and this has obviously found a place in the research literature. (2)In several studies, we see the tension between the abstract (mental) concept of information and information as a concrete, physical thing. (3) In any discussion about information as a natural phenomenon, entropy (thermodynamics) plays a prominent role. (4) The term information is usually not clearly defined. (5) Despite the diverse descriptions, there are several commonalities in terms of information existing in nature. (6) Information in nature is closely related to organization in nature (i.e. its structure). (7) Information in nature can be quantified. (8) Information in nature is often conceptualized as part of a matter–energy–information complex.

In the second part, we reviewed studies by Carl von Weizsäcker (1970), Krzysztof Turek (1978), Mynarski (1981), Michał Heller (1987, 2014), John Collier (1989),Tom Stonier (1990), Jadacki and Brożek (2005), Hans von Bayers (2006), Gordana Dodig Crnkovic (2012), and Cesary Hidalgo (2015). We then formulated eleven claims about information: (1) the notion of information associated with knowledge does not exhaust the concept of information. (2) Information is a physical/natural phenomenon. (3) Information is a physical/natural phenomenon with no meaning. (4) The meaning of information is derived by the mind of a cognitive agent and not intrinsic to information as a physical/natural phenomenon. (5) The role of information in nature may be conceptualized within a matter–energy–information complex. (6) Information as a physical/natural phenomenon is fundamental to nature, so whatever exists physically contains information. (7) Information as a physical/natural phenomenon is expressed in the structure/form and organization of things. (8) Information as a physical/natural phenomenon is not, and cannot be reduced to, what we conceptualize as structures. (9) Information as a physical/natural phenomenon is responsible for the internal organization of nature's objects and artifacts. (10) Natural processes are information processes that we may denote as computing. (11) Quantifications of information provide measures of sensible structures that reflect the presence of this information but are not information itself.

All the named authors regard information to be something other than knowledge or a message. They all perceive it as a fundamental element of nature that is related to the structures and organization found in nature. Several authors also attribute causal power to information, so information is responsible for the way nature is. However, the external structure of a phenomenon is never in itself identified directly with information but rather as a manifestation of information, or maybe information is a deep, hidden structure. Some authors prefer the term organization to structure, because it is less loaded with meaning. Most researchers think of information as having no intrinsic meaning, with meaning being bestowed by an agent receiver or other interpreter of information. Some authors look back to the concept of hylemorphism or its variants to explain the information–matter–energy interaction ,but these interpretations lean only lightly on the Aristotelian concept, serving rather as an inspiration than a reference. Several authors also refer to the Latin origins of the word “information” (i.e. *informare*) to reveal the original meaning of information. Only a few recent authors have extended the concept of meaning to biological systems and machine-to-machine (M2M) systems, thus avoiding anthropomorphism, although it is an open question as to whether such an extension is justified. Some authors perceive natural processes as information processes in both inorganic and organic entities. The image of information emerging from the review is that information is a foundational element of natural objects, artifacts, and natural phenomena (i.e. an intrinsic part of the universe). Information does not have to have meaning to exist, because it is embedded in physical forms, and as such, it is closely associated with nature.

Based on the studied literature, we attributed three properties to ontological information:

- (EN) Information has no meaning; meaning is derived from information by a cognitive agent.
- (PE) Information is a physical phenomenon.
- (FN) Information is responsible for the organization of the physical world.

With two corollaries:

- (C1) Information is quantifiable.
- (C2) Changes in the organization of physical objects can be denoted as computation or information processing.

5 Applications of Ontological Information

We concluded in Chapter Four that we can assign three properties to ontological information, namely (EN), (PE), and (FN), as well as two additional features, (C1) and (C2). The concept of ontological information has illuminated many of the current discussions about the nature of information, because it questions the role of information in nature. It also questions how we conceive nature itself and the role of information in specific sciences, such as computing, communications, physics, biology, social sciences, cognitive sciences, philosophy, metaphysics, for example. The range of problems that the concept of ontological information may affect is quite broad, as can be seen from the literature we examined in Chapter Four. That said, we discuss below a few select issues that seem to have relatively greater import for the overall discussion about the nature of information.

5.1 Ontology and epistemology: Two perspectives on information

At the beginning of this study, we proposed two broad divisions for the concept of information: ontological and epistemic (see Chapter One). Ontological information is information without meaning, and it does not need either a sender or a receiver to exist, because it is a physical phenomenon. This form of information is the subject of this study. Epistemic information, meanwhile, is information that relates to the concepts of knowledge, cognitive agents and cognition, and meaning. This is how information has been most commonly understood to this day. But what is the relation, if any, between ontological and epistemic information? Do they depend on each other at all, and if so, how? Which form of information is more fundamental? In other words, does one need to exist first for the other one to also exist, so the existence of one is contingent upon the other existing? We do not need to discuss what ontological information is here, because this whole study is about it, so we will focus on epistemic information.

5.1.1 Epistemic information

The epistemic perspective is how information is understood in communication sciences, cognitive sciences, library science, biology, social sciences, some strands of pancomputationalism, and information technology. Indeed, this is how we most often perceive information these days. The concept of epistemic information has been through many incarnations, but there is no single definition that would be accepted by everyone or even some majority.[195] For some examples, see the works of Bar-Hillel and Carnap

[195] The number of supporters for an idea does not count, because in philosophy, ideas are not selected through democratic voting, and ideas that are rejected by the majority often contain the truth.

(1953), Brooks (1980), Rucker (1987), Buckland (1991), Devlin (1991), Losee (1998), Sveiby (1998), Dretske (1999), Casagrande (1999), Floridi (2010, 2013), Burgin (2003), Lenski (2010), Vernon (2014), DasGupta (2016), and Carroll (2017), among others. Each of these authors painted a somewhat different picture of epistemic information. We therefore grouped conceptualizations of epistemic information into classes related to human cognitive agents, biological agents, artificial cognitive agents, and formal models, including logical models and quantitative models. These formal models include the one of Shannon-Weaver-Hartley and other related proposals, Chaitin models, statistical models, and Devlin information logic. A common element in all these conceptualizations, however, is how information is conceived as having some meaning to a receiver or sender, where information comes in a message that is communicated to a system. The receiving system can be a human being, a biological organism as simple as a cell, or an artificial cognitive agent, such as an autonomous robot. Table 3 below summarizes the main elements of some selected models for epistemic information, but this is certainly not exhaustive.[196]

Category of model	**Author**	**Main claim**
Human cognitive agent	Beyond-Davies (2009)	Information is data + meaning.
	Bateson (1979)	Information consists of differences that make difference.
	Dretske (1999)	Information is sharply distinguished from meaning, at least for the concept of meaning relevant to semantic studies.
	Floridi (2013)	Information is data + meaning.
	Buckland (1991)	Information-as-a-thing, information-as-knowledge, information-as-a-process
	Ratzan (2004)	Information is meaning.
	Davenport (1997)	Information is “data endowed with relevance and purpose.”
Biological agent	Smith (2000)	DNA transmission is equivalent to a human communication channel.
Artificial cognitive agent	Vernon (2014)	Information is what an artificial cognitive system extracts from the environment.

[196] One should also mention the “classification of schools” of information, with each school taking a different view on what information is. This list of schools was created by Gordana Dodig Crnkovic (Dodig Crnkovic 2006).

Formal models, including logical and quantified models	Shannon (1948) and other models related to Hartley–Shannon–Weaver entropy	H(X) $= \sum_{i=1}^{m} \frac{p(xi)\log 1}{p(xi)}$ (measure of information entropy in the communication theory)
	Solomonov, Kolmogorov, and Chaitin	String complexity measures based on the UTM model
	Fisher and Klir Models	Statistical measures

Table 3. Summary of selected models for epistemic information

Epistemic information is conceptualized within a range of domains, applications, and methods. These conceptualizations include human cognitive agents, biological systems, artificial cognitive systems, and logical and formal conceptualizations. The common element in all these concepts, however, concerns how information is being conceived as something relative to an agent or other cognitive systems (i.e. the knowledge of that agent/system). Of course, what an agent, cognition, and knowledge are must be understood in relation to the context. Epistemic information in any of the above definitions does not exist on its own, because its presence must be recognized by some reference system (i.e. an agent with some sort of cognitive capacity). Therefore, how do we define an agent, cognition, and knowledge? No single definition would suffice due to the fact that we need to deal with natural agents (human and non-human organisms) and artifacts (computers, robots, etc.). One may refer to the literature for reference,[197] and there are plenty of examples showing the relativity of epistemic information. For example, forgot ten scriptures, such as the Egyptian hieroglyphs or Assyrian cuneiform writings, are just symbols with no meaning without the continuity of tradition.

Epistemic[198] information is associated with knowledge; semantics, belief, a communication process, or other more broadly understood meaning.[199] Epistemic information exists only if someone or something—such as an artificial or biological system, although we need to be careful what we assign

[197] For a general definition of an agent, see, for example, the work of Poole and Mackworth (2019).

[198] "*Epistemic […] describes anything that has some relation to knowledge*" and "*Epistemology, or the theory of knowledge, is that branch of philosophy concerned with the nature of knowledge, its possibility, scope and general basis*" (Honderich 1995). For this specific domain of discourse (e.g., computer systems and artificial cognitive agents), the concept of knowledge may be defined in domain-specific terms while retaining the generic meaning.

[199] Meaning has many interpretations. For this study, unless otherwise stated, we follow the definitions from the philosophy of language, where the term "meaning" denotes how language relates to the world. A review of theories of meaning is beyond the scope and purpose of this work. An extensive list of references can be found in Speaks (2018) and other sources. The theories claiming that meaning is the correlata to the world are contested with good arguments (Chomsky 2013, 2016).

epistemic processing capacities to—recognize it as information after receiving or creating it. Epistemic information exists specifically in, and for, the mind, which can be broadly understood as a complex of cognitive faculties of the receiver or the originator.[200] This information exists when communicated (i.e. created, sent, and received) as a message or a sequence of symbols. The dependency on the sender, receiver, and their cognitive functions therefore makes information epistemically subjective. Thus, this information depends on something else to exist and to denote something. We may also claim that epistemic information is relative to the cognitive faculties of the receiver or sender. Interpreting information as an epistemic concept somewhat reflects the current mode of philosophy, where epistemology (the theory of knowledge) is regarded as more important and fundamental than the concept of metaphysics or ontology, so it holds that an important concept like information should be primarily regarded as epistemic. [201]

Epistemic information is defined in the context of a communication system between sender and receiver. This system may have many realizations—such as those of Cherry (1978), Shannon (1948), Shannon and Weaver (1964), Smith (2000), and Vernon (2014)—but the general format of the model described by Caste (1989) is shown in Figure 1. How epistemic information arises in a cognitive system is a separate issue that is not discussed here.

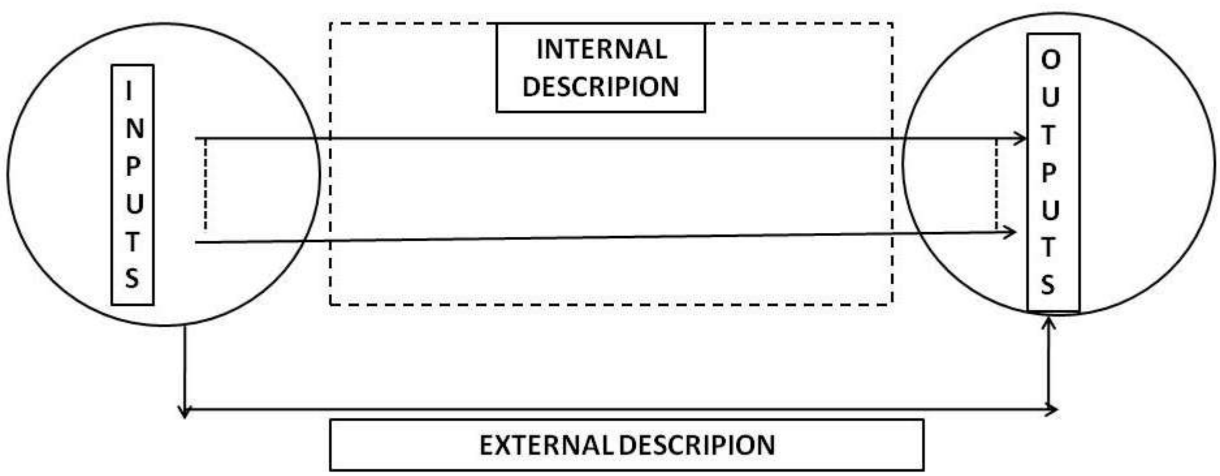


Figure 1. A communication system (following Casti 1989, p. 255).

[200]The originator or receiver may here have an extended meaning that includes natural (i.e. not man-made) and artificial systems. We may also use the term “cognitive system” rather than “the mind” as a more general term.

[201] This epistemic turn in philosophy is attributed to Descartes and Kant, among others. The roots of this change in philosophical focus may also be traced to the fact that we cannot explain the fundamental causes of reality. We can only describe the reality and then only in a rather superficial way. You can see this problem emerging in the Newton–Leibniz discussion about the interpretation of calculus (Guicciardini 2018).

In a superficial description, the communication system processes inputs into outputs. In the internal description, meanwhile, the input is a message that is processed into outputs through the following steps: (1) Inputs are interfaced with the communication channel M. (2) The internal rules for encoding input are applied to the inputs to produce an internal representation of them. (3) This new representation, through a set of rules, is decoded to produce the outputs (Casti 1989, p. 254). The internal rules or the internal encoding representation is not specified, so the model is generic, and it is equally applicable to humans, biological agents, and computers. This model is important for understanding epistemic information, because its elements, although not always all of them, always play a role in defining information.

The meaning of epistemic information is relative to the cognitive agent (i.e. the sender or receiver). Thus, epistemic information depends on the state of a cognitive agent and its cognitive faculties, which some may call previous knowledge, and information-processing capacities and abilities. The same sensory stimuli may or may not be information for different agents. In addition, an uninterpreted stimulus is often denoted as data, despite the fact that data assumes some prior interpretation. The cognitive agent may be a human agent, a biological system, or an artificial cognitive system with the ability to change its internal state in response to stimuli or create a message by modifying a physical carrier under specific rules. The exact boundary between cognitive and non-cognitive information-processing systems is not entirely clear. (See the brief discussion about information processing abilities in the earlier sections.)

If we want to consider information as an essential element of nature, as information is indeed understood in this study and the referenced works, epistemic information clearly has significant shortcomings. These shortcomings indicate that information must in essence be something other than epistemic information, because our intuitive understanding of information is not matched by concepts of epistemic information. This list of specific problems is rather long.

(I) The epistemic concept of information is incomplete because it requires, as was mentioned above, additional concepts to explain its presence. These auxiliary concepts are usually called data or raw information, but data is again interpretation-dependent, so where is the basis for saying that data do not depend on anything? Is it raw physical phenomena? It seems that with epistemic information we are on shaky grounds, because its foundations are elusive.

(II) Epistemic information always misses something about the state of nature. Cognitive systems (CS) are (reductive) filters, so they select and interpret the physical sensory stimuli in a selective matter. In other words, what is missed is in principle physically the same as what is absorbed by a cognitive faculty. For example, human hearing detects only air pressure waves within a certain frequency range with sufficient amplitude, but what is registered and what is omitted is the same physical phenomenon. The difference is the filter function of the CS. Epistemic information does not recognize this unity of nature but rather divides it into "meaningful" information and everything else. It artificially bifurcates nature into meaningful and neutral elements even though they are part of the same phenomenon.

(III) The different concepts of epistemic information lay out several contradictory claims, so one may even say there are many epistemic "informations [sic]." How can such a multifarious concept be regarded as foundational for nature?

(IV) If we are information systems geared toward surviving in our environment, our information cannot just arise from us or exist only as an interpretation of what is out there, because we would be unable to evolve and survive. Information must therefore be out there first, and then we interpret it for our own needs. We are shaped by our environment, and information exists in it whether we are there or not.[202] We do not project our intentions into the external world—it works the other way around.

(V) Information, if it is indeed a foundational factor in nature, cannot be probabilistic in Shannon's sense. The probabilistic nature of information would mean that information either may not exist or that information may only exist with 100% certainty at certain times. However, if information is part of the fabric of reality, how can we reason that there is no information or that it only exists at certain times, which would be the case if information were intrinsically probabilistic? It would be a rather disturbing ontology if we made Shannon's claim ontological. Such information does not make claims about what it is or how it exists. This does not mean that probability calculus cannot be used to describe information under epistemic interpretation, because it is used to describe many deterministic phenomena in classical physics (e.g., entropy), but here probability is used *in lieu* of precise knowledge. If we later prove that on the sub-particle level, the world is indeed intrinsically random, we may have to amend this claim.[203]We

[202] It seems the role of information in evolution is mostly discussed within the context of inheritance (Goodfrey-Smith and Sterelny 2016) and the role of DNA. However, other voices indicate the role of environmental information acting upon the organism. Madden (2004) realizes that an organism is an information-processing system paired with an environment: "*It is proposed that information was derived from the environment as a direct result of the evolution of organisms that used other organisms as a food source*." However, for Madden, *"for there to be information, there must be something or someone to inform; to be capable of 'being informed*.'" Thus, information is epistemic. Ontological information and its role in the evolution of life and organisms is expressed in the following line from Avery (1993, p.72):"*we discuss the work of Maxwell, Boltzmann, Gibbs, Szilard, and Shannon. Their research established the fact that free energy contains information, and that it can thus be seen as the source of the order and complexity of living systems*." Here, information is seen as a factor in creating life forms, not just an interpretation of nature by an organism. The literature on information, entropy, energy, and chaos is extensive, but this line of research will not be pursued here except when absolutely necessary. (For additional information on this topic, see, for example, Weber (2018), Bishop (2017), Avery (1993), and Schrödinger (2012), as well as Nagel's discussion in Chapters Three and Four.)

