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Why Information Grows
The Evolution of Order, from Atoms to Economies
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IX **The universe is made of energy, matter, and information, but information is what makes the universal interesting**. Without information, the universe would be an amorphous soup, it would lack the shapes, structures, aperiodic orders, and fractal arrangements that gives the universe both its beauty and its complexity.

Where does information come from? Why is information concentrated in our planet, and how is the growth of information facilitated by life? What are the social and economic mechanisms that enable information to continue growing in society? **How does the social accumulation of information improve our capacity to accumulate even more information?** And how do the mechanisms that contribute to the growth of information contribute to the social and economic unevenness of the global economy?

In the following pages, we will **learn what information is, where it comes from, and why it grows**. We will learn about **the natural, social, and economic mechanisms that help information rebel against entropy**. We will learn about **the mechanisms that help information win small battles, prevailing stoically in our universe is only truel war: the war between order and disorder; between entropy and information.**

XIV Encoding and decoding messages. Mathematicians continued to formalise the idea of information - **cybernetics**.

XV As the 20th-century continued, the idea of information grew in status to an idea of global importance. Yet **as the idea of information became more popular, we slowly began to forget about the physicality of information (that had troubled Boltzmann). The word information became a synonym for the ethereal, the under physical, the digital, the weightless, the immaterial. But information *is* physical. It is as physical as Boltzmann's atoms or the energy they carry in their motion**.

Information is not tangible; it is not a solid or of fluid. It does not have its own particle either, but it is as physical as movement and temperature, which also do not have particles of their own. **Information is incorporeal, but it is always physically embodied**. Information is not a thing; rather, it is the arrangement of physical things. It is ***physical order***, like what distinguishes different shuffles of a deck of cards.

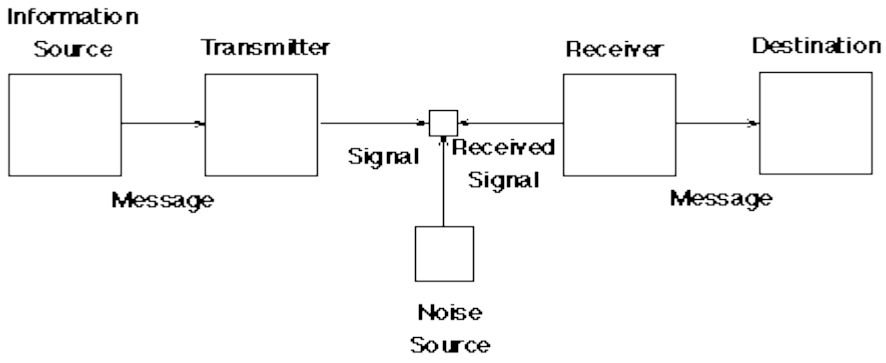
What is surprizing to most people, however, is that **information is meaningless**, even though the meaningless nature of information, much like its physicality, is often misunderstood.

In 1949 Claude Shannon and Warren Weaver published a short book entitled **The Mathematical Theory of Communication**.

In its first section, Weaver described the **conceptual aspects of information**. In the second section, Shannon described **the mathematics of what we now know as information theory**.

For information theory to be properly understood, Shannon and Weaver needed to detach the word information from its colloquial meaning. Weaver made this distinction early on his essay: "The word information, in this theory is used in a special sense that must not be confused with its ordinary usage. In particular, information must not be confused with meaning".

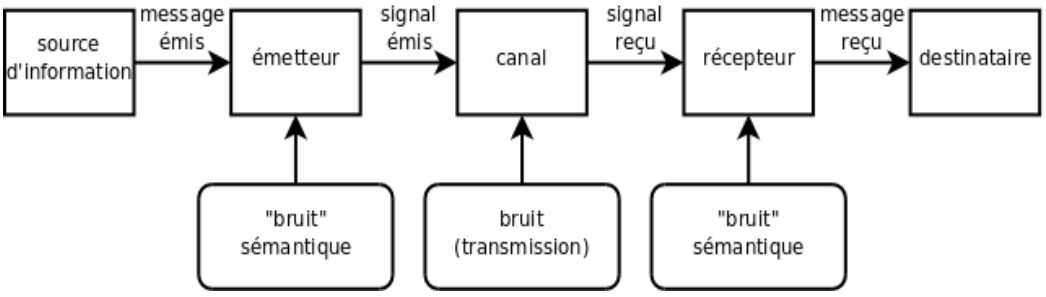
XVI **Shannon and Weaver needed to separate information from meaning for both technical and philosophical reasons**. On the technical side, Shannon was interested in the construction of machines that could help **communicate information** regardless of the meaning of the message. Mixing information and meaning obfuscated the engineering problem. On the philosophical side, Shannon and Weaver understood that their use of the words information and meaning refer to concepts that were fundamentally different.



Humans, and some machines, have the ability to interpret messages and infuse them with meaning. But what travels through the wires or elegant the magnetic waves is not that meaning. It is simpler. It is just information.

