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An Inquiry Concerning the Persistence of Physical Information

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Abstract: Physical information is a property of nature. How does physical information persist over time? Does it do so as an object, process, or event, which are things considered in the current persistence theories? Physical information is none of these, however, this implies that persistence theories cannot explain the persistence of information. We therefore study the persistence of snowflakes, ephemeral natural structures, to better understand the persistence of natural things, such as physical information. The transitory nature of snowflakes suggests that physical information persists as nature's latent order, therefore, it is associated with natural structures, but it is not identical to them. This interpretation preserves the properties attributed to physical information, particularly its foundational character. The concept of physical information as latent order accords with Burgin's General Theory of Information (GTI), which is currently the most comprehensive conceptualization of information that has been proposed.

Keywords: information; physical information; persistence; snowflakes; latent order in nature; General Theory of Information

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1. Introduction

Information is a physical phenomenon that is perceived as a form or organization of nature. (For the different explanations of this concept, see the works of physicists and philosophers like Turek [1], Collier [2], Wilczek [3], Carroll [4], and Rovelli [5]; cosmologists such as Reeves [6], Stonier [7], or Heller [8,9]; and philosophers such as von Baeyer [10], Seife [11], Burgin [12], and Krzanowski [13].) As every physical[1] phenomenon exists in time and space, at least for a certain time, so does physical information. All physical things (including the Universe itself)[2] persist in that they come into existence, exist for a certain time (maybe in changing forms), and disappear (as with Heraclitian flux)[3], but what happens to information?

We will define the concept of persistence more rigorously later, but for now, persistence should be interpreted as the property of something to exist through time simpliciter (after Lewis [22], p. 202)[4]. Persistence theories, as well as common sense, tell us that there are different modes of persistence, so different things will persist differently. Here, we ask the following question: How does physical information persist? Does it persist as a physical object, or perhaps as a process, event, or something else? What, if anything, does its persistence tell us about its nature?

Thus, we begin our inquiry by reviewing how physical information has been conceptualized and which properties have been attributed to it. We then review the main theories of persistence. On concluding that the current theories of persistence cannot account for the persistence of information, we proceed to examine the persistence properties of snowflakes, assuming that this will help us learn about the persistence of physical information. We ultimately conclude that physical information persists as a latent order, or natural potential, to form low-entropy complexes that can be perceived as complex structures (with complex morphologies) in nature, much like snowflakes are. Furthermore, the concept of physical information as the latent order of nature to form structured complexes aligns with the claims about information within the General Theory of Information (GTI) put forward by Burgin [12,26,27], which is the most fundamental and universal conceptualization of information proposed thus far.

2. Information: Physical and Epistemic

Information is a polysemantic concept with many, often contradictory, definitions, and this view is reflected in most studies[5]. Nevertheless, information can be viewed, not reductively[6], from two perspectives, namely epistemic and physical (or ontological in the sense explained by John Searle)[7].

The prevailing view is that information is epistemic, so it is centered on humans or other conscious agents. The concept of epistemic information has seen many incarnations, so no single definition will be acceptable to everyone or even some nebulous majority. Take for example, Bar-Hiller and Carnap [36], Brooks [37], Rucker [38], Buckland [39], Devlin [40], Loose [41], Sveiby [42], Dretske [43], Casagrande [44], Floridi [30,45], Burgin [26], Lenski [46], Vernon [47], and Dasgupta [48], among others. Each of these authors created a somewhat different version of epistemic information, yet they all share several key similarities. For example, they all associate information with meaning, value, knowledge, or semantics, with a common thread enabling them to be collected under one heading. Epistemic information is associated with knowledge, a belief, or a communication process in its more generally and broadly understood meaning. However, epistemic information can only exist if someone, or something, recognizes something as information, usually in a communication process (e.g., Shannon [49], Cherry [50], Casti [51], Smith [52], Vernon [47]). For an in-depth discussion of epistemic information, see the work of Krzanowski [13], for example.

Information has also been conceptualized as physical information (also referred to as ontological information (Burgin and Krzanowski [34]). Physical information is an objective, mind-independent phenomenon, as physical phenomena generally are. We perceive it as a part of the real world, and no person or other cognitive agents, whether artificial or natural, is a reference point for it. Original studies that conceptualize information as a physical phenomenon have been published by von Weizsäcker [53], Turek [1], Heller [8,9], Collier [2], Stonier [7], Reeves [6], De Mull [54], Polkinghorne [55], von Baeyer [10], Seife [11], Dodig-Crnkovic [56], Hidalgo [57], Wilczek [3], Carrol [4], Rovelli [5], Davies [58], Sole and Elena [59], and Krzanowski and Polak [60] although this list is of course not exhaustive.

The properties attributed by these studies to physical information reflect its physical nature, such that physical information is characterized by epistemic neutrality (EN), physical embodiment (PE), and formative nature (FN) [13]. We formalize this in Definition 1:

Definition 1. *Physical information is characterized by epistemic neutrality (EN), physical embodiment (PE), and formative nature (FN)* [13].

Epistemic neutrality (EN) refers to how the phenomenon of physical information exists independently of any observer or other cognitive system, whether biological or artificial. Thus, physical information exists independently of any mind[8] (natural or otherwise), any system or process, or any cognitive state. Physical information is therefore objective, a natural phenomenon with no inherent meaning, and an element of nature itself. Physical embodiment (PE), meanwhile, positions information as a physical phenomenon that is subject to physical laws[9]. Furthermore, information exists much like other physical phenomena exist, because it exhibits the same class of properties (quantifiability and operational properties) as other physical phenomena. Furthermore, it seems that any matter that exists in a physical sense contains information. Finally, formative nature (FN) implies that information is responsible for the organization of the physical world, such that information is expressed through structures/forms and the organization of things, but it is not the structure itself (see e.g., [60]).