[203] For ideas about randomness as an intrinsic property of nature, see, for example, (Mścisławski 2014, Acin & Masanes 2016).

need to clarify, however, whether the intrinsic randomness of nature (i.e. at the QM level) denotes ontological randomness (it exists randomly) or epistemic randomness (its properties can be described with random calculus) at the macro level. It seems that at our present state of knowledge, the first view is true (Lukasik 2017) with respect to some aspects of QM.

(VI) Epistemic information is an abstract concept. Information, as it is defined in this study, cannot be an abstract notion. Abstract notions, aside from in Plato's ontology, do not exist in the same sense and in the same way as concrete things exist. After all, abstract things are abstract because they lack a physical or concrete existence, so they cannot be foundational factors in nature. Information that is foundational cannot be just "in the eyes of the beholder, "like subjective notions of beauty or knowledge, unless this beholder is some supreme creator, which is obviously Berkeley's theme and to some extent Newton's.

5.1.2 In search of the locus of epistemic information

Ontological information is a part of nature, but where is epistemic information and where does it come from? The dependency, or relative nature, of epistemic information on the background knowledge/state of the cognitive agent has of course been recognized by several researchers attempting to define epistemic information (e.g., Bar-Hillel and Carnap 1953, Dretske 1983, Jadacki and Brożek 2005, Floridi 2013). Ontological information, on the contrary, is free from this dependency on interpretation. The differences between ontological and epistemic information are illustrated in Figure 2 below.

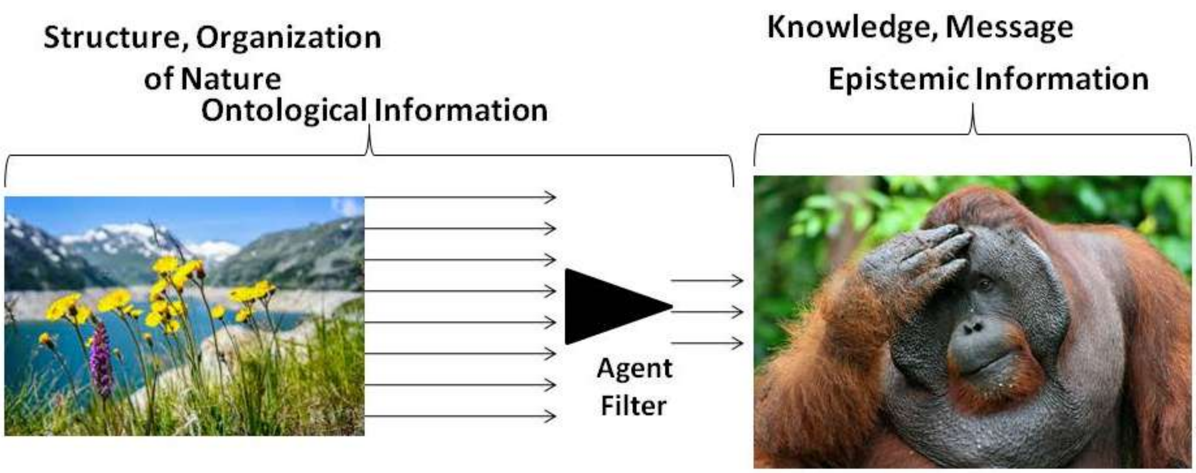


Figure 2. Differences between ontological and epistemic information[204]

[204] Credits. CC0 Public Domain; Free for personal and commercial use; No attribution required. Image on the left: https://pxhere.com/en/photo/655865. Image on the right. https://evolutionnews.org/2014/12/court_declares/

Figure 2 shows how nature is organized and structured into objects and phenomena with various forms and shapes. Elephants exists whether we give them a name or not and so do the mountains, seas, and volcanoes. Nature's organizational factor is ontological information information—this is our claim. A cognitive agent filters physical stimuli in its environment and with it ontological information, through sensory apparatuses and then organizes it through cognitive processes into knowledge or epistemic information in the mind.

We denote the process in which ontological information is absorbed into the agent's mind as a filter. We may more specifically call this filter a semiotic filter,[205] because it imposes an interpretation on the received and translated physical stimuli. By organizing ontological information into knowledge about the world, the agent derives meaning for itself from something meaningless, namely physical stimuli, which is ontological information. Different agents can derive different meanings from the same ontological information. To sum up this process, we say that nature provides ontological information in the form of physical stimuli to an agent, which then creates for itself knowledge about nature that is a reflection of nature but not nature itself, so this knowledge is epistemic information.

The source of "information about the world" (i.e. the raw input) for a human agent are the senses. This information about the world is transformed by the mind, at least in the case of human agents, to inform us about how the world is. The purpose of the cognitive apparatus and cognitive processes is to tell us about the world based on the senses. We denote the information (knowledge) created in this process as epistemic information, so it is information about something or knowledge of the outside world.

Epistemic information is not what comes to us through the senses of sight, hearing, smell, taste, equilibrium, and somatic senses of touch, temperature,[206] pain, and proprioception.[207] What comes to us

[205] The term "semiotic filter" is understood here as the ability of a system (biological or artificial) to create signs, which in general are abstract references to the specific features of the world or other signs. Semiosis was originally attributed to living systems, but it may now be extended to artificial agents (e.g., Ferreiria et al. 2013).

[206] Temperature is understood here as a subjective feeling of cold or hot rather than as a thermodynamic property of physical systems in the sense of the Zero Law of Thermodynamics (e.g., Guggenheim 1985, Atkins, 2010). Thermodynamic temperature is related to Kelvin temperature as $k\beta = 1/T$, where T may be called conventional temperature and k is Boltzmann's constant expressed in J^{-1} units. k is a conversion parameter between the common measure of temperature in K and the thermodynamic properties expressed byβ. β is a more natural measure of temperature as it is more meaningful in that it is related to the physical state of the system. From the molecular perspective, temperature expresses "*the most probable distribution of populations of molecules over the available states of a system at equilibrium*" (Atkins 2010). Temperature in the thermodynamic context is a state function or, in other words, a property of a system independent of how that state was achieved. A state function is the internal energy of a system, and we may risk conjecturing that information as system organization is a state function as well, but such a claim would require further exploration.

[207] An awareness of body movement and position in space.

through the senses is variously denoted as sensory information, stimuli, external stimuli, or a form of physical energy (e.g., Rock 2015, Silverton 2007). This is in no way exactly analogous to the representation of reality. It is a series of pure physical flows of energy in different forms. Where then does epistemic information in the form of colors, houses, trees, flowers, cars, faces, sweetness, sourness, heat, cold, smooth come from if it does not come through the senses? Let us look at the perception process as we understand it, which is mostly guesswork for now, and see where epistemic information emerges.

The sensory systems, at least in higher level mammals, generally have a common architecture for responding to different stimuli.[208] The stimulus acts on a sensory receptor, a transducer. This transducer converts the stimulus into an intracellular signal and then builds up action potential until it reaches a certain threshold that triggers a sensory neuron along the central nervous system, which integrates the incoming signals. Some stimuli proceed up to the cerebral cortex where they reach conscious perception, while others remain on a subconscious level. The sensory organs differ in form and biological composition, as does the transmission of sensory stimuli. Sensory information, the action potential passed on through sensory pathways, can be modulated and reshaped during its transfer from the receptor to the cerebral cortex. The receptors in sensory organs respond to particular forms of energy, and the passing of stimuli is not like the flow of current through a wire. It is a series of events triggered by an outside stimulus and the activation of the transducer receptor, ending with the signal reaching the cortex or other site of awareness, according to our current knowledge. (See, for example, Kalat (2007), Passer and Smith (2007), Coon and Mitterer (2013), Kandel et al. (2013)).

The process of perception can be represented as follows: A physical stimulus of type “i” (Phi) is detected by a sensory organ. It is converted through biochemical processes into a biochemical stimulus (BCi) and transmitted along nerve pathways to the appropriate area of the brain. In the brain, the BCi undergoes a process of integration of which we currently know little about, and it then sometimes reaches consciousness, making us aware of the sensation (Si). That is the sequence of processes for sensory stimuli to trigger conscious experiences, and this is where epistemic information, or information about something, is created. The pathway may be presented as the sequence:

$$\text{Phi} \rightarrow \text{BCi} \rightarrow \text{BCi'} \rightarrow \ldots . \rightarrow \text{Si.}$$

There is no physical equivalence between the stimuli originating the perceptual process and the stimuli in the sensory pathways. These stimuli are recoded, albeit in a specific way rather than randomly. The lack of physical equivalence can be symbolized below as:

[208] This description follows closely that of Silverton (2007).

$$\text{Phi} \neq \text{BCi} \neq \text{BCi'} \neq \ldots \neq \text{Si}.$$

The "≠" sign should not be interpreted as the mathematical symbol of "not equal to" but as a symbol denoting non-equivalence. Likewise the "=" sign should be interpreted as symbolizing equivalence rather than as meaning "equals to." Finally, the "→" sign should be interpreted as a symbol meaning "transformation" rather than mathematical implication.

By "physical equivalence", we refer to similarity in the type of the physical phenomenon stimulating the perceptual process and stimuli in the sensory pathways. This does not mean that these signals (i.e. the stimuli and signals in the neural pathways) are random, because they are highly correlated. Indeed, they are a function of the stimulus and tightly coupled to the stimulus itself, and they are repeatable and reproducible. However, their physical form, as a sort of physical carrier, is not that same as that of the external stimulus. More specifically, the various external stimuli have different physical forms in nature (e.g., electromagnetic radiation for vision, biochemical content for taste, airwaves for sound, etc.). A visual stimulus is very physically different from the corresponding biochemical signal in the visual path, and the same goes for other the senses. They are mediated by specific processes (F(x)) that transfer some aspect of the stimuli (i.e. a certain subset of it) from one stage of the perceptual process to the next:

$$\text{Phi} \neq \text{BCi} = \text{F'(Phi); BC'j} = \text{F''(BCi)}$$

and

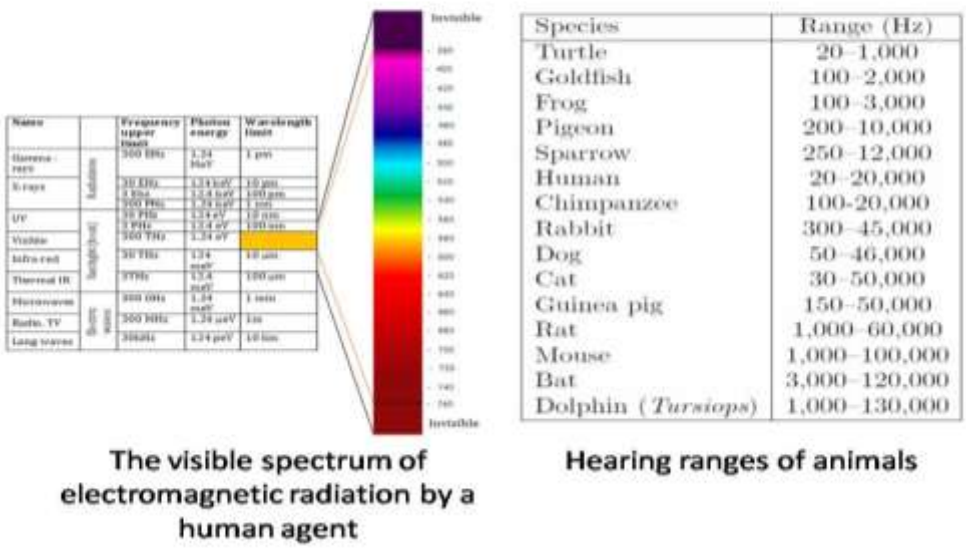
$$\text{Si= F''' (BCi'') or Si=F'''(F''(F'(Phi)))},$$

where F' is the stimuli mediation function between sensory pathways.[209] Phi ≠ BCi≠ F'(Phi) means that the mediated physical stimulus {F'(Phi)} is not physically equivalent to the original sensory stimulus (Phi) or to the physical signal in the neuronal pathway (BCi). Si=F'''(F''(F'(Phi))) means that the awareness of sensation (Si) is a result of several stages of mediation (i.e. F'''(F''(F'( ))))for the input stimulus (Phi).

Now, if Si is epistemic information giving us knowledge about the world, what is Phi? We know that Phi is a specific type of physical phenomenon, such as light, heat, pressure, or a chemical compound. Each of these phenomena has its own specific structure/form to which the sensory organs respond, but the sensory apparatuses do not respond to any phenomenon in its entirety. For example, we do not respond to every electromagnetic wave but rather only to those within a narrow frequency range (i.e. the visible spectrum).

[209] Details about sensory pathways, transfer mechanisms, and biochemical signalling in neurons can be found in, for example, the work of Kandel et al. (2013).

Therefore, a sensory apparatus responds only to a narrow subset of a selected phenomenon (see Figure 3). This could be determined by the frequency for electromagnetic waves, the shape of molecules for taste sensation and specific concentration, the kinetic energy of the molecules in a substance for the sensation of heat, or the frequency for air pressure waves. No human sense responds to the full range of possible stimuli. What is more, the human consciousness acknowledges only a portion of the received stimuli (e.g., Augusto 2010, Hasher & Zacks 1984). Evolution in this case is very frugal, and we only get what we need or sometimes not even that. For example, endowing humans with an energy-intensive and functionally overdesigned brain seems “unevolutionary” in a way, seeing as we usually only get what we need from evolution, if that. It seems that in the case of the brain, we got more than simple survival would require.



Species	Range (Hz)
Turtle	20–1,000
Goldfish	100–2,000
Frog	100–3,000
Pigeon	200–10,000
Sparrow	250–12,000
Human	20–20,000
Chimpanzee	100-20,000
Rabbit	300–45,000
Dog	50–46,000
Cat	30–50,000
Guinea pig	150–50,000
Rat	1,000–60,000
Mouse	1,000–100,000
Bat	3,000–120,000
Dolphin (*Tursiops*)	1,000–130,000

Figure 3. Perceivable ranges for vision (Danila et al. 2016) and hearing[210]

A common aspect among different physical stimuli that trigger a chain of physical processes in sensory pathways that eventually result in the emergence of epistemic information is the form or organization of the physical phenomenon. If you change the structure of the phenomenon, such as by taking it above the perception threshold, you change the awareness of the phenomenon and the related epistemic information. In most cases—although the sensory system of an agent does not react to changes in all cases—this is

[210] A comparison of the audible ranges of various species can be found in (“Before it is” 2019).

related to the sensitivity of the sensory apparatus or certain inertia in sensory response. Of course, epistemic information requires the existence of the mind in addition to the physical stimuli.[211]

If epistemic information is conceptualized as a thought or the content of the mind and many studies explicitly state this, ontological information is described here is a causal factor in shaping the mind or its structure if we say that the structure of the mind is its thoughts. This can be expressed as:

$$I_O \rightarrow M(I_O) \rightarrow I_E$$

Where Io is ontological information, M () is a mediation process described before as {F''' (F''(F'( )))}, and I_E is epistemic information. Of course, the I_E for the same I_O will be different for different individuals, at least to some degree.[212]

I_O is physical (located in nature), while I_E is mental (located in the mind/brain). This is not, as will be explained later, such a good differentiation, because it may be controversial. To be more precise, we should say that I_O is not dependent on the mind, while I_E is. This commonly accepted division can be the

[211] Can we say that a radio receiver sees radio waves? The interesting question is whether a smartphone processes epistemic or ontological information. A smartphone certainly has a wider range of senses of physical stimuli than a human agent. It senses electromagnetic waves in its transmission range (cellphone signal) and visible range (camera). It also processes signals from GPS satellites, magnetic fields, heat, pressure, position in the gravitational field, movement, touch, and even recognizes a voice, and this is only a small portion of what a modern smartphone can "know." All these signals change the internal status of the smartphone by affecting its counters, memory, and the internal state of its software (e.g., Bharadway & Sastry 2014, Fong 2019, MCGonigle et al. 2019). So, does the smartphone have a state of mind? It certainly "knows", in some sense, more than a plant about its *umwelt* in that it has internal states that reflect the outside world according to how the smartphone "sees" it? But if a smartphone has a mind, then so does every piece of computer machinery to some degree. How far can this analogy be pushed? Three responses are possible. One is that yes, smartphones exhibit all or most features of a cognitive agent, so smartphones process epistemic information. This position could be held by those who are prone to attributing cognitive abilities to plants and primitive life. The second response is a little more restrained in saying that computers in general model the mind, and eventually they will have consciousness, so current smartphones are like an early form of primitive life with some rudimentary consciousness that can produce/processepistemic information. This position could be held by Daniel Dennett, Jerry Fodor, Gualtierro Piccinini, D. J. Chalmers, Edelman, and many others(e.g., Rescorla 2017). Finally, the third answer recalls Searle and the Chinese room argument in that the computer model of the mind is simply a categorical mistake and computer devices (i.e. UTMs) will never have a mind and become conscious beings in the same sense as humans and animals, so they process only ontological information. This position would be held by John Searle, Roger Penrose, and others. See, for example, the discussion of Hauser (2018). All three positions are argued for in the literature, and on this matter, I am with Searle.