It is hard for us humans to separate information from meaning because we cannot alb interpreting messages. We infuse messages with meaning automatically, fooling ourselves to believe that the meaning of a message is carried in the message. But it is not. It is only an illusion.

Meaning is derived from context and prior knowledge. **Meaning as the interpretation that the knowledge agent, such as a human, gives to a message, but it is different from the physical order that carries the message, and different from the message itself. Meaning emerges when a message reaches a lifeform or a machine with the ability to process information**.



XIX **Information, when understood in its broad meaning as physical order, is what our economy produces**. It is the only thing we produce, whether we are biological cells or manufacturing plants. This is because **information is not restricted to messages.**
It is inherent in all the physical objects we produce: bicycles, buildings, streetlamps, blenders, hairdryers, shoes, harvesting machines and underwear are all made of information. This is not because they are made of ideas but because they embody physical order. Our world is pregnant with information. It is not an amorphous soup of atoms, but then neatly organised collection of structures, shapes, colours, correlations. Such ordered structures are the manifestation of information, even when these chunks of physical order lack any meaning.

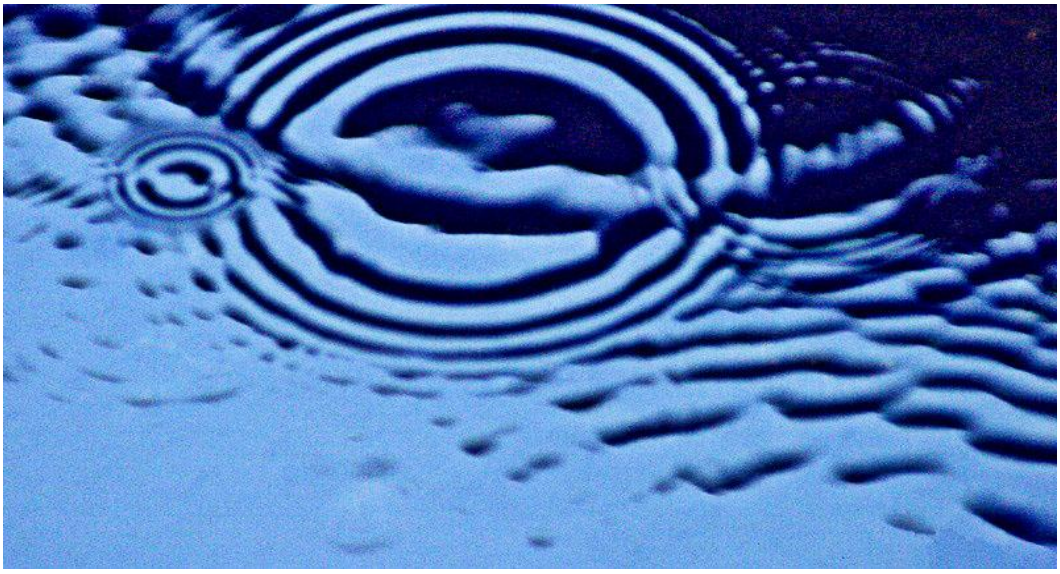
175 **The Evolution of Physical Order**

The universe is made of energy, matter and information, and while energy and matter are here by default, information needs to find ways to emerge. This is not always easy.
We began our story by describing some of the **basic physical mechanisms that contributed to the growth of information**. These included three important concepts:

the spontaneous emergence of information in out-of-equilibrium systems (the whirlpool example),
the accumulation of information in solids (such as proteins and DNA),
and the ability of matter to compute.

The first idea connects information with energy, since information emerges naturally in out-of- equilibrium systems. These are systems of many particles caracterized by substantial flows of energy. **Energy flows allows matter to self-organise**.

As Prigogine taught us, the **energy flows that keep a system out of equilibrium explained the spontaneous emergence of order or information**. **Out-of-equilibrium systems beget information naturally as they organise into dynamic steady states**. Everyday examples of such systems include the whirlpool that forms when you empty bath top all the swirls that emerged when you pour milk into your coffee.



176 But out-of-equilibrium systems cannot help us understand **more complex forms of information**. This is where the existence of solids and the computational capacities of matter comes into play. The steady march of entropy implies that information is always at risk of being destroyed. To survive, information needs to hide, since a universe where information is short-lived is also a universe where information cannot grow. Solids provide the stubbornness that information needs to fend off the growth of entropy. By allowing information to endure, solids allow information to be recombined. These three combination is essential for the continued growth of information.

177 The fact that matter can compute is one of the most amazing facts of the universe. Think about it: if matter could not compute, there would be no life. Bacteria, plants, and you are nigh are all, technically computers. Our selves are constantly processing information in ways that we poorly understand.

The ability of matter to compute is a precondition for life to emerge. It also signifies an important point of departure in our universe's ability to beget information. As matter learns to compute, it become selective about the information it accumulates and the structures it replicates. Ultimately, it is the computational capacities of matter that allow information to experience explosive growth will stop

Out-of-equilibrium systems, solids, and the computational abilities of matter help us understand the growth and presence of information in our universe. These three mechanisms **help matter cheat the steady march of entropy, not universally, but in well-defined pockets such as a cell, a human, a city, or a planet**. But to bring these ideas into our modern reality, we need to recast them in the language of humans, societies, and economies. The growth of information in the economy is still the result of these basic mechanisms. But in these large- scale social and economic systems these mechanisms take new forms.