Physical information appears to be more fundamental to the concept of information than epistemic one for at least two reasons. (1) Epistemic information requires a physical medium for existence; thus, it needs a presence of physical information. (2) If information is perceived as foundational in the universe it must be independent of any cognitive agent[10], which physical information, by definition, is.

In the remainder of this paper, any references to information refer to physical information, so when we discuss the persistence of information, we mean the persistence of physical information and not anything else[11]. In the literature physical information in the sense used here is also referred to as ontological information [13,34]. In the following section, we inquire as to whether persistence theories, as they stand today, can account for the persistence of information.

3. Persistence in Philosophy

Persistence is the propensity of an object to exist through time. It was originally formulated by Lewis through the following statement: "something persists iff, somehow or other, it exists at various times; this is the neutral word" [22]. More specifically, persistence theories are concerned with the identity and constitution of things over time, whatever they may be. Lewis's definition—with its use of vague terms like something, somehow, and various times—is quite generic and denotes nothing specific[12]. Feeding on this ambiguity, numerous theories of persistence and multiple variants have been proposed, with them often contradicting each other.

Two leading proposals are the theories of endurance and perdurance [21,22,67–77].

When something endures, it exists in time as a whole with no missing parts and no temporal parts ("something endures iff it persists by being wholly present at more than one time" [Lewis [22], p. 202). Endurantism is denoted as a three-dimensionalism because enduring objects persist wholly in three dimensions over time and at every point in time. Endurantism is how we commonly perceive physical objects (e.g., [21,38,71]. For example, a glass bottle endures this way, such that a bottle discarded in the forest occupies a specific place as a whole. Moreover, it will occupy that specific place in time for as long as it exists as a whole, regardless of whether it exists for minutes, hours, days, years, and so on. An enduring object as a whole can occupy different places in space, or more specifically, a space is occupied by the object filling that space. Though, as a whole it also occupies different time intervals (i.e., places in time) at different times, but it is "wholly present" in those places it occupies in time. In this way, enduring objects persist over time.

When things perdure, they do so in temporal parts by retaining their identity over time, or in the words of Lewis [22] "something perdures iff it persists by having different temporal parts, or stages, at different times, though no one part of it is wholly present at more than one time." Thus, these parts exist at different times, so only a part of that thing exists at any present moment. For example, travel perdures, with us being at the start of a journey at time t_1 or at the end at another time t_n. Likewise, the rain perdures, and processes (a paradigmatic case of perdurance) perdure (e.g., [68,74–78]). Perdurantism is denoted as a four-dimensionalism, because perduring objects extend over four dimensions. Perduring objects persist in time because different parts (i.e., proper parts)[13] of them exist at different time intervals. In other words, a perduing object is partially present at any specific time interval. This contrasts with the "wholly present" nature of enduring objects because perduring objects persist in time as different parts (e.g., [68,71,77]).

The theory of perdurance may see objects as time worms (worm theories) or object-worms extending through time, or it may see objects through a stage-based view (exdurantism). From this perspective, things perdure in a series of instantaneous stages with different indexes to each stage, such that objects exist like time-lapse photos (e.g., [68,80]). Nevertheless, the stage-based view seems to run roughshod over physics and common sense. (See Costa's list of arguments [77].) Of course, one may argue that all endurance theories run into similar problems at one point or another, which leads us to the next paragraph.

Now, which theory of persistence is closer to reality (and common-sense) is a matter of semantics, personal beliefs [68], and the definitions of identity, parts, time (continuous vs. discrete), space, and spacetime, as well as our interpretation of reality, because these theories are, after all, about what reality is. Thus, there are good arguments for and against each of these theories (e.g., [69,73–75,77,81–84]). The differences in these theories are especially evident when addressing so-called puzzle cases, such as the cases of David and the Lump, Lump and Goliath, and the Ship of Theseus (e.g., [73,85]). We will not pass judgement on the veracity or vacuity of these theories because our question is more about which of the current persistence theories, if any, apply to information.

4. The Persistence of Information

Theories of persistence apply to objects with proper parts (i.e., things, hunks of matter), persons (e.g., [74]), events, and processes (e.g., [70,73,86]). However, physical information is not any of these, so the current theories of persistence do not seem to apply[14]. Furthermore, as all the current persistence theories have been criticized, selecting one or another to account for the persistence of information would not resolve the problem but rather initiate a debate because each option would be contested.

What we can say, however, is because Lewis's original theory of persistence (something endures iff it persists by being wholly present at more than one time) states the general concept of persistence. In addition, because of its neutrality, Lewis's theory of persistence (in its general formulation) is in principle applicable to the persistence of information as well, as it applies to anything (the "something" of Lewis) that exists in time, much like how Heraclitian flux applies to more than rivers! The same cannot be said of the more-specific theories of persistence. Let us formalize this observation as Argument (1).

(P1) Theories of persistence are about objects, events, and processes.
(P2) Theories of persistence treat persisting entities as wholes or a composition of (proper) parts.
(P3) Information is defined by three features: EN, PE, and FN.
(P4) Information is not an object, event, or process.
(P5) Information cannot be seen as being whole or having parts (proper).
Thus,
(C0) Theories of persistence cannot account for the persistence of information.

Now, (C0) indicates that the persistence of information is not resolved by the current persistence theories, but it does not disappear as a problem[15]. Indeed, we are still left with questions about how physical information persists because we assume that as an element of nature, it must persist. We posit that our understanding of the persistence of information may be enhanced by studying the persistence of snowflakes as epitomes of natural objects caught up in Hericalitian flux.