[212] "*Because people have widely different experiences throughout their lives, it follows, that no two people will process a given piece of information in the same way*" (Kandel et al. 2013, p. 319). There should be no doubt that the essence of conscious perception (the M() function, i.e. is a mediation process) depends on the complex functions of the mind or, as some may have it, the brain. There is nothing like Hume's fleeting impressions. The lectures in Oliver Sacks' books, such as in the book *An Anthropologist on Mars* (Sacks 1996), should dispel any doubts as to what is seen and what is perceived, although this is restating a rather obvious fact.

source of many problems with regards to interpreting the nature of information, so it should not be taken as a declaration of the dual nature of reality. It simply means that ontological information is found in nature regardless of the mind, while epistemic information depends on the mind for whatever its nature is. (Note that this is also physical in the sense that it is hosted in a physical system, namely the brain. Disembodied mind is rather out of the question in this discussion). Thus, I_O is embedded in a physical carrier as its structure or form, so it is a physical phenomenon. I_E, meanwhile, is located in the mind and described as the content of the mind. The term "located" is misleading, however, because it incorrectly implies that I_E occupies some physical space, but it is only "located" in the sense that the content of the mind is located in the mind, to our best knowledge.

Of course, physical structure is a complex multilevel organization. Which levels of organization interact directly with the sensory apparatus is not always obvious, even if these levels are closely dependent. This dependency means that, for example, the frequency of light depends on the shape of the light wave, which in turn depends on the properties of a photon, while the molecular shapes that the sense of taste responds to depend upon the atomic properties of its constituent elements, which in turn depend on the structure of atoms and their subatomic particles. From the individual atoms themselves, one cannot deduce their taste, because they have none. Thus, to say that taste buds respond just to the external shape is a gross simplification. The existence of different levels of organization does not imply these properties can be reduced, because the sensory system responds only to a portion of the available natural stimuli. I_E is not a response to everything in nature or even to everything detected by the sensory organs. As we said earlier, I_E represents I_O in a mediated form, so I_E is always just a fragment of the I_O. This should be an obvious conclusion from analyzing the mechanics/physics of sensory systems in cognitive agents. (For more details about the sensory apparatus, see the works of Kalat (2007), Passer and Smith (2007), Nolen-Hoeksema et al. (2009), Coon and Mitterer (2013), Kandel et al., (2013)).

In clarifying the distinction between epistemic and ontological information, we need very precise terminology. The notions of the mind, intelligence, knowledge, meaning, messages, and communication may be interpreted in many ways. With these interpretations, we may assign epistemic capacities to a human agent, an artificial agent, complex animals, lower animals, cellular organisms, plants, and even entities on the border of life and the material world, such as viruses. But why stop there? We may say that physical systems communicate. We may also state that all these systems are organized complexes, some inanimate and some animate, and they exchange organized matter-energy elements with the environment. Some systems do it as a chain of physical processes, while some involve what we call cognitive functions, which also seem to be physical processes of some kind, or to put it differently, processes based on the physical properties of biological matter. Epistemic information emerges when cognitive functions come onto the scene. But where does it occur? Where do we position cognitive functions in the range of information processing performed by natural agents? This question is not trivial, and an incorrect answer trivializes the question and the problem, because we will see cognitive functions everywhere or merely only in humans. Both options seem to be incorrect.

This discussion is more than just a search for some minimally conscious life. It is actually a reflection of the fact that biological information-processing systems existed before consciousness emerged. In other words, information in nature existed before information in consciousness appeared on the scene**.** Attempts to extend the cognitive abilities to biological processes in plants (somewhat backwards, or *post factum*), for example, were met with strong criticism from biologists who were less prone to such flights of fancy.[213] Nobody denies the information-processing capacities (in the sense of ontological information) of these lower organisms on the phylogenetic tree. What is denied is that this represents consciousness. Thus, the existence of information-processing capacities in biological systems means that information in nature, or ontological information, existed long before epistemic information emerged, because biological life emerged eons before human consciousness.

There is a danger in extending the concept of meaning without qualification over unrelated or vaguely similar cases. Such generalizations impair our ability for rational discourse. If everything is alike, and if everything is like everything else, how can we have a discussion about anything? This is what trivialization means. Now, take the case in point: If we use the term "intelligence" without qualification, all terms like machine intelligence, human intelligence, intelligent systems, intelligent animals, artificial intelligence, and animal language are meaningless (see the comments of Chomsky (2014)). Likewise, if we employ the unqualified use of the term "information", we fall into the same trap. We need to be wary of the differences and apparent similarities.[214]

Traversing the hierarchy of the information-processing abilities of different physical entities (including complex chemical and biological entities in the wider sense), these create localized meaning from **stimuli**.

[213] In the recent study of Tiaz et al. (2019) on plant biology, the authors state, "There *is no evidence that plants require, and thus have evolved, energy–expensive mental faculties—such as consciousness, feeling, and intentionality—to survive and reproduce."* It seems that the whole plant "neurocontroversy" has hinged on a liberal interpretation of the meaning of words like intelligence and cognition and the somewhat irresponsible use of terms like "machine intelligence" by computer scientists and AI researchers. The latter observation comes as a surprise seeing as these two occupational groups are not well known for flights of fancy, so we would expect some reservation from them in their overly poetic use of language. This is why we may have been duped about AI's possibilities.

[214] From time to time, we hear news that someone has succeeded in storing data in a DNA strand or used DNA to process some data. This should not be interpreted as proof that DNA is information or stores information, but rather that any biological, physical, or chemical structure (including DNA) can store what we would interpret as information.

Epistemic information comes in different degrees, so its presence and content varies from system to system. The boundary (locus) between epistemic information and ontological information may be tentatively placed when or where the system interprets "the physical aspects of the world" not as the physical aspects of the world but rather some abstract, generalized interpretation that has been associated with them. (Would we ascribe this interpretation to a phenomenological perspective?) We may say that meaning, or the creation of meaning, is a distinguishing human feature that is not present in the same form in non-human animals.[215] By diluting the concept of meaning, we can extend it to even include stones, but then the concept of meaning becomes meaningless.

One suggestion for the "boundary condition" separating epistemic information from ontological information is provided by Strawson in his discussion of perceptual experience. Strawson says that when speaking about conscious experience, we talk about something that is "*not merely sensitive to its environment. So much can be said of a plant or an instrument. But we are speaking of something which is not merely sensitive to its environment […] but of which the sensitivity takes a form of conscious awareness of its environment. We are speaking of subjects who employ concepts in forming judgments about the world, judgments which issue from the experience enjoyed in sense perception*" (Strawson 1992, p. 62). Strawson saying that *"subjects who employ concepts in forming judgments about the world* "is another way of saying what we said earlier about attributing abstract notions to the physical aspects of the world. Do autonomous robots with Artificial General Intelligence (AGI), trees, and plants count as epistemic agents according to these definitions? They probably do not. The same likely applies to other simple forms of life. But *inforgs* (see below) include all living things, not necessarily just those processing epistemic information. We may risk the claim that semantics, semantic information, or epistemic information appears when symbols appear (i.e. when ontological information is "symbolized" or tokenized) or, using Strawson's ideas, when an agent forms a judgment about the environment.

In this sense of symbolization, the DNA and RNA exchange between viruses and a cell is not cognition because what is being exchanged are direct physical structures, or so it seems. However, interpreting a written language is a process that Carl von Weizsäcker puzzled about, because we interpret shapes as letters with some abstract concepts associated with them. In this cognitive process of understanding a

215 We are meaning-seeking animals (Armstrong 2006, p.2). It may seem that the talk about artificial agents, plants, and animals creating meaning is a gross categorical mistake propagated by a rather shallow, technically focused perspective. To really put the discussion in the right perspective and place, we need to read books like *A short history of myth* by Karen Armstrong (2006), which exposes the layers and layers of meaning created by millennia of humanity, something that does not apply to other biological systems that we know of.

language, the physical structures in nature act in some way as pointers to the abstract features of the physical (i.e. real, concrete) world that exists in the brain. This structure–abstraction relation is never precise, so the match is approximate and not always unique.[216] What is more, the physical structure is never like the numeric address for a memory location in the brain, as in modern computer memory technologies[217]—such as in RAM, ROM, or on a hard drive—it is not even remotely similar to this (e.g., Squire & Butters 1992).

The progress in information-processing capacities is in no way a linear path, as the figure above may suggest. This figure is a gross approximation because we are simply not sure about the process for assimilating information in different organisms. As a rule, biological systems possess information-processing capacities to a degree that matches their survival needs. For example, dogs have a better sense of smell than humans, while bats are better in sensing "sounds", because it suits their functions in nature. It may seem an anthropomorphism to place a human agent on one end of the spectrum and non-living systems on the opposite end, yet I would argue that only human agents have managed to augment their sensory capacities beyond the evolutionary imperative of survival, and this has given us a somewhat privileged position as information agents or inforgs.[218]

A point to observe is that concepts of cognition, cognitive function, and knowledge, which are so critical to the concept of information, are highly anthropomorphized. Even when we talk about machine cognition, we talk indirectly about human capacities, because human capacities are always, or at least very often, used as a reference point in these discussions, because we lack any other reference point for these capacities. It is rather difficult to find a conceptualization of cognition that is not "informed" by the human perspective. (This should not be a surprise if cognition is a distinctly human feature. For example, the anthropomorphizing of cognition is not the same as anthropomorphizing the cosmos or the solar system.) Would this mean that human cognitive faculties are the only reference point for the cognition we possess, barring some fringe views about extraterrestrial cognition, whatever that may mean, or superhuman faculties that are not new but rather just human faculties infinitely expanded (not a very clear

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216 See the discussion of human cognitive functions in (Chater 2019, pp. 192-223). Of course, the book expounds the point of view that the mind is a computer. See also the work of Steward and Cohen (1997) for a similar discussion.

217 In humanity, the physical organization of memory and the memory retrieval process is nothing like in computer memory or even ANN constructs. More details can be found in, for example, (Schacter et al. 2009, pp. 167-209) or (Passer & Smith 2007, pp.232-273).

218 The term "inforg" is coined by Floridi (2013). The term denotes entities made up of information and existing in the infosphere. One may admire Floridi's penchant for creating catching neologisms or remain puzzled by this (con) fusion and long for Ockham's parsimony. The infosphere is another one of these newspeak terms. The first documented use of the word was in a 1971 *Time Magazine* book review by Sheppard ("Rock Candy" 2010). Both terms have been subsequently "legitimized" through the use by other authors.

goal)? From some not-so-recent studies there emerges the concept of cognitive functions in single and multicellular organisms like bacteria and plants (e.g., Trevanas 2016, 2017, Van Loon 2016). However, whether we can accept such an extended concept of cognition is dubious.

While we are not going to attribute human-level cognitive abilities to these simple organisms, we do attribute to them several analogous capacities, although an open question is how analogous they are and what "analogous" may mean in this case. It seems that a sign of life is active engagement with the environment. Some may denote this as "information exchange" in one or both ways, while others may claim there is no life without information exchange, so in this view, all living organisms are information systems of sorts. Thus, within this perspective, some level of "active engagement with the environment" or cognition (if one wants to call this function of a biological system this way) may be determined based on a continuous scale for everything alive. However, assigning cognitive capacities without precisely defining what they mean here would be overly cavalier (Firn 2004). In addition, what "information" exactly means in this context is not so clear.

Shifting the boundary between cognitive and non-cognitive systems may lead to panpsychism, which is the view that "*mentality extends from humans to animals, insects, plant cells, and other natural bodies exhibiting persisting unity of organization*" (Clarke 2004). Panpsychism is rarely accepted these days, yet it was supported by the ancient Greeks, modern poets, and even prominent scientific figures like Leibnitz and Whitehead. Aside from the magical attraction of this idea, it seems that it does not stand up to the facts, so panpsychism is certainly not a view supported by this study. Finally, panpsychism is not the same as paninformatism, where information is considered an organizational element of nature.

So, what is the conclusion then? If we conceptualize information as knowledge or information$_E$, we must admit that everywhere where this information exists, there is, underlying it or carrying it, a physical stratum. This stratum is the source or carrier of I_E or something that may become I_E. Some may say this carrier is information *in potential*, but we would say that this information *in potential* that underlies epistemic information is actually ontological information.

5.1.3 Ontological information as a bearer of epistemic information

Epistemic information is always derived from some sort of stimuli, because epistemic information can be seen as the complex stimuli response of a cognitive system. This stimuli may be a signal in a telecommunications channel (e.g., Shannon–Hartley–Weaver and related models), or it may be an environmental stimuli interpreted by the cognitive system of a cognitive agent, or it may be an exchange between chemical complexes, such as in DNA processes in some interpretations. In all these cases, there is a physical phenomenon that is called a signal, data, message, or such like underlying the generation of epistemic information. The characteristic of this phenomenon that makes it a source of epistemic information is its structure or physical organization. Due to the complex hierarchical organization of physical objects, which are often denoted as structures of structures, it is not always clear which level of organization plays the role of information carrier for a given cognitive agent. Thus, epistemic information is an interpretation of some level of organization in physical objects.

Now, if we accept the conclusions of this study, this structure, order, or arrangement is an exact expression of ontological information. We stay clear of stating that these structures—or at least the structures for a particular domain like physics, biology, or chemistry—are information. However, this is what ontological information is seen as. Thus, epistemic information is an interpretation of ontological information being carried in a physical system and seen as its organization. We do not need to postulate data, data structures, or *infons*. Data are, in reality just stimuli that have already been interpreted. Thus, were we to postulate that epistemic information is derived from data, as is often assumed, we would be postulating that epistemic information is derived from epistemic information, thus creating an infinite regress. But where does the buck stop? We have a schema:

(1) (infons ?) → epistemic information (as data) →….→epistemic information

Schema (1) reads as follows: Some unknown pre-epistemic phenomenon (infons?) is perceived by a cognitive agent and converted into data. This process is then repeated until the data are converted into, or recognized as, epistemic information. This study proposes the following schema:

(2) Ontological information: structures visible or recognizable → interpretation of physical stimuli **by a** cognitive system → epistemic information

Schema (2) reads as follows: Nature has a specific organization denoted as ontological information, which is seen as visible or detectable structures. These visible structures are perceived by a cognitive agent's sensory apparatus and converted into epistemic information.

How information is imposed on physical media, in the case where an agent is the originator of epistemic information (i.e. a message), where it comes from, and how meaning is associated with it by a cognitive system are different matters that we will not be pursuing here.

We have attributed to ontological information three properties:

- (EN) Information has no meaning; meaning is derived from information by a cognitive agent.
- (PE) Information is a physical phenomenon.

- (FN) Information is responsible for the organization of the physical world

A phenomenon with these properties could not be epistemic information, because the characteristics of ontological information exclude it from being epistemic information and vice versa, because something that is objective cannot be subjective, something that has no meaning cannot have meaning, and something that is subject to the physical laws cannot be not physical, which epistemic information seems to be. Likewise, something that is foundational in nature cannot depend on the cognitive faculties of some agent for its existence (God excepted). Thus, epistemic information cannot be the thing that satisfies the properties of ontological information.[219] Thus epistemic information and ontological information represent two different concepts, because two things can be the same only if they have the same properties (following Leibnitz Law of The Identity of Indiscernibles). Table 4 below compares the proposed main features of ontological (concrete) and epistemic (abstract) information.

	Information$_O$	**Information$_E$**
1	Information$_O$ is a physical phenomenon, so it exists objectively and is not relative to anything.	Information$_E$ is a (artificial or biological) cognitive agent's interpretation of physical stimuli, which may be a signal, the state of a physical system, or some other physical phenomenon.
2	Information$_O$ has no intrinsic meaning.	Information$_E$ exists for a cognitive agent, or it is relative to a cognitive agent. In other words, information$_E$ is agent-relative or ontologically subjective. Information$_E$ has meaning for a cognitive agent.
3	Information$_O$ is, in a sense, responsible for the organization of the physical world.	A cognitive agent may be a human, a biological system, or some artificially intelligent system.
4	For information$_O$, existence implies existence in the physical world, somewhere in the space–time continuum.	For information$_E$, existence denotes the presence of an abstract notion somewhere outside of space and time.