178 Our world is populated by structures that are more complex than whirlpools and proteins. These include people and objects. **People are the ultimate incarnation of the computational capacities of matter. We embody the capacity to compute, as we organise our brain and our society to beget new forms of information**.

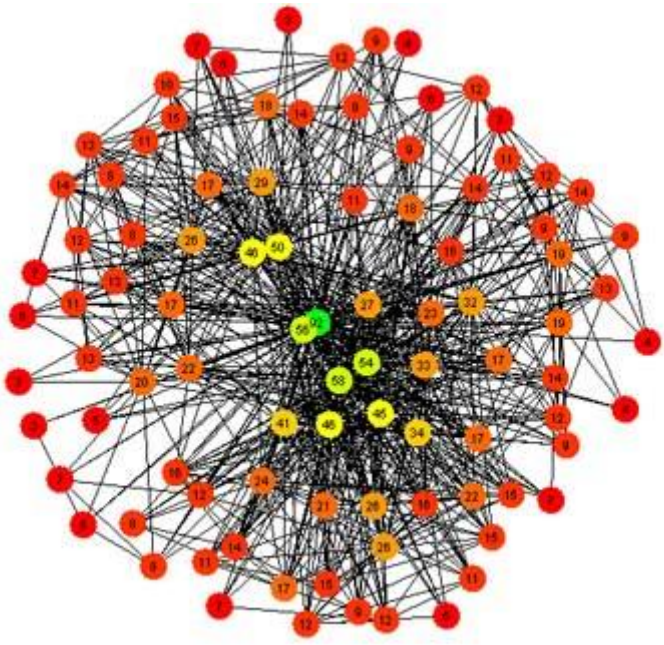
Objects are where we deposit information. They allow us to communicate messages and coordinate our social and professional activities, but more importantly, they allow us to transmit the practical uses of **knowledge and know-how**.

The economy of early hominids and that of 21st-century society have enormous differences, but they do share one important feature: in both of these economies **humans accumulate information in objects**. Our world is different from that of early hominids only in the way in which atoms are arranged. The objects of today - the arrangements of atoms - are what make our world essentially different from the one in which our ancestors evolved.

The physical embodiment of information is the blood of our society. Objects send messages connect us, allowing us to push the growth of information even further. For tens of thousands of years we have embodied information in solid objects, from arrows and spears to espresso machines and jetliners. More recently, we have learned to embody information in photons transmitted by our cellphones and wireless routers. Yet, what is most amazing about the information that we embody is not the physicality of the encasing but the mental genesis of the information that we in case. Humans do not simply deposit information in our environment, **we crystallise imagination**.

Our ability to crystallise imagination is the ability to create objects that were born as works of fiction. The aeroplane, the helicopter were all thoughts before they were constructed. Our ability to crystallise imagination sets us apart from other species, as it **allows us to create in the fluidity of our minds and then embody our creations in the rigidity of our planet**.

But crystallising imagination is not easy. Embodying information in matter requires us to push our computational capacities to the limit, often beyond what the single individual could ever achieve. To beget complex forms of information, such as those that populate our modern society, we need to **evolve complex forms of computation that involve networks of humans**. Our society and economy, therefore, act as a distributed computer that accumulates the knowledge and know-how needed to produce the information that we crave.



180 Our need to form networks, however, emerges from one important consideration: the **limited ability of humans to embody knowledge and know-how. To fight our individual limitations we need to collaborate**. We form networks that allow's to embody more knowledge and know-how, because without them our ability to process information and create crystals of imagination would be highly limited. These networks are essential to produce products that require more knowledge and know-how than can be embodied in a single individual.

181 So in the world of atoms and economies the growth of information hinges on the eternal **dance between information and computation**. This stance is powered by the flow of energy, the existence of solids, and the computational abilities of matter. The flow of energy drives self-organisation, but it also fuels the ability of matter to compute. Solids, on the other hand, from proteins to buildings, help order endure. Solids minimise the need for energy to produce order and shield information from the steady march of entropy. Yet the Queen of the ball is the **emergence of collective forms of computation**, which are ubiquitous in our planet. Our cells are networks of proteins, which form organelles and signalling pathways that help them decide when to divide, differentiate, and even dive. Our society is also a collective computer, which is augmented by the products we produce to compute new forms of information.

The Queen of the **the eternal dance between information and computation**

As the universe moves on and entropy continues to increase, our planet continues its rebellious path marked by pockets that are rich in information. Enslaved by the growth of order, we form social relationships, make professional alliances, beget children, and of course, laugh and cry. But we often lose sight of the beauty of information. We get lost in the urgency of the moment, as our minds race like whirlpools and our lives compute forward in a universe that has no past. We worry about money and taxis instead of owning the responsibility of perpetuating this godless creation: a creation that grew from modest physical principles and which has now been bestowed on us.