5. Snowflakes, Information, and Persistence

We regard snowflakes as low-entropy complexes that epitomize the persistence of natural objects [6][16]. Forming complexes (i.e., ice crystals) that later disintegrate exemplifies nature's flux—transition from low—high- low organization states. Snowflakes come into being in specific conditions (see below), under the spontaneous (natural) process of crystallization, such that water vapor crystallizes to form a solid- an ice crystal. They exist for a certain period before disappearing when the surrounding conditions change.

Snowflakes are single ice crystals formed from water vapor. They usually form complex symmetric, hexagonal structures, with none of these structures ever being identical, at least in natural conditions[17]. Ice crystals form under specific conditions related to temperature, humidity, and other external factors (e.g., [87,90–92]. In 1951, the International Association of Cryospheric Science differentiated, as a function of temperature and humidity, ten morphological types (phenomenological classifications) of ice crystals, although recent studies have increased this number [87][18]. The formation of snowflakes is spontaneous (natural); we can say that snowflakes are self-organizing systems, given the right environmental conditions. Thermodynamically, snowflakes form in open systems in which there is an energy transfer between the local system and the surroundings (e.g., [88,92,96–98]), thus preserving the overall entropy growth when entropy of the local system (a snowflake) decreases.

To get the entire picture of a snowflake's lifecycle, we needed to account for changes in the entropy and energy exchange of the ice crystal (local system) and the surroundings. Thus, during snowflake creation the total entropy (of the surroundings i.e., of the Universe) increases (The Second Law of Thermodynamics) with local entropy (of a snowflake) decreasing. The reverse applies when the snowflake dissolves, with the energy influx increasing the local entropy as the snowflake transitions from an organized crystal state to a less organized (with higher entropy) liquid state[19], the total entropy balance (local + surroundings) increases; all these phase transitions occur spontaneously (naturally) (e.g., [88,92,98–100]).

Changes in phase transition in a snowflake's lifecycle can be more formally expressed using Gibbs energy[20]. Gibbs energy is expressed as $G = H - TS$, where G is Gibbs energy, H is enthalpy, T is an absolute temperature, and S is entropy[21]. The change in the Gibbs energy can be identified with a change of total energy for a process that occurs under the constant pressure and temperature ([98], p. 71). Gibbs energy change, ($\Delta G < 0$), is negative for spontaneous processes under the constant pressure and temperature. With ($\Delta G > 0$) the process requires influx of energy (process is not spontaneous), and with ($\Delta G = 0$) the process is in equilibrium state. When snowflake fission, T increases and TS becomes larger when G decreases (spontaneous process has G decreasing). When freezing occurs T decreases, TS becomes smaller and G (H-TS) increases. Still the total entropy increases (system + surroundings) (see e.g., [98,101,102])[22].

Let us formalize snowflakes crystallization-fission process as Argument (2):

(P5) Snowflakes are created spontaneously in nature.
(P6) Snowflakes have complex structures.
(P7) Information, by definition, is associated with structures (see the discussion in previous sections)
Thus
(C1) Snowflakes have complex structures, by definition, associated with information.

How does information persist in snowflakes? We can discern two options.

Option (1): Let us assume that information is the physical form or structure or morphology of an object. Snowflakes are objects with complex shapes that emerge through a spontaneous process of crystallization and later disappear along with their complex shapes. Thus, if information is equated with a snowflake's morphology, it must also emerge and disappear, making information an unstable property. Let us again formalize this observation as Argument (3):

(P8) Snowflakes contain information (from C1).
(P9a) Information in snowflakes is their physical form perceived as organization.
(P10) Snowflakes are unstable objects, i.e., they change form.
Thus
(C3) Information is unstable.

Option (2): Let us assume that, as we have defined it in this paper, information is latent order[23], the potential of nature to create complex morphologies, or low-entropy complexes like snowflakes under the right conditions[24]. Thus, the latent order disclosed in such processes exists in nature, so it exists for as long as nature exists[25]. It does not emerge out of nowhere, nor does it vanish along with the object. Latent order in nature persists, and we denote this latent order as information. Now, let us formalize this observation as Argument (4):

(P8) Snowflakes contain information (from C1).
(P9b) Information in snowflakes is IN their physical form.
(P11) The physical form of snowflakes is an expression of latent order in nature.
(P12) Latent order in nature persists alongside nature.
Thus

(C4) Information as the latent order of nature persists with nature.

Now, what is Argument (4) telling us about information and its persistence?

Information in snowflake crystals is disclosed through their complex morphologies, but it is not morphology as such. Information is rather latent order in nature that is seen in nature's organization. By definition (see Definition 1), information (as latent order) is not directly observable, so what is observed as natural structures are its effects, i.e., information discloses itself through the morphology (i.e., structure, form) of a physical object. This is what the formative nature (FN) property of information tells us.

So, how does information persist? (C3) would force us toward a definition of information as an ephemeral, unstable phenomenon that is hardly suitable for a foundational feature of nature, never mind the Universe. Conversely, in (A4), we concluded (C4) that information as latent order in nature is a permanent (intrinsic) feature of nature. We could say it co-exists with nature. Thus, Option (2) seems better suited for describing the persistence of information in snowflakes and as defined in Definition 1.

Generalizing this observation from snowflakes to nature, we could say that Option (2) establishes information as a fundamental element of nature that is responsible for nature's structural properties, one that is always present and not vanishing or emerging as a "force" or "tendency" that counteracts the Second Law of Thermodynamics (e.g., [88,103,104]).

Nevertheless, can we really generalize, as we just did, this observation from snowflakes to nature? It seems that we can. A snowflake's emergence and disappearance are results of the interplay between two tendencies of nature, namely (a) the creation of local low-entropy complexes and (b) nature's drive toward the increased global entropy [88,104–106]. It may be suggested that (a) is an expression of nature's power for latent order (the term used in this study) or an inherent feature of nature much like entropy is, although it may counteract it in a local context. Thus, the interplay between (a) and (b) resulting in the emergence of natural complexes that is observed for snowflakes discloses persistent properties that are intrinsic in nature in general, not just in snowflakes.