Table 4. Comparison of ontological and epistemic information

So, what is the conclusion? Well, we have said it several times over already. Ontological information that "gives" shape to nature is intercepted by a cognitive agent and interpreted as epistemic information. In this schema, ontological information is a carrier of epistemic information and its partial source.

[219] *The Identity of Indiscernibles is usually formulated as follows: if, for every property* F*, object* x *has* F *if and only if object* y *has* F*, then* x *is identical to* y*. Or,* $\forall$F*(*Fx ↔ Fy*)* → x=y, (Forrest 2016).

5.1.4 Millikan and natural information

For the sake of completeness, we should mention Ruth Millikan's (2010) concept of natural information. We pose the question, one that has puzzled others as well,[220] as to whether natural information is ontological information or a kind of epistemic information. After all, we talk about ontological information as a part of nature, so it is in some sense natural.

Millikan defines natural information through a series of descriptions and analogies without explicitly defining it, as she admits herself. She claims that natural information "*is carried by natural signs such as a sign of fire or ambient energy patterns that initiate perception*" (Millikan, ibid., p. 110). Furthermore, she states that "*natural information is carried by informative human language, by maps or diagrams. Electronic patterns or neural patterns that are involved in information processing by computers and brains* ***can also carry*** *natural information*" (ibid.). She also writes that "*natural information resides only in sign vehicles. It is not something that is first generated at a source and then carried by the sign. Being housed in an infosign—having a vehicle—is intrinsic to natural information*" (ibid.). Furthermore, she says that *"natural information does not have a privative form. There is no such thing as natural misinformation*" (ibid., p. 111).

Now, what do we do with such a concept? On the one hand, natural information exhibits the properties of ontological information (e.g., "*being housed in an infosign*" and *"does not have a privative form*"). It is also carried by "*ambient energy patterns,* "so natural information is embedded in a carrier and not something subjective. Millikan's natural information is somewhat related to the state of physical systems. On the other hand, natural information exists only when it is interpreted, as seen in this claim: "*Electronic patterns or neural patterns that are involved in information processing by computers and brains* ***can also carry*** *natural information.*" This means that the same physical patterns may or may not carry natural information.

It appears that Millikan's natural information is a concept that combines some notions of epistemic information (i.e. meaning for an agent) and some recognition that information is carried by the patterns of physical systems, which are objective and independent (i.e. natural information *"does not have a privative form*"). Thus, we would not call natural information a new concept but rather a recognition that information has a physical basis (i.e. an objective existence), while epistemic information is derived from the state of a system. We should not read too much into the reference that "*electronic patterns or neural patterns that are involved in information processing by computers and brains*", because the nature of information in these two carriers is very different. The nature of these patterns (electronic or neural

[220] The question was posed by the audience during a presentation of the concept of ontological information. Private communication (2019).

patterns) and the possibilities for carrying information are completely different. Yes, both these patterns are involved in information processing but only in completely different ways, so the analogy is misleading. The individual neuronal states, in all probability, do not carry any meaningful information, and only their totality may in some sense do this, although how meaning arises from the neural base is as yet unknown. Conversely, the individual flows of electrical currents in wires or light pulses in optical communication conduits are encoding a specific meaning or, if you prefer, a message (with of course some level of noise).

5.2 Ontological information and quantified models of information

Our discussion of quantified models of information will not focus on the details for the models themselves, because enough has been written about them and replicating these efforts would serve no purpose. The discussion therefore focuses on the impact these models have on our understanding of information and how ontological information places these models (or what they represent) in a different light. In discussing the quantified models of information, we need to keep in mind the ontological separation between the quantified phenomenon and its mathematical representation.[221] These are entirely different things, although not everyone would agree with this view.

Now, let us begin with Shannon's Theory of Communication (ToC). Claude Shannon's concept of information has been elaborated many times over,[222] so there is no need for a further rehash of Shannon's work—a brief review will be sufficient. Therefore, we will focus on aspects of the theory that seem to be overlooked but are important to understanding Shannon's concept and the view of information implied in his work.

Shannon's theory of communication (ToC) describes the functioning of a communication system comprising a sender, a communication channel, and a receiver. This is a standard communication model (e.g., Cherry 1978, Fiske 1990, Holmes 2005, Littlejohn et al. 2017), but obviously, in Shannon's case, the context is that of a digital communication system. The sender forms a message (i.e. encodes it into the signaling media) in an attempt to convey something, which we call information, about himself or something else for someone else. The sender sends it through the communication channel in some physical form, and the message is received by a receiver. The receiver decodes the received message in an effort to recover the original information encoded by the sender. In Shannon's model, the channel

[221] We need to recognize the fact that the mathematisation of a phenomenon does not constitute its explanation.

[222] See, for example, Shannon (1948), Shannon and Weaver (1964), Pierce (1961), Klir and Folger (1988), Avery (1993), and Stone (2015), but the list is much longer. Also see Hartley (1928) as the originator of the idea of digital communication that is used in Shannon's work.

supports the binary encoding of the signal (i.e. the physical media carrying the message), so the message comprises zeros and ones. In other words, the physical phenomenon forming the channel is modulated (shaped, organized) according to some predefined rules that were agreed upon by the sender and receiver. These coding rules allow the receiver to decode the binary sequence from the physical media and recover whatever has been encoded by the sender. Without the same imposed encoding and decoding rules at both ends of the communication channel, there would be no communication.[223] The establishment of an encoding/decoding method is usually assumed in simple communication models like Shannon's.

The sign that can take 0/1 values is conventionally denoted as a bit. Shannon's measure of information (i.e. the amount of information) is the number of bits required to encode the message. So, if a message has only two possible values, one bit would suffice. If a message has "n" possible vales, one needs 2^n bits. Therefore, a message that can be encoded with one bit contains less information than a message that requires 2^n bits. For example, two values requires 1 bit, four values require 2 bits, eight values require 3 bits, and so on. The bit metric should be read as "the message has fewer bits" rather than as some metaphysical claim that the message has less "information", because Shannon's measure of information is a number of bits, nothing more. In Shannon's measure of information, there is not much beyond this for the concept of information. In addition, this "amount of information" is for this message only, not for the channel, the communication process, the world, or the sender.

So, where is the probability in Shannon's formula coming from? After all, the messages are what they are—they are not random. The probability in the messages comes not from the apparent random nature of the source or randomness in the receiver's perception of the message content. The source of the messages in Shannon's ToC is the repository of the English language, which is a well-organized collection of signs that are highly correlated internally. Indeed, it is only because they are so well organized that they can be used in communication. The probabilities in the message in the ToC arise from the faulty assumption that the message is a kind of random pooling by the source, with some elements being more probable than others. However, the assumption of a random pooling in the case of language is clearly wrong. The assumption that some elements are more probable than others is right, though. The assumption that elements are highly correlated is missing from Shannon's model, and Shannon's simplified model of communication results in a simplified model of information transfer and misconceptions about the nature of information. So, why does Shannon's formula work? It works when applied as a coding and decoding recovery strategy in digital systems, but it does not function as a general model of information of any sort

[223] Recall the fate of ancient scriptures where the encoding rules of the sender have been lost to the receiver. This is in fact the principle behind encryption, where the encoding rules are known only by the selected ends of the communication channel.

if we impart some epistemic, semantic, or metaphysical properties to information, which, by the way, Shannon excludes from his theory. Can he really exclude all these properties by decree, or are they being implicitly unstated?

Discussing the probability space of the ToC model is critical if we want to apply the ToC to other physical phenomena such as DNA structure or cosmic phenomena. The conclusions about the results and the significance of the results applied in Shannon's model can only be generalized to other phenomena if both phenomena have isomorphic probability spaces. It is questionable whether this is the case with thermodynamic entropy, with DNA or quantum information (e.g., Lukasik 2017).

The measure of the amount of information defined by Shannon is the entropy of the information source (symbolized as H) of a message, and the more bits that are needed for encoding a message, the more entropy that is attributed to the message. The sender has a pool of signs from which the message is composed, and each sign has an associated probability (defined over the pool of available signs) of being in a message. In the original formulation of the theory, the pool of signs and assigned probabilities were the letters of the English alphabet, with the frequency of occurrences for each letter corresponding to its use in English (Shannon 1948),[224] but the specific language is not important of course. Information entropy is the average number of bits to encode the sign. In addition, *"the concept of information applies not to the individual messages, but to the situation as a whole*" (Shannon and Weaver, op. cit., p.9).[225] The term information, in the context of Shannon's theory, is used in the special sense of "*meaning that it measures freedom of choice and hence the uncertainty as to what choice has been made. Uncertainty arises by virtue of freedom of choice (limited) on the part of the sender or errors (noise)*" (Shannon and Weaver, op.cit., p.19). Shannon's formulas are defined over the probability space under the assumptions for probability calculus (Kolmogorov 1965):

1- All probabilities pi is <= 1.0 and>= 0.0.
2- Particular events are not correlated.
3- Individual events are additive.

The formula for information entropy (of a discrete source) is:

$$H(X)= \sum - p(x) \log(p(x))$$

where X is a variable with probability density distribution p(X), and H(X) is the information entropy of p(X). For p(xi) = 0, which means that this particular event-message is improbable, the formula is

224 It really does not matter whether the language is English or some other set of symbols, because they all encode semantics in syntax if they are to function as a language.
225 "The situation" is a process of pooling signs from a predefined collection of signs with a specific frequency of occurrence that is characteristic of the given language.

undefined, while for p(xi) = 1, the entropy or amount of information is zero (implying no coding is possible so it is not information in Shannon's sense?). This obviously requires some explanation, because assured information is information. So why is this? The explanation seems obvious. As the source has only one message to send, there is no shortest coding (or no coding at all) to encode this message, but this is obviously flawed, because the message is sent in some form of encoding. The meaning of Shannon's model at the outer limits is therefore not well defined when looking at information as a concept. (In fact, the boundary interpretations of Shannon's entropy of information were arbitrarily assumed and did not come from the model itself or from the concept of information)[226]. These results are the artifacts of the mathematical model used to represent information, but who worries about what happens at the boundaries of the definition space?

Shannon clearly states that his concept of information, which is represented by a measure of information, has nothing to do with semantics, which is a property usually associated with information. This would seem to exclude Shannon's entropy of information from the class of epistemic information, but does it really? Shannon's entropy, or measure, of information in its original definition is defined over the probability space of events that are intentional in origin, so they have semantics in language communication. They therefore exist only as expressions of human cognitive faculties; at least in the original formulation (Shannon used English as an exemplar language). What is more, the encoding of the message is not some random process but rather a carefully designed intentional action. Thus, Shannon's claim that his model is semantic-free is incorrect when we talk about the larger picture of the communication model. It is, however, correct if we restrict the model to pure technology.

Probability is generally regarded as a measure of ignorance, a lack of knowledge for predicting events. But one may ask for whom this predictability is—it is for us. Events in nature just occur, and uncertainty (as an epistemic concept) does not come into play. For purely random events (ontologically random) in nature, if any do indeed exist, such as atomic decay or particle creation,[227] what would Shannon's measure give us? Probably not much, because the information entropy of one specific event would tell us nothing about another event (see the case of measurements in QM), if they are indeed truly random, nor would it say much about the state of the source. So much for the "reduction in uncertainty" interpretation of Shannon's metric of entropy of information.

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[226] Someone may also notice that the analogy between information entropy and thermodynamic entropy breaks at these boundaries as well. Physical systems with entropy equal zero (a crystal may have zero entropy only if the crystal has a ground state with only one configuration (see e.g., Kozliak and Lambert 2008, Atkins 2010)) represent concrete physical systems, not something not definable (Atkins 2010).
[227] The problem of randomness in nature is still an open question. See, for example, Nicolic (2007).

The concept of information buried in Shannon's ToC conflicts with the intuitive understanding of what information is. Thus, it is difficult to accept it as a general conceptualization of information (Cherry 1978, Pierce 1961). We may see it as an index or measure of structures that can be identified with information, and certainly it is safe to attribute this to Shannon's entropy of information as a purely probabilistic interpretation of the properties of a coding channel. In other words, it considers the content of the channel expressed as a formal measure of the probability density function (PDF) of the signals transferred over the channel, much like other measures of the PDF, such as the average, median, standard deviation (and other moments of higher order). Such an interpretation agrees with von Weizsäcker's interpretation of information.

A purely numeric interpretation of information (based on Shannon's theory) would have the following definition: Information is a certain measure of the PDF of the encoding media and expresses for discrete variables the average (expected) value of logarithms based on the probability of individual messages. All interpretations of this information should then be related back to the specific event probability space in which the specific PDF is founded. Information, the entropy of information, or the measure of the amount of information in the ToC is essentially an abstract measure/number assigned to a certain probability density defined over the space of certain uncorrelated random events. Shannon's interpretation of the concept of information is therefore tied to the probability space of the events in his model of communication. As we said, an interpretation from one probability space cannot be automatically carried over to another space if these spaces are not isomorphic (e.g., Yokey 1999, p.70). One problem, although not the only one, in carrying over interpretations from Shannon's theory from one context to another is that for Shannon, the most important message is the one with the lowest probability of occurrence, because it yields the more information (in terms of bits) than messages with a higher probability. This is certainly an important feature for decoding the signal and reconstructing the message in a known language, and this was the basic assumption of Shannon's model. However, in the general case, information with a very small probability of occurrence may have no significance for the receiving agent.[228]

So what is Shannon telling us about information in his ToC? First, he tells us only about the coding complexity of a message in the binary channel and not the semantics or meaning of what is encoded. We talk about semantics in the model itself, as explained earlier, but not about the semantics in the message. It tells us about the state of the source sending the message, and it tells us how to decode/encode the message efficiently but not accurately, because the signal is presumably based on random choice. It is

[228] When decoding ciphers, one looks for repeated, recurring patterns. The least probable occurrences of signs do not tell us much about the cipher. See, for example, Sutherland and Koltko-Rivera (2009).

based on implicit coding rules and probability axioms (see Kolmogorov 1956). In addition, it is in no way unique in representing a coding schema.

The question needs to be asked as to whether ontological information is probabilistic? The reality is that it is not probabilistic, at least on a macro scale. Probability is a measure of some uncertainty of knowing, some inability to accurately predict something, but not a measure of what that something is. This is an epistemic metric par excellence, even in the case of QM. Nature is not random in a metaphysical sense; it just is the way it is. If one takes Shannon's communication channel as a reference point, the signal is a deterministic, physical phenomenon. Only the interpretation with respect to the original source and the pooling process make it probabilistic.[229] Thus, one may venture to suggest that Shannon's theory of communication with its measure of information is not measuring some objective feature but rather the effects of the message-creation process (barring the case of white noise).

We also need to discuss the relation between Shannon's entropy of information and the entropy of physical systems, because the discussion of entropy as a kind of information and information as a kind of entropy pervades the literature. Some examples of this can be found in the first part of this study. A few saner voices have advocated restraint in these analogies but to no avail. To close the door on this issue for this study we refer to the work of Ingo Muller (2007) about entropy, Shannon, and information entropy.

Muller points out that entropy (thermodynamic) is not something unknown or poorly understood, as it was suggested by von Neumann. Thermodynamic entropy is well understood physical phenomenon that has little to do with chaos, disorder, message as used in the context of Shannon's entropy of information. Extrapolations of well defined physical concepts (i.e., thermodynamic entropy) to other fields do not explain anything. On the contrary such (ungrounded) extrapolations make these explanations more obscure (vide Schrödinger's cat. See Mann 2020). As Muller states "*For level-headed physicists, entropy—or order and disorder—is nothing by itself. It has to be seen and discussed in conjunction with temperature and heat, and energy and work. And, if there is to be an extrapolation of entropy to a foreign field, it must be accompanied by the appropriate extrapolations of temperature and heat and work. If we wish, we can now assign an entropy to the message which Shakespeare sent us when he wrote Hamlet: We look up the probability of each letter of the English alphabet, count how often they occur in Hamlet and calculate Inf. People do that and we may suppose that they know why*." (Muller 2007. p.133-134).

[229] With the "reduction in uncertainty", a typical interpretation of information makes sense only against the deterministic and well-defined source of the signal. If the source is random (completely unpredictable), such as we assume atomic decay to be, there cannot be any reduction in uncertainty with additional information. Thus, this interpretation of information only makes any sense, if at all, for a deterministic signal source.

As Muller suggests, mixing the concepts of information and entropy brings more confusion and harm than help in explaining anything about the nature of either concept. Information as ontological information does not dissipate in chaos. Indeed, information in this sense pervades both highly organized and highly disorganized phenomena. Organization and disorganization are simply part of our insignificant anthropomorphic perspective. Information in the sense of organization exists everywhere all the time. The following passage from Mott-Smith (1964, p.172) explains this clearly: "*To say that the entropy of the universe tends to a maximum is simply to say that the universe is passing from an interesting, useful and significant state, to an uninteresting, useless and meaningless state. Apart from us human beings, that is quite indifferent. There is just as much going on in a chaos as in what appears to us as an orderly universe—only it means nothing to us. We cannot make head or tail of it; we can do nothing with it; we have no use for it; we do not like it. And of course we could not live in it*."