6. The Persistence of Information: Conclusions

In the introduction we asked three questions: (Q1) How does physical information persist? (Q2) Does it persist as a physical object, or perhaps as a process, event, or something else? (Q3) What, if anything, does its persistence tell us about its nature? Did we find the answers to them and if yes, what are they?

As a reminder, as we have said in the introduction in paper, any references to information refer to physical information, so when we discuss the persistence of information, we mean the persistence of physical information and not anything else. In the literature physical information in the sense used here is also referred to as ontological information [13,34].

On the persistence of information (Q1, Q2), we may say (A1, A4):

- Physical information as latent order (i.e., the potential of nature to create complex morphologies or low-entropy complexes) is intrinsic to nature. It does not disappear when an object disappears, nor does it emerge out of nothing when a complex object emerges. It persists alongside nature.
- Consequently, persistence theories (i.e., endurance, perdurance, and their derivations) do not apply because these theories have been mostly constructed to account for the persistence of ordinary objects.
- Information cannot be the subject of endurance theories dealing with physical objects simpliciter. In addition, formative nature is not an event or a process as they are defined in persistence theories. We also cannot say that information behaves as "wholly present" objects like in endurance theories, nor is information "partially present" at different times as time-indexed parts or a time worm with temporal parts.
- If information were equated with shape/form/morphology (which is not), the current theories of persistence might be applicable to persistence of information in some form.
- On the properties of information (Q3), we may say (A3, A4):

- If physical information plays a fundamental role in nature, information cannot be identical to, or identified with, the external form or shape of an object because this is temporal and ephemeral. These forms would be better regarded as the medium through which information discloses itself to us at any given moment in time as unstable states of matter, rather than information itself[26].
- Thus, information conceptualized as latent order in nature, or nature's potential to spontaneously form local low-entropy complexes, satisfies the properties attributed to information in the works of Burgin [12,27], Burgin and Mikkilineni [107], and Burgin and Krzanowski [34][27].
- Further, the definition of information formulated by Burgin [12,27], Burgin and Feinstel [108], and Burgin and Mikkilineni [107] stating that information is a capacity (ability or potency) of things, both material and abstract, to change other things (Ontological Principle O2) [12,27,107,108][28] reflects best information (in the sense of physical information or ontological information) as latent order in nature[29].
- Finally, about information as nature's potential (Q3), we may say:
- The concept of physical information as the potential of nature to create low-entropy complexes appears similar to the concept of Aristotelian potency. Several current studies imply the existence in nature of the potentiality, which is also referred to as self-organization, to create forms or complexes (see e.g., [103], p. 69). However, we should add that potentiality in its modern form does not attribute Aristotelian telos to nature[30].
- Information (physical information or ontological information) as nature's potency or power should be the topic of a separate study. (See the discussion of nature's potencies in the work of Bird [110] or Austin and Marmodoro [111].

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Notes

1 By "physical," we mean "real," "pertaining to the material universe," "material," or something "subject to physical laws." The concept of something physical being fundamental to our thoughts is difficult to define, and any definition will be open to controversy (see Stoljar [14]). See also the discussion of the physical world in Armstrong [15].

2 At least this is the view of The Standard Model of Cosmology (see the discussion about the SMC in, for example Smeenk and Ellis [6,16], Scott [17], Page [18]).

3 An interpretation of Heraclitian flux must be conducted with care. Heraclitian flux may mean that everything changes, such that nothing ever stays the same (Graham [19]). For example, a Heraclitian river may seem to stay the same, but the water in it changes—see, for example, Kirk et al. [20]. The modern expression of Heraclitian flux can be found in one of Haslanger's sentences: "Things change: objects come into existence, last for a while, go out of existence, move through space, change their parts, change their qualities, change in their relations to things" (Haslanger ([21], p. 326).

4 Persistence, in common parlance, is often associated with an intentional agent and intentional action (see common uses of "persistence" in The Britannica Dictionary [23], Collis Dictionary [24], or Meriam Webster Dictionary [25]. However, this meaning is not applicable to this discussion.

5 This conclusion is shared by many researchers who have investigated the nature of information. See, for example, the works of Wersig and Neveling [28], Janich [29], Floridi [30], Nafria [31], Adriaans [32], and many others.

6 By "non-reductively," we mean that most information types can be classified into one of these two classes or variants thereof, as well as perhaps a mixture of the two; Popper's Third world may be an exception here [33], but see also [34].

7 See the lecture of John Searle [35] for an explanation of the objective/subjective ontological and epistemic claims.

8 The word *mind* is understood here as a set of cognitive faculties that include a consciousness, perception, thought, judgment, and memory. This could include an artificial system with a subset of cognitive-like functions.

9 We make no claims about what the laws of nature are and whether they exist and how, such as with the Regularity theory vs. the Necessitarian theory [61,62]. The term "laws of nature" cam be interpreted in this context in a generic way as "a stated regularity in the relations or order of phenomena in the world that holds, under a stipulated set of conditions, either universally or in a stated proportion of instances" [63].

10 This goes against Wheeler's "It from bit" and similar conjectures [64].

11 "Ontological information is orthogonal and complementary to mental information. Epistemic information, which has been studied by different researchers, is a type of mental information and, thus, it is orthogonal to ontological information" [34].