It may also be the case that we tend to attribute names to abstract objects or ideas, not necessarily using some logical justification, so this naming may cause problems in the long term. This is the case with imaginary numbers, which have nothing to do with the imagination or incommensurable numbers which are numbers as other numbers are, but with some unique properties. Such names were certainly chosen to signify something, yet they do not necessarily reflect the nature of the named object. The names may have been chosen for entirely different reasons. This may be the case with information entropy, which bears some formal similarities to thermodynamic entropy but little beyond that.[230] Maybe we should stop uncritically identifying entropy with information and vice versa.

Gregory Chaitin (1997, 2004) and Andrei Kolmogorov (Kolmogorov 1965, Solomonov 1997)[231] independently developed the concept of an information metric based on the Universal Turing Machine (UTM) model, and they called this algorithmic information complexity (e.g., Baldwin 2005). Algorithmic information complexity is the minimum size of a computer program that can reproduce a given string. The link to the UTM is there because the programs having their algorithm complexity considered are Turing machines. There are different formalizations for this measure. Algorithmic string complexity (H(S)) for a string S for a given UTM is the shortest program "p" that reproduces string S (Baldwin 2005). The algorithmic complexity for S depends on the UTM type. For a completely random string,[232]

[230] "*But the essential principle involved (in naming) was quite clearly enunciated to Alice in Wonderland by Humpty Dumpty, when he told her, apropos of his use of words I pay them extra and make them mean what I like*" (Whitehead (1911, p. 61). Of course, Humpty Dumpty's response bears an uncomfortable similarity to von Neumann's advice to Shannon.

[231] Ray Solomonov is also referred to as a co-inventor of algorithmic complexity.

[232] The word "randomness" reflects an absolute lack of predictability, and it is a rather elusive phenomenon (Prömel 2005), particularly in computer-generated structures: "*Anyone who considers arithmetical methods of producing random digits is, of course, in a state of sin*" (von Neumann as quoted by Frantzen 2007).

the size of the program approximates the size of the string, while for less random string, the program has a lower algorithmic complexity, because the Turing computational model (Universal Turing Machine) represents the complexity of strings or a series of symbols. As such, it is similar to Shannon's measure of information (Baldwin 2005), and its interpretation of the type of information resembles that of Shannon's measure of information.[233]

For the sake of completeness, we should mention Fisher information and Klir's concept of information. Fisher information is a statistical measure of how much information one may obtain about an unknown parameter from a sample. Technically, Fisher information is the inverse of the variance of the Maximum Likelihood Estimator (MLE) for a parameter Θ from a sample X (for a normally distributed X). (The MLE is the maximum of a function of a specific parameter Θ given a random sample.) To simplify this, the concept of Fisher information allows us to find the value of the parameter(s) of a function fitted to the experimental data such that it minimizes prediction error.[234] Fisher information has found many applications in experimental studies in fields like astronomy, biology, and social sciences (e.g., Friden 1998, Ly, et al. 2017). For George Klir (Klir & Folger 1988), information is a reduction of uncertainty. Uncertainty may be considered as ambiguity or vagueness. Such uncertainty may be measured by Shannon's entropy of information (a measure of ambiguity), the Hartley measure (H),[235] or measures of fuzziness. Both Fisher and Klir define information as a reduction in uncertainty based on information from perceived observations,[236] so these concepts clearly belong to the class of epistemic information.[237]

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[233] For the sake of completeness, we need to mention/list the mathematical models related to Shannon's measure (Shannon's entropy of information), such as Reniy Entropy, Tsalis Entropy, Hartley Entropy or Max-Entropy, Collision Entropy, and Min-entropy. See, for example, Hartley (1928), Tsallis (1988), Da Silva and Rathie (2008), Cho (1961), and Rényi, (1960*).*These are mathematical variants of which Shannon's entropy is just a specific case. An analysis of them is beyond the scope of this study, nor would it further the objectives of this research because they are all probabilistic metrics.

[234]"*Fisher information essentially describes the amount of information data provide about an unknown parameter. It has applications in finding the variance of an estimator, as well as in the asymptotic behavior of maximum likelihood estimates* ("Intuitive explanation" 2004). The website provides a simple demonstration of the relationship between Fisher Information I and σ as the Gaussian likelihood for the mean. It has been also suggested that Fisher information can be a unified concept for all of physics ("Fisher information" 2018), but this claim did not gain support (von Baeyer 2005, p. 216).

[235] According to Hartley",*'H' is the information as the message is the logarithm of the number of possible sequences of symbols, which may be selected as H = s log (s), where n is a number of symbols selected, and s is the number of different symbols in the set from which symbols are selected*." See Pierce (1961, p. 40).

[236] The question is what does this reduction in uncertainty amount to? It is not uncertainty about this or that event but rather an uncertainty about the structure or composition of the probability space to which particular events belong. Uncertainty is the opposite of knowledge. Thus, uncertainty measures our knowledge of something, a situation, or a process, and a reduction in uncertainty increases our knowledge of the process.

[237] "*A reduction of uncertainty by an act is accomplished only when some options considered possible prior to the act are eliminated after it. This requires a semantic connection between the prospective outcomes of the act involved (observations, received message, experimental outcomes) and the entities to which they are applied*"

A quite extensive list of quantified models of information is also provided by Burgin (2010, pp.131-132), but the sheer number (32 formulas) of models for measuring information does not translate into clarity about the nature of what is being measured. In fact, the models listed by Burgin measure quite different properties of abstract constructs, usually probability spaces, so they do not necessarily convey the same concept of information. To clarify this point through an analogy, the numerous measures of mass led to multiple interpretations for the concept of mass, and these did not necessarily converge on a single concept of mass. Indeed, the concept of mass as we now know it has evolved significantly over the history of science.[238] These measures pointed to varying conceptualizations of mass, but they did not address the question of what mass actually is. Likely, multiple measures for information do not translate into a better understanding of what information is—it only shows a range of possible interpretations (Hintikka 1984, pp. 175-181).

We can now draw some conclusions. With ontological information, Shannon's and other quantified measures of information can be safely interpreted as just some measure of the organization of physical phenomena associated with ontological information. These measures reflect the form or structures that characterize ontological information for particular objectives (e.g., digital communication channel decoding (Shannon), experimental uncertainty (Fisher), program size (Chaitin)).How these quantified measures are interpreted, however, is immaterial to the definition of ontological information. They are just interpretations of a measured phenomenon, with the formal aspects of the metric (like probability assumptions or boundary conditions) being imposed on these interpretations. Depending on what structures/forms they are applied to, their interpretations may be more or less in agreement with the nature of ontological information, but they were not designed to do this, nor were they designed to reflect the phenomenon of ontological information as it is but rather only as far as it is applicable for some purpose.

(Klir and Folger 1988, p. 188). This "semantic connection" is what makes Shannon's entropy of information measure, in its original formulation, epistemic.

238 Wikipedia lists 107 different units of mass ("Units of mass" 2019). Multiple measures of mass are also listed in the Wikipedia entry "Mass" ("Mass" 2019). The evolution of the concept of mass is discussed by Jammer (2000), Okun (1989), Mashood (2009), and Hecht (2006).

5.3 Ontological information and data

Why do we question the relation between ontological information and data? After all, what does data have to do with ontological information? When we look at definitions of epistemic information, these definitions often, if not almost always, claim that information (i.e. epistemic information in this study) is "data + meaning" (Floridi 2013). There are similar claims that "information is derived from data" or "information is data endowed with relevance and purpose" (Davenport 1997, Drucker 2001), "information is organized data" (Saint-Onge 2002, pp. 28-29), or it is "interpreted data" (Terra and Angeloni 2010). It somehow seems that we need data to get information, that data is some kind of input to the process of creating information, that data differs from information, or that data is some "primitive stuff" from which information is formed. Data certainly seems to be not information—they are different. But are these claims warranted? Could it be that data can be considered the primary stuff of the universe, a position we reserved in this study for ontological information? Let us look at how data is defined and where this fits in our conceptual schema of the world in relation to epistemic and ontological information.

According to Drogan (2009), "*data are a prerequisite for information and information is a prerequisite for knowledge.*" Liew, meanwhile, defines data as *"recorded (captured and stored) symbols and signal readings. Symbols include words (text and/or verbal), numbers, diagrams, and images (still and/or video), which are the building blocks of communication. Signals include sensors and/or sensory readings of light, sound, smell, taste, and touch*" (Liew 2007). Another definition tells us that *"Data is the term used to describe the information represented by groups of on/off switches*" (Surbhi 2016). From three authors, we have three definitions, and these do not necessarily converge. Even though the terms data and information are often used interchangeably, there is an important distinction between them. Data consists of the raw numbers that computers process to produce information. We also get very elaborate comparisons and a clear differentiation "*data and information are interrelated. Data usually refers to raw data, or unprocessed data. It is the basic form of data, data that hasn't been analyzed or processed in any manner. Once the data is analyzed, it is considered as information. Information is 'knowledge communicated or received concerning a particular fact or circumstance.' Information is a sequence of symbols that can be interpreted as a message. It provides knowledge or insight about a certain matter*" (Ackoff 1989, pp.3-9). Furthermore, Ackoff states that *"Data are symbols that represent properties of objects, events, and their environment. They are products of observation. To observe is to sense*." Yet another take on data is given by Machlub (1983), who states, *"Data are the things given to the analyst, investigator or problem-solver, they may be numbers, words, sentences, records, assumptions, just about anything, no matter of what form and what origin*" (Ackoff ibid.). Table 3 below (Machlub 1983) shows the many possible interpretations of data and information, where information is interpreted here in its semantic meaning.

	Data	Information
Definition(Oxford Dictionaries)	Facts and statistics collected together for reference or analysis	Facts provided or learned about something or someone; Data as processed, stored, or transmitted by a computer
Refers to	Raw data, stimuli, signal	Analyzed data
Description	Qualitative or quantitative variables that can be used to propose ideas or draw conclusions	A group of data that carries news and meaning
In the form of	Numbers, letters, symbols, or a set of characters.	Ideas and inferences
Collected via	Measurements, experiments, etc.	Linking data and making inferences
Represented through	A structured format, such as tabular data, a data tree, a graph, etc.	Language, ideas, and thoughts based on the data
Analysis	Not analyzed	Always analyzed
Meaning	Carries no specific meaning	Carries meaning that has been assigned while interpreting data
Interrelation	Information that is collected	Data that has been processed

Table 5. Comparison between concepts of data and information.

Based on Table 5, it seems that the differentiation between data and information is somewhat arbitrary, a matter of interpretation as to what constitutes raw data versus analyzed data, no special meaning versus assigned meaning, collected versus processed, formal formats (tree, tables, graphs) versus linguistic interpretations, symbols versus ideas, and so on. These differences are not very well accentuated, so the boundary between data and information seems to be somewhat fluid, and the multitude of definitions of data only confirms this impression. Zins (2007) documents no less than 130 definitions for data. It seems that we are in the same situation as we are with trying to define information, namely that we have so many definitions that we do not know what we are defining. The multitude of definitions supplied by experts is positioned as an important scientific feat but I would claim that for science and philosophy, it is more of an embarrassment.

Including data in some conceptualizations of information is a sign, in my view, of not being able to see the forest for the trees. Whatever is denoted as data already has some meaning imparted on it.[239] Whatever information is, from this perspective, already has some additional meaning imparted onto

[239] There is a separate section in Chapter Four about data and information.

already processed data. Knowledge it therefore processed information. The distinction between data, information, and knowledge can be therefore made, and this is certainly operationally useful in certain areas of research or technology, such as computing, artificial agents, Big Data, cognitive artificial systems, and artificial intelligence. Indeed, it is helpful whenever we want to denote or differentiate one narrow aspect or stage of information processing, especially with computers. However, these divisions overlook the strong similarities and stress the rather relative differences (e.g., Dasgupta 2016, Floridi 2013). This division into data, information, and knowledge, which is often referred to as the DIKW (data, information, knowledge, wisdom) hierarchy, wisdom hierarchy, knowledge hierarchy, information hierarchy, or the data pyramid (e.g., Zeleny 2005, Livesley 2006, Rowley 2007, Zins 2007). A detailed discussion of the DIKW lies outside the scope of this study, however.

Unfortunately, this (con)fusion of data, knowledge, message, meaning, and so on is how information has been largely understood in the 20th century, which will be referred to in the history books as the age of information or the age of something we are not sure of yet. As we have said, we refer to this information as epistemic information—thus emphasizing the relation to, or reliance on, knowledge—or information_E or I_E for short. Of course, the reader may find others who refer to this information as cognitive information, thus highlighting information's dependency on cognitive systems; semantic information, emphasizing meaning as a defining feature of information; or most often just as information.

On trying to find some firmer ground for the concept of data, we may say that data are a sort of epistemic information, symbols imposed on natural stimuli, elements in communication, numbers stored in digital form, or some kind of information (i.e. interpreted stimuli). The boundary between data and information is fluid and not very well defined. Thus, in some cases and for some purposes, data will be data, while in other cases, the same data will be information or information will be data. It seems that how we refer to data depends on where we are situated on the spectrum of information processing, from stimuli to knowledge.

Now, let us try to position data and information within the perspective of this study. To begin with, we cannot say that data are uninterpreted stimuli, because data must have been interpreted under some symbolic convention, because it represents stimuli through symbols, data structures, and such like. Every stimulus we receive has already been interpreted by our sensory/perceptual system. The moment we attempt to record something, we interpret it again in some kind of formal language with its own symbols, grammar, and syntax. Thus, if stimuli are interpreted, someone or something must have interpreted them, either directly by recording symbolic representations in a sort of note-taking or indirectly through the use of some equipment or apparatus, such as the digital recording of sound waves. There is no data without interpretation, there is no interpretation without an interpreter, and there is no interpreter without a format or language to interpret stimuli into. Imposing a format on something is to impart meaning, or at least some form of it. Following this logic, we see that the concept of data is clearly one of epistemic information. It is physical phenomena interpreted by a system or ontological information interpreted by a cognitive agent. Data are not elements or components of nature, nor are they in any way fundamental to the physical world. They represent, however, a link in the process of interpreting natural stimuli, the process by which cognitive agents process ontological information, albeit an early link in this process. Table 6 presents a comparison between data and epistemic information ("Data vs. Information" 2019). The differences here are somewhat arbitrary, often being imposed due to operational concerns rather than their inherent properties.

	Data	**Epistemic Information**
Meaning	Data is raw, unorganized observations, being recorded on some media and in need of processing. Data can be something simple and seemingly random, and it is useless until it is organized.	When data is processed, organized, structured, or presented in a given context so as to make it useful and it is called information.
Example	Each student's test score is a piece of data.	The average score of a class, or of an entire school, is information that can be derived from some given data.

Table 6. An example of data and epistemic information.

One may argue that in this comparison, data is the information for a particular student and the average score is of lesser importance to this individual, so the difference between data and information is rather arbitrary and relative, a matter of preference. We do not deny that this division can be useful or even an operational requirement, however. In computer information systems, knowledge systems, and computer decision systems, information is usually defined as the result of processing data, the outcome of bestowing meaning on what we call "input data." In his book on business information systems, Paul Beyond-Davies (Beyond-Davis 2009) states that "*data are concerned with form and representation of symbols in storage and transportation. Information is concerned with the meaning of symbols and their use in human actions. Hence, information is data + sense making*" (Beyond-Davis, op.cit., p.75). This statement is inaccurate, because imposing form and representation, as we pointed out earlier, is already imposing some level of meaning or interpretation. Within this technical or operational definition, data are already classed as epistemic information.

From the perspective of computer information systems, however, this differentiation into data and information plays a useful role. Rajendra Arvind Akerkar and Priti Srivinas Sajja (Akerkar & Sajjaa 2010) provide definitions of data and information and point to the differences. For them, data and information are "*factual, discrete and static things, and raw observations of the given area of interest. Information can be generated after systematic processing of such data*" (Akerkar & Sajjaa 2010, p.13). However, they do not realize that information for some may be data for others, making this distinction again relative. There is no interpretation-free data, just as there are no assumption-free scientific theories. What they are actually telling us, without realizing it, is that information, however they mean it, is processed/interpreted data or that data is information minus some processing. This is true even if they later say that information is not data because information is data that has been processed and connected with some meaning. Such claims assume that data has no meaning, but we recall the previous definitions of information (or semantic information) as "data+ meaning", but in this view, data has already had some meaning imparted on it, so we have the following dependency:

$$\text{“?”} \rightarrow \text{data + meaning} \rightarrow \ldots \rightarrow I_E$$

where the question mark represents some undefined "original" source of an uninterpreted physical process.

That said, Akerkar and Sajja's book is not written by, or for, philosophers, so such distinctions may not be visible or even needed for their narrative. The concepts of data and information must be stated simply in a clear technical way that computer heads can understand, and there is no place for metaphysics here.

We need to state this to avoid any attempt to assign an objective, ontological status to data. There is no data out there, nor is the world a stream of digital data like it is presented in *The Matrix* movies. Data are interpreted, theory–laden observational facts.[240] The world is full of the uninterpreted or as we call it, ontological information. Data are just as subjective as epistemic information is. Something is not data by its very nature but rather because some agent denoted it as data. Thus, any definition of information that claims that this information has at its foundations data is committing a circular fallacy (*circulus in demonstrando*).The answer begs another question *ad infintum*, because in actuality, these definitions claim that epistemic information is founded on epistemic information or that epistemic information is the

[240] This resembles the problem of "pure" observation in experimental sciences as it was initially imagined (e.g., Chalmers1994), where every observation is theory-laden.

source of epistemic information. Table 7 compares the characteristics most often attributed to epistemic information and data to illustrate their similarities.

Epistemic Information	Data
Epistemic information is an interpreted physical stimulus—call it data, a signal, a state of a physical system, or some physical phenomenon—by a cognitive agent	Data are interpreted stimuli in some format or language.
Epistemic information exists for a cognitive agent or is relative to one, so epistemic information is agent-relative or subjective.	Data are specific to an interpretation system and interpreting agent
The cognitive agent may be a human agent, biological system, or an artificial cognitive system.	The interpretation of data may be performed by a biological or artificial agent/system.

Table7. Comparison between epistemic information and data.

For the sake of completeness, we also need to mention the so-called metadata. Metadata, as a concept, represents data about data.[241] It usually describes the origins, the processing context, the originating systems, and other information about some data. Metadata is therefore nothing more than data about data—it does not enjoy any special metaphysical status, let along grant such a status to data. The concept of metadata does not bring any new arguments to the discussion of data, at least from the perspective of this study.

5.4 Ontological information and infons

The *infon* is a concept described by Stonier (1990), Devlin (1991), Floridi (2013), and Martinez and Sequoiah-Grayson (2014). Infons are positioned as "elemental (natural) units of information, "not as something like binary bits but rather in the sense of the elementary constituents of matter, much like quarks. In other words, they are elements that are fundamental to the construction of information.[242] Thus, much like how nothing is smaller than a quark, at least with our current knowledge, no information is smaller (whatever that may mean) than an infon.

[241] *Metadata is simply **data about data**. This means it is a description and context of the data, which in turn helps to organize, find and understand data* ("Metadata" 2020). See also Snowden (2019).

[242] We compare infons to bits because a bit is the smallest unit of data in digital computer information systems. But what is the smallest processing unit in analogous systems?

Stonier claims that there may exist "*a class of hypothetical particles which consist of only information. Such 'infons' might not show up in traditional physical experiments since such particles would possess neither mass nor energy—they could, however, manifest their effect by changes in organization*" (Stonier 1990, p.126). The physical interpretation of an infon provided by Stonier is just conjecture, however. He does not propose how we could conduct an experiment that could prove the existence of infons. After all, if they exist, we should be able to detect them. Thus, Stonier's infons are not like bosons in the way they were conceptualized (in terms of their properties) before they were detected. Indeed, Stonier's infons have been conceptualized without a chance of ever being detected.

Floridi (2013, p.84) uses the term infon in his General Definition of Information (GDI) stating, "*GDI σ (an infon) is an instance of information, understood as semantic content*." He also explains that an infon "*refers to the discrete item of information, irrespective of its semiotic code and physical implementation*." Furthermore, he also says that *"the term 'infon' and the symbol refer to discrete items of factual semantic information quantifiable in principle as either true or false, irrespective of their semiotic code and physical implementation*" (Floridi op.cit., p.110) and that "*infons are messages formulated by a source*" (ibid., p.111). Floridi's infons are clearly elemental units of semantic information, so they are foundational to the semantic conceptualization of information. Thus, Floridi's infon is the smallest form of an interpretable something, and it is not physical, so it must be abstract.

Infons have been also defined by Devlin (op.cit., p. 35) in many ways. For example, infons *"do not have some kind of physical existence*." It is an "item of information" that is theory absolute or representation-independent; it is "*an equivalence class of a pair <R, C> of a configuration, R, and a constraint, C*." Infons are *"semantic objects within the framework of our theory… their status is the same as ... the real numbers within mathematics*", and they are "*independent of representations*." What is more, *"status as abstract objects does not mean that infons have any kind of physical existence… [they are] intentional abstract objects… as abstract objects, infons may be regarded as being as much a part of our world as numbers*" (Devlin op. cit., p. 45). For Devlin, information comes in infons, elementary bits of information for a specific agent. Infon information essentially comprises propositions about the state of the world, or facts if you will. The source of this information is perceived stimuli processed by a cognitive system, and each cognitive system may have its own infon-based ontology that suits its needs. (Note that ontology here refers to preexisting information/knowledge that enables the interpretation of stimuli.) For example, a cat will have a different infon-based ontology from a bee, as would a fish and an autonomous car.

Yet another definition of infons is proposed by Martinez and Sequoiah-Grayson (2014). They define an infon as *"informational issues that may or may not be supported by particular situations; what is expressed as s ⊨ σ., with s being a situation and σ being an infon*." This definition is developed in the context of the situation theory of information (Martinez & Sequoiah-Grayson, op.cit.).

The lesson to take from this discussion is that the infon is clearly an attractive concept, as many people seek to define it. Indeed, the infon seems to enable the quantification or discretization of information, thus making it measurable. Yet the infon is not a clearly defined concept like electrons and protons, assuming we regard them as being clearly defined. It is not elemental in the sense that an elementary particle is in physics, nor is it sufficiently well defined to use it without qualification. The infons of Stonier, Martinez and Sequoiah-Grayson, and Devlin are clearly not the same, even if they all seek to play the role of "*elementary units of information*."

From the perspective of this study, an infon must be smallest quantity of identifiable information, much like today's opinion that quarks are the smallest identifiable form of matter. From the perspective of epistemic information, an infon appears to be a unit of thought, so it is a unit of epistemic information.[243] We do not know what this unit is, though. For example, what is an elementary thought? Is it a simple Humean impression? The search for it seems rather pointless. From the perspective of ontological information, though, we may see the infon in a different light. With ontological information, we assume that information is always embedded in a physical carrier, so the simplest ontological information relates to the simplest organizations of nature or to the fundamental elements of nature, much like elementary particles do. As we recall, some authors in the reviewed publications do mention that matter and information cannot be considered separately, with there being no priority between matter and information. Thus, if information is always carried by a physical phenomenon, the smallest physical element, elementary particles like the muon, may be also the smallest "quanta" of ontological information, although this is just conjecture.

5.5 Ontological information: abstract or concrete?

5.5.1 Dilemma of existence

What is this dilemma about? It was posited by Davies, Mynarski, von Weizsäcker, and others, and it emerges when under the single heading of information as ontological, we group the concepts of

[243] As the smallest amount of matter that we know of today, this complex object is somewhat reflected in the combinatorial ontology of Perzanowski (1965), where objects appear only after reaching some level and some structural complexity from the fundamental ontology realm. In other words, the simplest objects that exist are already complexes.

information being conceptualized as objective, having a physical presence, and being epistemically neutral. In other words, it is something concrete, while information conceptualized as knowledge is associated with thoughts and the mind, so it is an abstract thing. Davies claims, "[Information] *used as informing about something is a purely abstract concept like … love. On the other hand, information clearly plays a physical role in the world, not least in biology. The challenge to science is to figure out how to couple abstract information to the concrete world of physical objects*" (Davies, op. cit., p.35).

Similar ideas about the immaterial nature of information are expressed by Wheeler: "*It from bit symbolizes the idea that every item of the physical world has at its bottom—at the very deep bottom, in most instances—an immaterial source and explanation; that what we call reality arises in the last analysis from the posing of yes-no questions and the registering of equipment-evoked responses; in short, that all things physical are information-theoretic in origin and this is a participatory universe*" (Wheeler op. cit., p. 331).

Such views are fascinating, yet they would imply a "Berkeleyism" of sorts, which is a rather difficult concept to accept today. These ideas come from the search for the ultimate foundations of reality and the fact that the deeper we delve into the hierarchy of physical phenomena,[244] the less solid are the things we find, at least in our everyday concept of solidity. However, a lack of knowledge does not justify such flights of fancy, and modern "Berkeleyism" is a discussion that lies well outside the scope of this work.

We claim here that the problem of information being split between abstract and concrete concepts is actually nonexistent, contrary to the claims in some previous studies. Information clearly cannot be both at the same time and in the same way. If something is abstract, it cannot be concrete, and vice versa. So how is this dilemma resolved? Ontological information is purely natural, and it exists in nature, in the physical world. There is nothing esoteric about it. Epistemic information, meanwhile, exists in the mind and has in this view, which incidentally has been tainted by Descartes and others to implying some "metaphysical" side to physical reality, "existence" in the mind of the beholder, whatever that may mean. Thus, in the same message written in a letter, spoken in words, or coded in a telegram, there is no magic "substance "that is common among these messages and transferred with them from one physical state to another. The attraction of some magical dust that bestows meaning on an otherwise inert substance is what led von Weizsäcker and others astray. They were looking for some "transcendent thing" over and above the media in question, something that is "preserved" between forms of physical media. Clearly, as

[244] By "deeper", we refer the scale of the universe in the sense described by Lamża (2017), which is in some approximation the scale of resolution.

this thing is not physical, it must be abstract in this view (*tertium non datur*). Let us look into the details of this thinking (Figure 5). A piece of music may be carried by through sound as "air pressure waves" with a physical structure S_A, by the physical organization of groove on a vinyl record with a physical structure S_B, or another transport media with a respective physical organization. They can all be interpreted as the same piece of music (i.e. the same information), so it seems obvious that this information must be common among them. It cannot be physical, however, because there is nothing common between structures S_A and S_B or any other physical structure conveying this music. The only commonality between these carriers is that they are physical substances with some form. There is no similarity between these structures. Thus, because the common factor is not in the structures, it must be abstract. This is information$_A$, and it is obvious from this argument that it must "exist" in some form. How otherwise could completely different physical structures carry the same information? We claim, however, that it is nothing like this, and the whole premise is simply wrong.

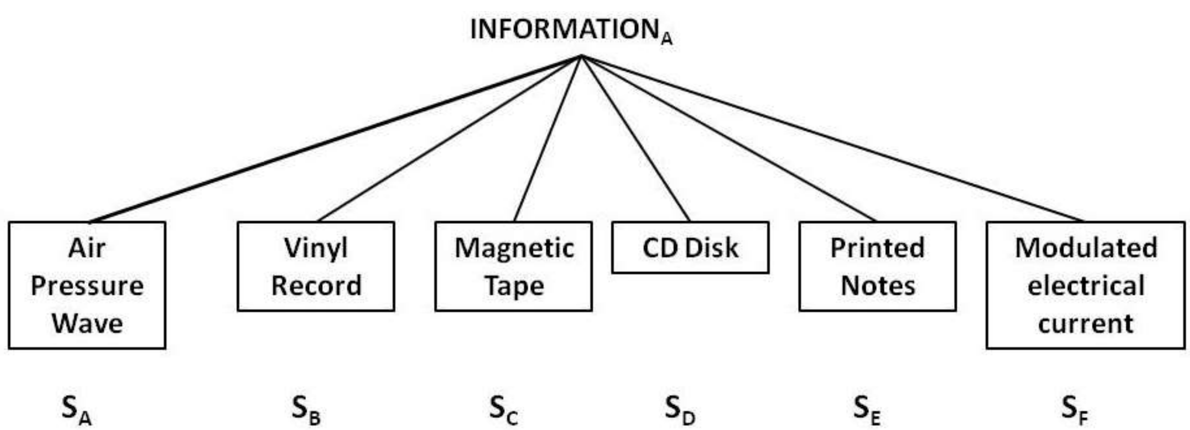

Figure 5. Perceived existence of epistemic information.

The correct explanation, we think, goes as follows: The various messages (S_A, S_B,…, S_Z) mean the same thing because we, as people, shape them in a certain way and interpret them in a way that is common to us. The music is in the ears of the listener, meaning that it is in the mind. There is no "abstract information "floating around in some extra-physical space that we tap into when needed. Indeed, it is possible that someone with a different mindset would interpret these physical structures entirely differently. This perspective is represented in Figure 6 below.

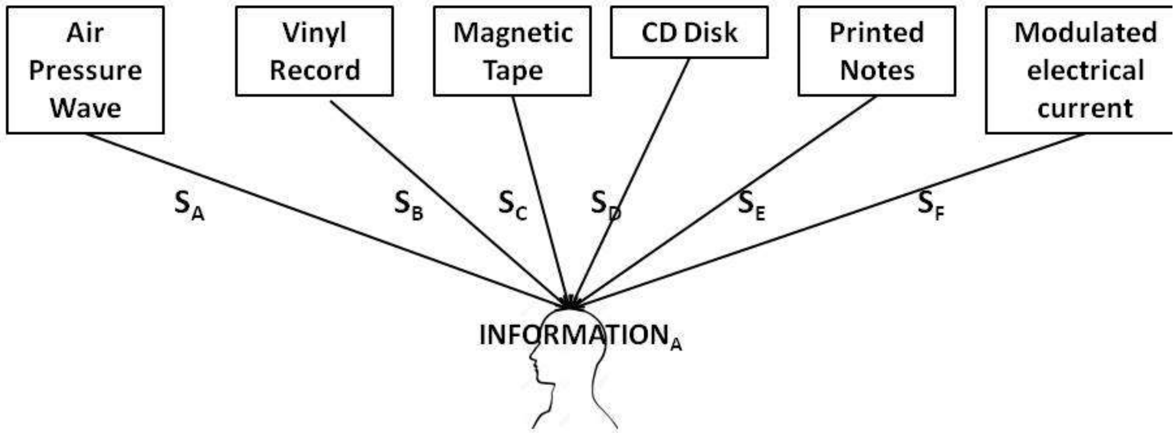

Figure 6. Perception of epistemic information as proposed in this study.

This figure illustrates what is actually happening with the piece of music. Everything is in the head (the mind) of the listener or composer. The music-carrying physical structures $S_A \neq \ldots \neq S_F$ are dissimilar, as are the different physical carriers. What makes them the same music is the interpretation of the agent, not some information$_A$ transcending the physical realm. An agent imposes a proper structure, encodes it, and decodes it through the appropriate physical process. The sequence of dots in a CD disk becomes music only after we learn how to encode and decode "music" in this physical media. The same applies for any other physical carrier of music. How the mind is actually achieving this we do not yet understand. We more or less know about neural perceptual processes, but we do not know how we perceive music.

The process of recovery of information$_E$ from different information$_O$ presented above is highly simplified. The relation between epistemic information and ontological information in different carriers is much more complex than it is suggested in Figure 6. If we assume, as in the example, that information$_E$ is a specific piece of music none of the ontological information in different carriers in principle encodes exactly the same information$_E$. Every change of carrier result in the changes in ontological information. The conversions of structures (i.e. ontological information) between physical carriers are not lossless. Thus, strictly speaking a specific piece of music recovered from S_A is not the same the piece of music recovered from S_B. They are only similar. It is a human mind that allows us to say that these different pieces of music are the same. Of course, only if a certain degree of similarity is preserved. The key in this process is a function of the mind that seeks commonalties and similarities in received stimuli. How this process is carried out exactly is for now only a guess[245].

245 This important remark was suggested by Prof. Paweł Polak.

We assume here that the mind is a non-reducible biological phenomenon, even if we cannot explain what precisely it is at our current level of knowledge. We obviously try to avoid Descartes' duality, and we do not need to postulate the existence of abstract information. This relieves the concrete-abstract dichotomy that was indicated by Davies. Of course, this argument can be applied only if the concept of the mind is posited as the *locus* of the epistemic information being created from different physical signals.[246]

While this explanation removes epistemic information from its "abstractness", it does not explain how epistemic information in our mind gets created and "transferred" into our artifacts. There is no natural law that directly shapes a car, a table, or a watch.[247] We must state that we simply do not know and that our theories of the mind do not provide conclusive explanation.[248] The only thing that we may assume is that the natural world, including the mind and its artifacts, is closed, and there is no "bifurcation" of nature as was implied by Descartes and denied by Whitehead (Whitehead 2015), as well as modern philosophers of science (under the various brands of naturalism)[249] who regard thoughts and the mind as being parts of this physical world, much like the other phenomena we experience and observe.

5.6 Ontological information and Popper's three worlds

One difficulty that arises in recognizing the existence of ontological information (i.e. information that is meaningless, objective, physical) is the deeply rooted notion that information is a human-centered concept akin to knowledge, meaning, and the mind in some form or mode[250], as we have said many times in this study.[251] Thus, the argument goes that if information is ontological information, then what is this epistemic information? We cannot reject the existence or reality (of sorts) of human knowledge in its various forms, such as history, culture, civilization, the arts, and so on—it would be like rejecting

[246] See, for example, *human behavior is determined by physical processes in the brain* (Shanahan 2015, p. 18). Similar views are widespread in the literature.