12 It seems that "something" for Lewis may mean an ordinary thing, a person, a body, or an electron [22] (with an electron Lewis may be missing an explanation, see [65,66]). There is an obvious difference between a person's mode of existence and that of an electron, however, and this difference escaped Lewis's attention. This makes us wonder if even a generic term like "persistence" can apply to both a person and an electron, as Lewis's definition would suggest. Thus, Lewis's attribution of persistence to "an ordinary thing, a person, a body, or an electron" is at best questionable, and so is the meaning of "something."

13 "Something is a proper part of something else if and only if it is a part of it, but is not identical to it" (Lando [79], p. 52). In this way, Democritus's atoms cannot have proper parts, because they are indivisible, but atoms in modern physics can.

14 Specifically, physical information has three properties: epistemic neutrality (EN), physical embodiment (PE), and formative nature (FN). Epistemic neutrality, as it pertains to knowledge or value, is of no consequence to the persistence (existence in time) of physical objects. Physical embodiment does not equate information with the physical object, because physical information is not a hunk of matter. Thus, information cannot be the subject of endurance theories dealing with physical objects *simpliciter*. In addition, formative nature is not an event or a process as they are defined in persistence theories. We also cannot say that information behaves as "wholly present" objects like in endurance theories, nor is information "partially present" at different times as time-indexed parts or a time worm with temporal parts.

15 If information were equated with shape/form/morphology, the current theories of persistence might be applicable to persistence of information in some form.

16 "In many ways, the formation of ice crystals from the vapor phase is an excellent case study of crystal growth dynamics and pattern formation during solidification" [87].

17 "The reason for why no two snowflakes are alike is that the particular shape is determined by the path the flakes take through the clouds as they are forming. It is unlikely that two would take the same path. In addition, a snowflake consists of 109 molecules of water. Having an identical arrangement of such a number of molecules is practically impossible" (e.g., [88,89]).

18 Depending on humidity and temperature, snowflakes may be formed as plates (dendrites, plates), columns (needles, hollow columns, solid prisms), plates (stellar plates, thin plates, solid plates), and plates and columns [86,93–95].

19 Entropy for organized systems (like crystals, complex molecules, compounds of molecules, etc.) decreases by comparison to the entropy of the same molecules existing in non-organized states.

20 "ΔG, matches what we know about the physical chemistry of water: below 0 °C, it freezes spontaneously ($\Delta G < 0$), at 0 °C solid water and liquid water coexist ($\Delta G = 0$), and above 0 °C, ice is unstable ($\Delta G > 0$). ΔG is negative for what we know is a spontaneous process, and it is positive for the reverse process. As we know from experience, a stretched rubber band will contract when released. What is the sign of ΔG for this process? Negative! ΔS is large and positive, making -T ΔS negative, and ΔH is negative. More generally, $\Delta G < 0$ is a basis for explaining chemical reactivity, equilibrium, and phase behavior ([101], p. 86)".

21 With G, H are given in joules (J) (1 J= 1 kg m^2 s^{-2}, S is given in joules per K (kg m^2 s^{-2} K^{-1}) and T in kelvins (K).

22 Natural systems spontaneously tend to lower Gibbs energy. Thus, high Gibbs energy systems like living organisms are unstable and have to have constant influx of energy to maintain their high energy states (more on this issue see [98,101,102]. We may say that all complex systems (including all living systems) are highly non-equilibrium systems that requires a constant influx of energy to maintain their state [101].

23 In this text the term "latent order" should be always interpreted as "latent order or the potential of nature to create complex morphologies". For sakeof brievity the term "laten order" is used more often rather than the fully expanded term.

24 Under specific conditions, nature forms low-entropy systems in local violation of the second law of entropy. Complex, highly organized natural systems are characterized by low entropy, while chaotic systems with simpler organization are high entropy systems. This process of forming low-entropy systems can go on for as long as the required conditions are satisfied.

25 Sean Carroll posited that natural laws and nature "come as a package deal," implying that one exists for as long as the other one exists [4].

26 Consequently, any measure of information based on shape/form does not measure information but rather its effect in nature. In addition, any measure of information based on shape/form/morphology actually contains/conceals a time variable, as pointed out by Burgin [12,27], so such measures should be indexed by time. For example, Shannon's information entropy "IE" should be written as "IE_t".

27 Wheeler denotes this latent order, it seems, as a principle of organization [64].

28 For a discussion of the GTI, consult the original publication of Mark Burgin [12,26,27].

[29] "Ontological information is the potentiality/cause of formations and transformations of structures in the physical world, i.e., of physical systems. As ontological information functions in the physical world, it is natural to treat it as a natural phenomenon" [34].

[30] Sachs states "(Aristotelian) the potency is the innate tendency of anything to be at work in ways characteristic of the kind it is." Furthermore, "A potency in its proper sense will always emerge into activity, when proper conditions are present and nothing prevents it" ([109], p. lvii). The process of the creation of snowflakes seems to be a literal depiction of the Aristotelian concept of potency (1047b35–1048a21).