[247] I refer to the 747junkyard argument. The details may be found in ("Junkyard Argument"2019).

[248] Mercier and Sperber refer to information "about some state of affairs" (i.e. epistemic information), when this state of affairs produces a unique cognitive state in an organism (Mercier & Sperber 2017, p.339), falling short of denoting this "unique cognitive state" as a neurological state of the brain. The theories of the mind or of consciousness offer quite a rich field of studies with a variety of "products", thus offering a real intellectual feast but falling short of supplying the solution. The publications are too numerous to list them here.

[249] Some may think that the essence of naturalism is expressed in the phrase "*The Cosmos is all that is or ever was or ever will be*" (Sagan 2002). Yet, under close scrutiny, this phrase is too vague to mean anything specific. It is so unspecific that it lacks the intended gravitas. (e.g., Papineau 2020, Gillet & Loewer2001).

[250] This section was added after the suggestions from Prof. P. Polak.

[251] A similar idea about epistemic information and physical information was expressed by Landauer. He wrote that "*The quaint notion that information has an existence independent of its physical manifestation is still seriously advocated. This concept, very likely, has its roots in the fact that we were aware of mental information long before we realized that it, too, utilized real physical degrees of freedom. Our intuition has misled us in other ways*" (Landauer op. cit.). However, as we see in the next section, Landauer's claim that "information is physical" does not mean exactly the same thing as what the statement "ontological information is a physical phenomenon" denotes. See more on Landauer's principle (e.g., Landauer 1996, Bennett 2003, Moore 2012, Lutz 2012, Hong et al. 2016, Ladyman et al. 2001).

humanity itself—so it would seem we have to reject the concept of ontological information, because these two "informations" cannot co-exist. However, ontological information in no way contributes to this conclusion. We can validly assume that both kinds of information, epistemic and ontological, exist but in different ways. These two forms of existence for ontological information and knowledge or epistemic information will be valid as long as we clearly define their modes of existence.

Karl Popper proposed the idea of Three Worlds (Popper, 1978). Popper's three worlds postulate that there are three realms of existence.[252] The first world "*consists of physical bodies: of stones and of stars; of plants and of animals; but also of radiation, and of other forms of physical energy*" (Popper, op. cit., p. 3). The second world consists "*of our feelings of pain and of pleasure, of our thoughts, of our decisions, of our perceptions and our observations; in other words, the world of mental or psychological states or processes, or of subjective experiences*" (Popper, ibid.). Finally, the third world comprises "*the world of the products of the human mind, such as languages; tales and stories and religious myths; scientific conjectures or theories, and mathematical constructions; songs and symphonies; paintings and sculptures. But also airplanes and airports and other feats of engineering*" (Popper, ibid.) and "*the American Constitution; or Shakespeare's The Tempest; or his Hamlet; or Beethoven's, Fifth Symphony; or Newton's theory of gravitation*." More succinctly put, the third world consists "*of the world of the products of the human mind*" (Popper, ibid.).Such a distinction between physical things, the workings of the mind, and the products of the mind is not surprising. In fact, Aquinas and Aristotle did something similar in a different way. What is surprising is how Popper assigns the same ontological status, the same meaning of "to exist", to the objects of these three worlds. He calls this construct "three worlds realism" as opposed to monism or dualism (ibid., p. 151). Popper says that "*the objects of world 3 may be in a very clear sense not fictitious but quite real: they may be real in that they may have a causal effect upon us, upon our world 2 experiences, and further upon our world 1 brains, and thus upon material bodies*" (ibid., p.150). Furthermore, he says that "*world 3 objects are real; real in a sense very much like the sense in which the physicalist would call physical forces, and fields of forces, real, or really existing*" (ibid., p.152).

So, what is Popper saying here? To justify existence or co-existence with the same ontological status of the objects in his worlds, Popper redefines what it means to be real; he says "*what is real or what exists is whatever may, directly or indirectly, have a causal effect upon physical things*" (ibid., p.154). Consequently, the usual question of existence is morphed into a question about causality, although

[252] Popper posed his concept in the opposition to the monist view, where everything is physical, and the dualist view, where there is the mind and the physical world, and positioned his perspective as a pluralist view of the world.

without defining how this causality can be understood. Popper states, "*Thus we may replace our central problem of whether abstract world 3 objects, such as Newton's or Einstein's theories of gravitation, have a real existence, by the following problem: can scientific conjectures or theories exert, in a direct or indirect way, a causal effect upon the physical things of world 1? My reply to this question will be: yes, they can indeed*" (ibid., p.155). I think this claim would leave most people with more questions. For example, Newton's theory of gravitation (Popper's example of something in world three) is only an approximation, so how can such a theory have a causal effect "*upon the physical things of world 1*?" To put it another way, what changed in nature's state with the introduction of Newton's theory? There must have been a difference in reality when this theory emerged as a new causal factor in the cosmos? We may ask similar questions about the other objects of world three. To leave no doubts, Popper adds that *"scientific conjectures or theories can exert a causal or an instrumental effect upon physical things; far more so than, say, screwdrivers or scissors*." So what are the objects of world three? We learn from Popper that these are "*Thought contents ... conjecture, products of human language; and human languages, in their turn, are the most important and basic of world 3 objects*" (ibid., p.159).

Now, why are these thoughts not the content of the mind? Popper claims that thoughts are processes in the mind rather than the contents of the mind. Thus, it is not clear whether these processes have content. If they do not have content, then are these thought processes just empty? In other words, are they about nothing? Alternatively, if they have content, what is this content? Popper claims that the product of these processes is the objects of world three, but we do not know where this world three exists. We know from Popper that it does not exist in the mind, because thoughts are empty processes, so where is it? He does not unequivocally explain what counts as the end product for a thought. Is it a theory, a conjecture, a false theory or a correct theory, an airplane, the idea of a book, a book, a belief, or a wish? We may ask whether we could accept the model of the mind as the seat of fleeting thoughts devoid of content. It seems a bit like Humean's model of the mind.

Popper also introduces the concepts of subjective and objective knowledge (knowledge in a subjective and objective sense). He explains that "*Knowledge in the objective sense consists not of thought processes but of thought contents*" (ibid., p. 156). What this means is that objective knowledge is the content of world three, but what does "objective" mean for Popper. "Objective" for him means not independent of the observer, as it is usually understood when we talk about objective reality, but rather something that is common between observers. As we read further, however, because the world three objects depend on world two agents, this objective knowledge is agent-dependent. As Popper claims, "*[this objective knowledge] consists of the content of our linguistically formulated theories; of that content which can be,* *at least approximately, translated from one language into another. The objective thought content is that which remains invariant in a reasonably good translation*" (ibid., p. 156). Thus, objective knowledge in Popper's version of objectivity is not what is usually understood when this predicate is used in statements like "physical things exist objectively." This is in fact an epistemic claim, not an ontological one.

To make things clearer, Popper adds "*Nothing depends here on the use of the word 'real': my thesis is that our world 3 theories and our world 3 plans causally influence the physical objects of world 1; that they have a causal action upon world 1*" (ibid., p.164). This claim is hard to accept, though, because we are not sure at this point whether we are talking about a complete abstraction, reality, or some shadow land of half-reality. If we are in reality (we still talk of *physical objects*), what kind of reality is it if reality, as he says, does not count? In his closing remarks, Popper explains that "*This influence* [the causal effect of world 3 on world 1] *is to the best of my knowledge always indirect. World 3 theories and world 3 plans and programmes of action must always be grasped or understood by a mind before they lead to human actions, and to changes in our physical environment, such as the building of airports or of airplanes. It seems to me that the intervention of the mind, and thus of world 2, is indispensable, and that only the intervention of the mental world 2 allows world 3 objects to exert, indirectly, a causal influence upon the physical world 1. Thus in order that Special Relativity could have its influence upon the construction of the atom bomb, various physicists had to get interested in the theory, work out its consequences, and grasp these consequences. Human understanding, and thus the human mind, seems to be quite indispensable*" (ibid., p.164). It seems that our everyday reality does catch up with Popper eventually. Popper needs an actor in the physical world for his causality to manifest, even if he states that *"Nothing depends here on the use of the word 'real'.*" It seems that the terms "ontology", "real", "causality", and "existence" have been somewhat confused or assigned obtuse meanings in Popper's worlds, such that they are too obtuse to avoid critique.

So, what about epistemic and ontological information and Popperian real–unreal worlds? We cannot deny that the products of human thought exist, and we call them epistemic information. We also cannot deny that these products can be represented in physical things, which we call ontological information. We cannot deny that the world of concrete things exists, and this is where ontological information persists. We also have to agree that the world of human products needs an agent, because without an agent who "understands" the content of world three, there is no causal link between the worlds, and the objects of world three do not exist without such an agent, like a lost scripture, which without an agent to read it is just a series of meaningless symbols. However, granting the same status of existence to the objects of these three worlds[253] seems rather too logically cavalier to be acceptable. (Keep in mind what Popper said: "*world 3 objects are real; real in a sense very much like the sense in which the physicalist would call physical forces, and fields of forces, real, or really existing.*")[254]

Despite the obvious contradictions in Popper's claims there are researchers that implicitly or not, support his views of three words. (See e.g., Mingers and Standing (2018)). As we have indicated these claims hinge on rather loose interpretations of the terms 'objective' and 'to exist'.

As an example we may quote the entry on information from Audi's Dictionary of Philosophy (Audi 1999). In the first sentence it states that *information is an objective (mind-independent) entity*. However, the next sentence it says that *it (information) can be generated or carried by messages or other products of cognizers*. Clearly the cognizers are originators or creators or carriers of information, i.e. information for its existence depend on them so it is hardly objective. Few sentences below the author states *information would exist independently of its encoding or transmission*. These claims postulate some form of existence outside of the physical carrier however still dependent on the cognizer to recognize it (from sentences before). We see in this claim reflections of both von Weizsäcker and Popper's concepts of information; the first one was shown to be incoherent, the second one impossible.

5.7 Chapter summary

In this chapter, we looked at several consequences of accepting the concept of ontological information. We observed that having a concept of information based on semantics, or epistemic information, leaves out information defined as an element of nature. However, many studies (i.e. those quoted in this work) indicate that information in nature is a concept with a solid scientific basis. Thus, epistemic information fails to account for the significant aspect of reality and the related concept of information. We also observed that a precise demarcation between epistemic and ontological information is based on how we define cognitive functions, meanings, and a cognitive agent. With these definitions in a state of flux, the precise boundary between epistemic and ontological information may be hard to establish. We also

[253] Why do we have to give the same ontological status to worlds one, two and three? The worlds should have the same ontological status to interact, otherwise we again have a dualism problem, but this time with three rather than two worlds. As Popper says, world three depends on world two to impact world one. If world two had a different ontological status than the other two worlds, the objects of world three connecting with the objects of world one would have to pass through a kind of ontological no-man's land in world two. Maybe this is not a problem for Popper!

[254] Popper's three worlds view is not acceptable "as is." It is a useful conceptual tool for talking about different modes in which information can be perceived but Popper's ontological claims (i.e. claims about existence) regarding the end product of thoughts are highly criticized (e.g., Carr 1977, Gilroy 1985, Albinus 2013).

observed how epistemic information may be conceptualized as being partially derived from, and thus dependent on, ontological information.

In the following section, we discussed quantified models of information. We pointed out that while these models offer significant operational benefits, they do not explain the nature of information, a point which is frequently missed by researchers.

The next section discusses the concept of data, which is usually positioned as something primary to epistemic information. We pointed out that in reality, data are already epistemic information or interpreted ontological information. The division into data and information has been done for operational reasons rather than any inherent differences between these two concepts.

We then moved on to discuss infons, which have been used in some studies as an ontological basis for information. We showed how the concept of the infon is poorly defined without an ontological, metaphysical, or scientific basis. Thus, once more, the infon is an operational concept that plays a role in standing in for something unknown, but it cannot be regarded as something ontologically fundamental.

The next section discussed the abstract–concrete dichotomy of information. We pointed out how this dichotomy stems from the misuse of the verb "exist" and the lack of the concept of ontological information. Once we recognize that we have two types of information, one abstract and one concrete, and when we recognize their dependence, we see how these two concepts denote different modes of existence: one in space–time for concrete information and one outside space–time for abstract information. We believe that the conflict is resolved with this perspective.

In the last section, we discussed Popper's three worlds. This discussion is somewhat in response to the critique that in this study, we deny the existence of the whole realm of human culture and thought, which we do not do at all. Indeed, we cannot deny that the products of human thought exist, and we collectively call them epistemic information. We also do not deny that these products can be represented or embedded in physical things, and we call this ontological information. We certainly cannot deny that the world of concrete things exists, and this is where ontological information persists. However, we also have to agree that the world of human products needs an agent, because without an agent who "understands" the content of world three, there is no causal link between world three and the concrete world of embedded ideas. Even we, as humans, are defined by our ideas, and we need to recognize the fragility of our world. The objects of the Popperian world three do not exist without a knowing agent. For example, in the case of a lost scripture, it is just a series of meaningless symbols without an agent to read it. Indeed, the fate of lost civilizations testifies to the fragility of our humanity.

6 Summary, Final Comments, and Conclusions

6.1 What is this work about?

This study has investigated the properties that can be attributed to the concept of ontological information. Ontological information is a physical phenomenon, and it does not have any inherent meaning or value . In other words, it is information that is meaningless and epistemically neutral, and its existence and properties are not dependent on any communication process or part thereof. Instead, it is perceived through the structure, organization, or form of natural and artificial (artifacts) objects.

This study has six chapters. The first chapter supplied the necessary contextual background for the study, defined its objectives, and provided the justification for the endeavor. The second chapter, meanwhile, searched for the properties of ontological information by reviewing brief claims about concepts bearing the characteristics of ontological information, as put forward in the works of Edmund Kowalczyk (1970), Keith Devlin (1991), John Polkinghorne (2000), Charles Seife (2006), Frank Wilczek (2015), Sean Carroll (2016), Carlo Rovelli (2016), John Barrow (2017), Paul Davies (2019), and Richard Sole and Santiago Elena (2019). Most of this research had been published in the first two decades of the 21st century, so it is as current as could reasonably be expected. In Chapter Three, we reviewed the more detailed studies of information that were carried out by Carl von Weizsäcker (1970), Krzysztof Turek (1978), Stefan Mynarski (1981), Michał Heller (1987, 2014), John Collier (1989), Tom Stonier (1990), Jacek Jadacki and Anna Brożek (2005), Gordana Dodig Crnkovic (2012), Thomas Nagel (2012), and Cesary Hidalgo (2015). These studies provide a vast range of perspectives on the idea of information, with the authors coming from diverse fields like computer science, philosophy, physics, biology, and cosmology. Despite this, they all see information as something of nature and in nature with the properties that we would attribute to ontological information. Each author's work is presented through direct quotations that are then thoroughly analyzed. Chapter Four then sought to formulate a minimalist list of properties that could be attributed to ontological information. We therefore collected the main observations about information from Chapters Two and Three in an effort to reduce the number of properties of ontological information to just the most essential subset. Next, Chapter Five discussed how ontological information may change our perception of several concepts related to information. These included, among other discussed issues, the concept of information itself, the concept of epistemic information, the relation between ontological information and data, the problem of the existence of information, the role of the quantified models of information, and the relevance of Popper's three worlds.

6.2 What was this study able to establish?

The concepts of information emerging from the works of Kowalczyk, Devlin, Wilczek, Barrow, Carroll, Sole and Elena, Rovelli, Seife, Polkinghore, and Davies can be summarized through eight observations: (1) Information is a natural phenomenon, without meaning and related more to the properties of the universe (i.e. nature) than knowledge. (2) In several studies, we see a tension between the abstract (mental) concept of information and information as a concrete, physical thing. (3) In any discussion about information as a natural phenomenon, entropy (thermodynamics) plays a prominent role. (4) The term "information" is usually not clearly defined but rather described through its properties. (5) Despite diverse views, there are several commonalities among the descriptions of information in nature. (6) Information is closely related to the organization of nature or its structure. (7) Information in nature can be quantified. (8) Information in nature is often conceptualized within a complex of matter, energy, and information.

The concept of information that emerges from the writings of Heller, von Weizsäcker, Turek, Stonier, Collier, Nagel, Mynarski, Jadacki and Brożek, Dodig Crnkovic, and Cesary Hidalgo can be summarized as eleven conjectures: (1) The notion of information associated with knowledge does not exhaust the concept of information. (2) Information is a physical/natural phenomenon. (3) Information as a physical/natural phenomenon has no meaning. (4) The meaning of information is derived by the mind of a cognitive agent, and meaning is not intrinsic to information as a physical/natural phenomenon. (5) The role of information in nature may be conceptualized within the matter–energy–information complex. (6) Information as a physical/natural phenomenon is fundamental to nature, so whatever exists physically contains information. (7) Information as a physical/natural phenomenon is expressed through the structure/form and organization of things. (8) Information as a physical/natural phenomenon cannot be reduced to what we conceptualize as structures. (9) Information as a physical/natural phenomenon is responsible for the internal organization of nature's objects and artifacts. (10) Natural processes are information processes that we may denote as computing. (11) Quantifications of information provide measures of sensible structures that reflect the presence of information, but these quantifications are not information itself.

We therefore concluded the following: ontological information has no meaning, with this being defined as representing some value for a cognitive agent. In other words, an agent obtains from ontological information something that has some significance for its existence, so this creates or derives meaning.

The same ontological information may have a different meaning for a different agent, though, or it may have no meaning at all. Ontological information is not abstract in the way that mathematical objects or thoughts and feelings are abstract. Ontological information exists like other physical phenomena, so it is real, observable, and measurable. Whatever exists contains information, and there are no physical phenomena without information in the same way that there are no physical phenomena without energy. Ontological Information is an essential constituent of nature, because it is a factor responsible for the organization of the physical world. Organization is a fairly broad concept, but in this study it is interpreted as the structure, order, form, shape, or (in some sense) rationality when perceived by a cognitive entity.

Finally, we attributed three properties and two corollaries to ontological information, namely:

- (EN) Information has no meaning; meaning is derived from information by a cognitive agent.
- (PE) Information is a physical phenomenon.
- (FN) Information is responsible for the organization of the physical world.

And the two corollaries:

- (C1) Information is quantifiable.
- (C2) Changes in the organization of physical objects can be denoted as computation or information processing.

We also concluded that these three properties and two corollaries represent the most minimalistic description for the properties of ontological information, at least in terms of what we were able to identify across the studies works. We are aware, however, that future research may change how we see and conceptualize ontological information.

We also looked at some of the consequences of recognizing the existence of ontological information. We observed that holding onto a semantics-based concept of information—or as we call it, epistemic information—would ignore information conceived as an element of nature. In other words, this epistemic information would fail to account for a significant aspect of reality, one that is essential to our concept of information. We also observed that the border between epistemic and ontological information is based on whatever definitions are used for cognitive function, meaning, and cognitive agents. With these definitions in flux, a precise boundary between epistemic and ontological information may be hard to establish. We also posited that epistemic information may be conceptualized as being partially derived from, and therefore dependent on, ontological information. We also discussed quantified models of information, pointing out that while these models offer significant operational gains, they do not explain the nature of information. This point is frequently missed by scholars. We also discussed the concept of data, which is usually positioned as some precursor to epistemic information. We pointed out that in reality, a collection of data is already epistemic information or interpreted ontological information, with the division into data and information generally being done for operational reasons rather than any inherent difference between data and epistemic information. We also discussed infons, which have been used in some studies as the ontological basis of information or a primary unit of information. We demonstrate that the concept of the infon is poorly defined and lacks any ontological, metaphysical, or scientific basis. The infon acts as an operational concept standing in for something unknown, and it may play a role in pointing out our ignorance, but it cannot be taken as representing something ontologically fundamental. Next, we discussed the abstract–concrete dichotomy of information. We pointed out how the problem with this apparent dichotomy stems from the misuse of the verb "to exist" and the lack of a sound concept for ontological information. Once we accept that we have two types of information, one abstract and one concrete, and recognize their dependence, we see that these two concepts do not refer to the same idea but rather two complementary ones. Indeed, these concepts refer to how different modes of information can be conceptualized: one that is concrete in space–time and one that is abstract outside space–time. When viewing it from this perspective, we think the conflict resolves itself.

In the final section of Chapter Five, we discussed Popper's three worlds. This was pursued somewhat in response to them is taken critique that in this study, we deny the existence of the whole realm of culture and human thought. However, we cannot deny that the products of human thought exist, and we call them epistemic information, while for Popper, they comprise his world three. We also do not deny that the products of human thought can be represented or embedded in physical things. Likewise, we cannot deny that the world of concrete things exists, and this is where ontological information persists. We also have to agree that the world of human products needs an agent, because without an agent who "understands" the content of world three, it would be meaningless. Indeed, we humans are defined by our ideas, so we need to recognize the fragility of our world. The objects of the Popperian world three do not exist without a knowledgeable agent, just like a lost scripture is merely a series of meaningless symbols without an agent who knows how to read it. Indeed, the fate of lost civilizations and their cultural heritage sadly confirms the fragility of our world three.

6.3 Selected criticisms of ontological information

Thus far, we have presented research that recognizes the existence of physical or ontological information (some denote also as concrete information or information$_C$), but some authors deny that such information exists. We look at some of these studies and weigh their arguments.[255]

Dinneen and Brauner (2018) talk about "information-as-a-thing", which for them is information as a physical phenomenon, as being unable to account for the "typical views of information." These problems are avoided, they say, if information is seen as an abstract entity. The only example of "information-as-a-thing" (i.e. physical information) they provide in their 2018 study is a book, which is a physical object. We could delve deeper into Dinneen and Brauner's argument, but this is not necessary, because it seems that they set up their definition of physical information to fail. Indeed, according to their own definition, the book cannot be information because anything physical cannot have meaning, so information is not physical. This is rather obvious, though. This book (a physical object) in their example is meaningless by definition. Dinneen and Brauner's claim is somewhat justified, however, because the book is meaningless in itself, just like all physical objects are. However, their argument against the existence of information as a physical phenomenon, based on the example of the book, is incorrect because they are looking for meaning where there is none to be found. Dinneen and Brauner's attempt was therefore destined to fail because they looked for meaningful physical information rather than just physical information. For Dinneen and Brauner, the "typical views of information" reflect what we refer to in this study as information$_A$, but there is nothing typical about it, even though it may be the most prevalent view of information. In science, though, the truth of a proposition is not determined according to a majority vote, and the minority opinion often turns out to be the correct one. Dinneen and Brauner, it seems, missed the nature of information$_C$, namely that it is not the physical object itself but rather its organization, at least in the sense discussed in this study.

In their earlier paper, Dinneen and Brauner (2015) formulate three arguments for why a physical thing cannot be information or, more precisely, why what they call "information-as-a-thing" cannot exist. First, "the value of the physical representation is first and foremost its content, and not the physical embodiment of it." Thus, putting forward information-as-a-thing as information clearly ignores the content of a physical thing, but we are concerned with this content. Second, talking about physical objects as information is not accurate, because when talking about physical information, we are less interested in the physical objects (e.g., DVDs, CDs, USB sticks) themselves, and more interested in what they contain. Thus, their definition of information as a physical object is misleading, as is their conclusion for the first argument. Third, the same physical object may contain different information depending on the time and

[255] This section was published in 2020 in a paper by Krzanowski (2020).

place: For example, a book's content may be interpreted differently. This creates, according to Dinneen and Brauner, a metaphysical problem of identity. If information is a physical thing, it must be the same in all circumstances; otherwise we would have two or more things being the same physical object. We partially addressed these three arguments in Chapter Five. In the above discussion, Dinneen and Brauner do not distinguish between physical or ontological information (information$_C$) and epistemic information (information$_A$), so when they talk about information, they are actually talking about information$_A$. In a way, they are trying to attribute information$_A$ to a physical presence, but as we have pointed out many times in this study, information$_A$ is not physical, and a physical object is not information$_A$. It may "contain" information$_A$ for one or more agents, at least in the sense of the word "contain' as explained above, but a physical object is never information$_A$. In a rather stretched analogy, we could say that energy is not work, nor does it contain work, but it is certainly related to work. The analogy stops here, however. By defining information (information$_A$) as a physical object or information-as-a-thing, we would be obviously making a misstep by conflating the abstract with the concrete, which will clearly never work. As we said before, physical information is not a physical object in the sense of a specific object—such as a book, a DVD, and so on—but rather the organization of these objects, as explained in the previous sections. What Dinneen and Brauner faced is the concrete–abstract dichotomy indicated by Davies (2019) and Rovelli (2016),[256] but while Rovelli and Davies managed to comprehend and overcome it, Dinneen and Brauner did not.

Bates (2015) following Edwin Parker (quoted by Bates), identifies information in nature as a pattern of, or within, physical things. However, Bates' information is not physical, because this pattern is an abstract concept realized through a physical medium and recognized by a cognitive agent. This interpretation is seen in Bates' claim that while information as a pattern is everywhere in the universe, total entropy is pattern-free,[257] so it has no information. Therefore, according to Bates, total entropy cannot be interpreted as a pattern, so Bates' notion of "information as a pattern of physical things" is added to some physical phenomena but not to others.[258] In short, we may say that in Bates' view, information is not a physical entity, even when it is associated with physical objects. Instead, it is a perceived pattern of physical objects. In her own example, some physical phenomena are information-free, so it therefore seems that Bates' information has nothing to do with information$_C$, and it is more akin to the concept of natural

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[256] The problem is stated as follows: "How can information be physical and abstract at the same time?"

[257] We do not go into details about what "total entropy" is or whether information as a pattern would appear if entropy was less than total (whatever that means for Bates) (i.e. would information as a pattern disappear at one point, or would it appear or disappear gradually?).

[258] The claim that "total entropy is pattern-free" is incorrect, because every physical phenomenon has some organization or pattern, although it may be beyond our understanding in some cases. Bates repeats the common misconception of equating entropy (assumedly thermodynamic entropy) with the popular notion of chaos (of sorts).

information in Millikan's work (2017), which is also not information$_C$. To recall the discussion from Chapter Five, by Millikan's very definition, natural information comprises infosigns carried by natural phenomena that "initiate perception" (ibid., 2017). In this definition, natural information appears to be simply information$_C$ plus some meaning or interpretation for a physical carrier. Recall that information$_C$ does not need to initiate perception to exist. A similar definition for natural information is given by Piccinini and Scarantino (2011).

The conviction that information must have meaning has prevented many researchers from recognizing the existence of physical information. This "epistemic turn"[259] is characteristic of modern philosophy, and it began with Descartes. For example, von Weizsäcker and others later on claimed that information must be also physical in some way, yet he could not recognize information without meaning.

Some of the arguments against the concept of information$_C$ have been generated by identifying information$_C$ with Plato's Forms. One such argument, namely a modified (for our context) version of the Third Man argument, asks: "If information$_C$ is in every physical object, is information$_C$ in information$_C$?" Another argument questions how the same information$_C$ may exist in different physical objects at the same time (i.e. how can one physical thing [information$_C$] exist in many different places at the same time?). These problems apply to Plato's Forms in his metaphysical view, but as we said from the start, information$_C$ is not one of Plato's Forms, because such objects exist outside space and time and would, in this sense, be abstract objects. While Plato's Forms are in some way physical (in Plato's view), the nature of their existence outside space and time and their relation to reality is exactly what makes them controversial. Information$_C$ as a physical phenomenon does not suffer from these shortcomings, just as physical objects do not suffer from them. For example, we do not question whether energy is within energy or whether matter is within matter, even though these phenomena are everywhere. Information$_C$ is more akin to the Aristotelian concept of *eidos*, but as we pointed out earlier, such analogies with the ancient ideas are very precarious and should be drawn with great restraint. This is why we do not discuss them further in this study, nor do we propose them as renditions of information$_C$.

Looking at the bigger picture, any researcher who claims that the concept of information is inherently and exclusively associated with meaning and knowledge is implicitly denying the existence of information as a physical phenomenon for the obvious reason that information cannot be both abstract and concrete in the same way and at the same time. Surprisingly, such claims are made with full knowledge that human agents are physical information-processing systems(e.g., Maturana 2011, Maturana & Valera 1980,

[259] The "epistemic turn" denotes the reorientation of modern philosophy from ontology to epistemology as the main philosophical perspective on nature.

Hintikka 2007, Kaplan 1989, Bajic 2005), and as computers, our main data-processing component is a purely physical, mindless, and meaningless device. We need to take us (or the mind) out of this picture in a kind of Copernican move to see information$_O$.[260]

As a reminder, the existence of information as a physical entity is supported by the studies in which information (the concept of information) has been found to have properties that are attributable to physical objects, the studies that have found information useful for explaining certain physical processes, and the studies that have found information as a unifying factor in explaining a range of natural phenomena. (See the authors quoted in the earlier sections of this study.)

6.4 Work to be done and future research

The study leaves several questions open about the nature of ontological information. Some of them are listed below. These questions are speculative, but they appear in the research on information$_O$, so they are related to this work. Of course, the true list of unresolved questions about the nature of physical information is likely to be much longer than the one presented below. In the questions below, the term "information" refers to information$_O$.

Question 1: Do laws for the conservation of information exist, and if they do, what do they claim? Is the total amount of information in the universe therefore constant? This question probes the problem of "the conservation of information." If information is fundamental to whatever exists in the physical world, does it follow laws for its preservation, much like energy? (Suggested by the writings of Carroll, for example.)

Question 2: Can we claim that whatever exists must contain information$_C$? Can we defend the paninformatism claim that information is everything that exists? What is more, is paninformatism related to panpsychism? This question probes the claim that information is in everything that exists. Can such a claim be justified? And does such a claim amount to some kind of paninformatism or panpsychism? If so, what precisely would this entail? Would such a claim trivialize the concept of information? (Suggested by the writings of Stonier, Turek, and Carroll, for example.)

Question 3: Can we interpret information$_C$ as a causal factor, and how could such a claim be verified? This question probes the alleged causal role of information in the physical world. It amounts to the question of whether information is a passive or active element in nature and what the nature of this activity would be. (Suggested by the writings of Carroll and von Weizsäcker, for example.)

[260] By "a Copernican move", we refer to taking a position where humanity is no longer the vantage point for looking at nature.

Question 4: Information$_C$ is foundational to the physical universe, but in what sense can this statement be made? This question probes the claim that information is fundamental to nature, but what exactly would this mean? Should such a claim be interpreted along the lines of the proposed information–matter–energy complex? Or should it be interpreted more metaphysically like the Logos of The Bible or the Tao of Tao-Te-Ching as an all-pervading and primordial element of existence? (Suggested by the writings of Heller, Dodig Crnkovic, and Stonier, for example.)

Question 5: Can we say that highly complex and chaotic (i.e. non-linear, dynamic) systems have no information$_C$? This concerns the problems of chaos and non-linear, dynamic systems. Does information play a role in such systems? Quite often, chaos is associated with a lack of information, which seems to be a questionable interpretation of a physical phenomenon. (This issue was indicated by Bates)

Question 6: Does information$_C$ imply some form of modern hylemorphism? This question seeks to identify the similarities between information and hylemorphism in its modern interpretations. The problem of the nature of information and matter and energy has resurfaced in the works of many authors (see the references in this paper), and they all seem to echo Aristotelian metaphysics (Suggested by the writings of Polkinghorne, Turek, Krzanowski, and Carroll, for example.)

Question 7: Does the fact that information is physical change the meaning of computation from one of symbolic processing to processing physical information? We associate computation with symbolic processing, but computation in computers is, in fact, a highly structured, pure physical process (e.g., as Searle said, “computation is in the eye of the beholder”). Could we extend the concept of computation to any physical process involving changes in physical organization without trivializing the concept of computing? Do we even care? (Suggested by the writings of Seife, Dodig Crnkovic, and Dodig Crnkovic and Mueller, for example.)

Question 8: Can information be equated to some kind of structure, and what would this mean for the concept of structure? This question proposes explaining the concept of information$_C$ through the concepts of structure and structural realism. (Suggested by the writings of Heller and Schroeder, for example).

Question 9: Can we propose some kind of definition for ontological information? The truth is that some physical phenomena avoid clear definitions and are characterized by their properties. Energy is one example of this. Energy has many definitions, and some are clearly too simplistic, while some are too narrow. For example, see the works of Richard Feynman (1963, p.4-2), Mario Iona (1973), Robert Lehrman (1973), Nancy Hicks (1983), Art Hobson (2004), Ricardo Coelho (2009), and Eugene Hecht (2007). One possible definition of energy states that it is a conserved scalar measure of the ability of a system to produce change (Hecht 2007), or in a more watered down version, energy is the ability to produce change. We have different measures for different forms of energy depending on the phenomenon we observe. Information, specifically understood as information$_O$, is related to the organization of a system. Depending on the system and the level of organization, we may therefore have different measures of information$_O$. The fact that information is a scalar measure just means that information$_O$ may be quantified, but it does not determine a unique quantification. Can such conjuncture be justified?

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Oświadczenie

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Kraków, dnia ………………..

……………………………..

czytelny podpis autora

Oświadczenie kierującego pracą

Niniejsza praca została przygotowana pod moim kierunkiem i może być podstawą postępowania o nadanie jej autorowi (autorce) tytułu zawodowego.

Data Podpis kierującego pracą

Oświadczenie autora pracy

Świadom odpowiedzialności prawnej oświadczam, że niniejsza praca dyplomowa została napisana przeze mnie samodzielnie i nie zawiera treści uzyskanych w sposób niezgodny z obowiązującymi przepisami.

Oświadczam również, że przedstawiona praca nie była wcześniej przedmiotem procedur związanych z uzyskaniem tytułu zawodowego w wyższej uczelni.

Oświadczam ponadto, że niniejsza wersja pracy (przedstawiona do obrony) jest identyczna z załączoną wersją elektroniczną

Data Własnoręczny podpis autora pracy