References

1. Turek, K. Filozoficzne aspekty pojęcia informacji. *Zagadnienia Filoz. W Nauce* **1978**, *1*, 32–41.
2. Collier, J. Intrinsic Information. In *Information, Language and Cognition: Vancouver Studies in Cognitive Science*; Hanson, P.P., Ed.; Oxford University Press: Oxford, UK, 1990; Volume 1, pp. 390–409.
3. Wilczek, F. *A Beautiful Question*; Penguin Books: London, UK, 2015.
4. Carroll, J.W. "Why There Is "Something" Rather Than "Nothing". Online Interview. 2016. Available online: https://www.youtube.com/watch?v=c-QkJUxcGt8 (accessed on 8 February 2023).
5. Rovelli, C. *Reality Is Not What It Seems*; Allen Lane: New York, NY, USA, 2016.
6. Reeves, H. *L'heure de S'eniver. L'univers a-t-il un Sens?* Editions du Seuil: Paris, France, 1992. (In Polish)
7. Stonier, T. *Information and the Internal Structure of the Universe*; Springer: New York, NY, USA, 1990.
8. Heller, M. Ewolucja pojęcia masy. In *Filozofować w Kontekście Nauki*; Heller, M., Michalik, A., Mączka, J., Eds.; PTT: Krakow, Poland, 1987; pp. 152–169.
9. Heller, M. *Elementy Mechaniki Kwantowej Dla Filozofow*; Copernicus Center Press: Krakow, Poland, 2014.
10. von Baeyer, H.C. *Information: The New Language of Science*; Harvard University Press: Cambridge, UK, 2005.
11. Seife, C. *Decoding the Universe*; Viking: London, UK, 2006.
12. Burgin, M. The General Theory of Information as a Unifying Factor for Information Studies: The Noble Eight-Fold Path. In Proceedings of the IS4SI 2017 Summit Digitalization for a Sustainable Society, Gothenburg, Sweden, 12–16 June 2017; Volume 1, p. 164.
13. Krzanowski, R. *Ontological Information*; World Scientific: Singapore, 2022.
14. Stoljar, D. Physicalism. In *The Stanford Encyclopedia of Philosophy*; (Summer 2022 Edition); Zalta, E.N., Ed.; Stanford, CA, USA, 2022. Available online: https://plato.stanford.edu/archives/sum2022/entries/physicalism/ (accessed on 8 February 2023).
15. Armstrong, D.M. *Sketch for a Systematic Metaphysics*; Oxford University Press: Oxford, UK, 2010.
16. Smeenk, C.; Ellis, G. Philosophy of Cosmology. In *The Stanford Encyclopedia of Philosophy*; (Winter 2017 Edition); Zalta, E.N., Ed. 2017. Available online: https://plato.stanford.edu/archives/win2017/entries/cosmology/ (accessed on 8 February 2023).
17. Scott, D. The Standard Model of Cosmology: A Skeptic's Guide. *arXiv* **2018**, arXiv:1804.01318.
18. Page, L. *The Little Book of Cosmology*; Princeton University Press: Princeton, NJ, USA, 2020.
19. Graham, D.W. Heraclitus. In The Stanford Encyclopedia of Philosophy; (Summer 2021 Edition); Zalta, E.N., Ed., Stanford, CA, USA, 2021. Available online: https://plato.stanford.edu/archives/sum2021/entries/heraclitus/ (accessed on 8 February 2023).
20. Kirk, G.S.; Raven, J.E.; Schofiled, M. *The Presocratic Philosophers*; CUP: Cambridge, UK, 1999.
21. Haslanger, S. Persistence through time. In *The Oxford Handbook of Metaphysics*; Loux, M., Zimmerman, D., Eds.; Oxford University Press: Oxford, UK, 2005.
22. Lewis, D.K. *On the Plurality of Worlds*; Blackwell: Oxford, UK, 1986.
23. Persistence. The Britannica Dictionary. 2023. Available online: https://www.britannica.com/dictionary/persistence (accessed on 8 February 2023).
24. Persistence. Collins Dictionary. 2023. Available online: https://www.collinsdictionary.com/dictionary/english/persistence (accessed on 8 February 2023).
25. Persistence. Mariam—Webster. On Line. 2023. Available online: https://www.merriam-webster.com/thesaurus/persistence (accessed on 8 February 2023).
26. Burgin, M. Information: Problems, Paradoxes, Solutions. *TripleC* **2003**, *1*, 53–70. Available online: http://tripleC.uti.at/ (accessed on 2 November 2017). [CrossRef]
27. Burgin, M. *Theory of Information*; World Scientific Publishing: San Francisco, CA, USA, 2010.
28. Wersig, G.; Neveling, U. The phenomena of interest to Information Sciences. *Inf. Sci.* **1975**, *9*, 127–140.
29. Janich, P. *What is Information?* University of Minnesota Press: London, UK, 2006.
30. Floridi, L. *The Philosophy of Information*; Oxford University Press: Oxford, UK, 2013.
31. Nafria, J. What is information? A multidimensional concern. *TripleC* **2010**, *8*, 77–108. Available online: http://www.triple-c.at (accessed on 6 October 2015). [CrossRef]
32. Adriaans, P. Information. In *The Stanford Encyclopedia of Philosophy*; (Spring 2019 Edition); Zalta, E.N., Ed.; Metaphysics Research Lab, Stanford University: Stanford, CA, USA, 2019. Available online: https://plato.stanford.edu/archives/spr2019/entries/information/ (accessed on 31 March 2020).
33. Popper, K. Three Worlds by Karl Popper. In *The Tanner Lecture on Human Values*; The University of Michigan: Ann Arbor, MI, USA, 1978.
34. Burgin, M.; Krzanowski, K.R. World Structuration and Ontological Information. *Proceedings* **2022**, *81*, 93. [CrossRef]

35. Searle, J. Consciousness in Artificial Intelligence. 2015. Available online: https://www.youtube.com/watch?v=rHKwIYsPXLg (accessed on 1 December 2019).
36. Bar-Hillel, Y.; Carnap, R. Semantic Information. *Br. J. Philos. Sci.* **1953**, *4*, 147–157. [CrossRef]
37. Brooks, B. The foundations of information science. Part I. Philosophical Aspects. *J. Inf. Sci.* **1980**, *2*, 125–133. [CrossRef]
38. Rucker, R. *Mind Tools*; Dover Publications, Inc.: Minneola, FL, USA, 2013.
39. Buckland, M.K. Information as thing. *J. Am. Soc. Inf. Sci.* **1991**, *42*, 351–360. [CrossRef]
40. Devlin, K. *Logic and Information*; Cambridge University Press: Cambridge, UK, 1991.
41. Loose, R.M. A Discipline Independent Definition of Information. *J. Am. Soc. Inf. Sci.* **1998**, *48*, 254–269. [CrossRef]
42. Sveiby, K.-E. What Is Information? 1998. Available online: http://www.sveiby.com/articles/information.html (accessed on 20 April 2016).
43. Dretske, F. *Knowledge and the Flow of Information*; CSLI Publications: Cambridge, UK, 1999.
44. Casagrande, D. Information as Verb: Re conceptualizing Information for Cognitive and Ecological Models. *Ga. J. Ecol. Anthropol.* **1999**, *3*, 4–13. [CrossRef]
45. Floridi, L. *Information: A Very Short Introduction*; University Press: Oxford, UK, 2010.
46. Lenski, W. Information: A Conceptual Investigation. *Information* **2010**, *1*, 74–118. Available online: https://www.mdpi.com/2078-2489/1/2/74 (accessed on 6 October 2015). [CrossRef]
47. Vernon, D.G. *Artificial Cognitive Systems*; A Primer; The MIT Press: Cambridge, UK, 2014.
48. Dasgupta, S. *Computer Science: A Very Short Introduction*; Oxford University Press: Oxford, UK, 2016.
49. Shannon, C.E. A Mathematical Theory of Communication. *Bell Syst. Tech. J.* **1948**, *27*, 379–423. [CrossRef]
50. Cherry, C. *On Human Communication*; The MIT Press: Cambridge, UK, 1978.
51. Casti, J.L. *Paradigms Lost*; Avon Books: New York, NY, USA, 1990.
52. Smith, J.M. The Concept of Information in Biology. *Philos. Sci.* **2000**, *67*, 177–194. [CrossRef]
53. von Weizsäcker, C. *Die Einheit der Natur*; Verlag: Berlin, Germany, 1971. (In Polish)
54. De Mull, J. The informatization of the worldview. *Inf. Commun. Soc.* **2010**, *2*, 69–94. [CrossRef]
55. Polkinghorne, J. *Faith, Science & Understanding*; Yale University Press: New Haven, CT, USA, 2000.
56. Dodig-Crnkovic, G. Alan Turing's Legacy: Info-Computational Philosophy of Nature. 2012. Available online: https://arxiv.org/abs/1207.1033 (accessed on 7 October 2015).
57. Hidalgo, C. *Why Information Grows?* Penguin Books: London, UK, 2015.
58. Davies, P. *The Demon in the Machine*; Allen Lane: New York, NY, USA, 2019.
59. Sole, R.; Elena, S. *Viruses as Complex Adaptive Systems*; Princeton University Press: Princeton, NJ, USA, 2019.
60. Krzanowski, R.; Polak, P. Ontological information–Information as physical phenomenon. *Proceedings* **2021**, *68*, 21.
61. Carroll, J.W. Laws of Nature. In *The Stanford Encyclopedia of Philosophy (Winter 2020 Edition)*; Zalta, E.N., Ed.; Stanford, CA, USA, 2020. Available online: https://plato.stanford.edu/archives/win2020/entries/laws-of-nature/ (accessed on 8 February 2023).
62. Swartz, N. Laws of Nature. IEP. 2023. Available online: https://iep.utm.edu/lawofnat/#H7 (accessed on 8 February 2023).
63. Britannica. The Editors of Encyclopaedia. "Law of Nature". Encyclopedia Britannica, Invalid Date. Available online: https://www.britannica.com/topic/law-of-nature. (accessed on 28 March 2023).
64. Wheeler, J.A. *Information, Physics, Quantum: The Search for Links*; Foundations of Quantum Mechanics: Tokyo, Japan, 1989; pp. 354–368.
65. Marletto, C. *The Science of Can and Can't*; Penguin: London, UK, 2002.
66. Johnson, H. Electron Lifetime is at Least 66,000 Yottayears. PhysicsWorld. 2015. Available online: https://physicsworld.com/a/electron-lifetime-is-at-least-66000-yottayears/ (accessed on 8 February 2023).
67. Armstrong, D.M. Identity through Time. In *Time and Cause*; Van Inwagen, P., Ed.; Philosophical Studies Series in Philosophy; Springer: Dordrecht, The Netherlands, 1980; Volume 19. [CrossRef]
68. Sider, T. *Four-Dimensionalism*; Clarendon Press: Oxford, UK, 2001.
69. McKinnon, N. The Endurance/Perdurance Distinction. *Australas. J. Philos.* **2002**, *80*, 288–306. Available online: https://aap.tandfonline.com/doi/pdf/10.1080/713659467 (accessed on 8 February 2023). [CrossRef]
70. Loux, M. Metaphysics. In *A contemporary Introduction*; Routledge: London, UK, 2006.
71. Baker, L. *The Metaphysics of Everyday Life*; Cambridge University Press: Cambridge, UK, 2009.
72. Benovsky, J. Endurance, Perdurance and Metaontology. *SATS* **2011**, *12*, 159–177. [CrossRef]
73. Garrett, B. What Is This Thing Called Metaphysics? 2011. Available online: https://books.google.com/books?id=qT (accessed on 8 February 2023).
74. Rea, M. Metaphysics. In *The Basics*; Routledge: London, UK, 2014.
75. Wasserman, R. Theories of persistence. *Philos. Stud.* **2016**, *173*, 243–250. [CrossRef]
76. Hawley, K. Temporal Parts. In *The Stanford Encyclopedia of Philosophy*; (Summer 2020 Edition); Zalta, E.N., Ed.; Stanford, CA, USA, 2020. Available online: https://plato.stanford.edu/archives/sum2020/entries/temporal-parts/ (accessed on 8 February 2023).
77. Costa, D. Persistence in Time. IEP. 2023. Available online: https://iep.utm.edu/per-time/ (accessed on 8 February 2023).
78. Heller, M. Ontology of physical objects. In *Four Dimensional Hunks of Matter*; Oxford University Press: Oxford, UK, 1990.
79. Lando, G. Mereology. In *A Philosophical Introduction*; Bloomsbury: London, UK, 2017.
80. Balashov, Y. Experiencing the Present. *Epistemol. Philos. Sci.* **2015**, *44*, 61–73. [CrossRef]

81. van Inwagen, P. Temporal Parts and Identity across Time. *Monist* **2000**, *83*, 437–459. [CrossRef]
82. Hales, S.; Hales, D.; Johnson, T.A. Endurantism, Perdurantism and Special Relativity. *Philos. Q.* **2003**, *53*, 524–539. [CrossRef]
83. Felletti, F. Is Endurantism more plausible than perdurantism froma common-sense perspective? *Prax. Filosófica Nueva Ser.* **2017**, *2017*, 77–99. [CrossRef]
84. Magidor, O. Endurantism vs. Perdurantism: A Debate Reconsidered. *Noûs* **2016**, *50*, 509–532. Available online: http://www.jstor.org/stable/26631403 (accessed on 8 February 2023). [CrossRef]
85. Lewis, D.K. Counterparts of Persons and Their Bodies. *J. Philos.* **1971**, *68*, 203–211. [CrossRef]
86. Casati, R.; Varzi, A. Events. In *The Stanford Encyclopedia of Philosophy (Summer 2020 Edition)*; Zalta, E.N., Ed. 2020. Available online: https://plato.stanford.edu/archives/sum2020/entries/events/ (accessed on 8 February 2023).
87. Libbrecht, K.G. The Physics of snow crystals. *Rep. Prog. Phys.* **2005**, *68*, 855. [CrossRef]
88. Heffner, X. Crystallization Primer. 2011. Available online: https://docslib.org/doc/3642038/crystallization-a-primer-with-pictures-and-minimal-equations (accessed on 8 February 2023).
89. Lecture 7 Notes. Statistical Mechanics. E0415. Fall 2021, Lecture 7. Entropy. 2017. Available online: https://mycourses.aalto.fi/pluginfile.php/1649021/mod_resource/content/1/2021Lect7.pdf (accessed on 8 February 2023).
90. Libbrecht, K.G. *Snow Crystals*; Princeton University Press: Princeton, NJ, USA, 2022.
91. De Mendonca, T. *The Science of Snowflakes*; The Oxford Scientists: Oxford, UK, 2017.
92. Schultz, M.J. Crystal growth in ice and snow. *Phys. Today* **2018**, *2*, 34. [CrossRef]
93. Nelson, P.J. How the Crystal Got Its "Six". 15 March 2011. Available online: http://www.storyofsnow.com/blog1.php/how-the-crystal-got-its-six (accessed on 8 February 2023).
94. Conners, D. How Snowflakes Get Their Shapes? *Erthsky.* 2019. Available online: https://earthsky.org/earth/how-do-snowflakes-get-their-shape/ (accessed on 8 February 2023).
95. Libbrecht, K.G. A Quantitative Physical Model of the Snow Crystal Morphology Diagram. 2019. Available online: https://arxiv.org/abs/1910.09067v2. (accessed on 8 February 2023).
96. Dugdale, J.S. *Entropy and its Physical Meaning*; Taylor and Francis. CRC Press: Boca Raton, FL, USA, 1998.
97. Petrenko, R.; Whitworth, W. *Physics of Ice*; Oxford University Press: Oxford, UK, 1999.
98. Atkins, P. *The Laws of Thermodynamics*; OUP: Oxford, UK, 2010.
99. Vardiman, L. Evolution and a Snowflakes. 1986. Available online: https://www.icr.org/article/evolution-snowflake/ (accessed on 8 February 2023).
100. Furukawa, Y.; Wettlaufer, J. Snow and Ice Crystals. *Phys. Today* **2007**, *12*, 70. [CrossRef]
101. Haynie, D. *Biological Thermodynamics (Textbook)*, 2nd ed.; Cambridge University Press: Cambridge, UK, 2008.
102. Morowitz, H.J. *Entropy for Biologists*; Yale University: London, UK, 1970.
103. Eigen, M.; Winkler, R. *Laws of the Game*; Princeton University Press: Princeton, NJ, USA, 1993.
104. Yockey, H. *Information Theory, Evolution, and the Origin of Life*; Cambridge University Press: Cambridge, UK, 2005.
105. Schrodinger, E. What Is Life? The Physical Aspect of the Living Cell. 1944. Available online: http://strangebeautiful.com/other-texts/schrodinger-what-is-life-mind-matter-auto-sketches.pdf (accessed on 8 February 2023).
106. Kondepudi, D.; Prigogine, I. *Modern Thermodynamics*; John Wiley and Sons: London, UK, 2002.
107. Burgin, M.; Mikkilineni, R. Is Information Physical and Does It Have Mass? *Information* **2022**, *13*, 540. [CrossRef]
108. Burgin, M.; Feistel, R. Structural and Symbolic Information in the Context of the General Theory of Information. *Information* **2017**, *8*, 139. [CrossRef]
109. Sachs, J. *Artistotle's Metaphysics*; Green Lion Press: Santa Fe, NM, USA, 1999.
110. Bird, A. *Nature's Metaphysics*; Clarendon Press: Oxford, UK, 2007.
111. Austin, C.J.; Marmodoro, A. Structural Powers and the Homeodynamic Unity of Organisms. In *Neo-Aristotelian Perspectives on Contemporary Science*; Simpson, W.M.R., Koons Robert, C., Nicholas, J.T., Eds.; Routledge: London, UK, 2018; pp. 283–307.