

THE INTEGRATION OF KNOWLEDGE

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We live in a fascinating time for the integration of knowledge. In particular, we have developed three great theoretical pillars whose immense explanatory power is destined to contribute to the unification of knowledge, a goal sought by so many visionary minds throughout the centuries: fundamental physics, evolutionary biology and neuroscience.

1. Physics, biology, and neuroscience

Physics has accomplished the feat of condensing the structure of the universe in a succinct elenchus of equations, such as the field equations of general relativity and the Schrödinger equation. It has not discovered *the* equation that rules the complete description of the universe, but it has notably approached this titanic dream; a utopia illusory for many, yet unquestionably legitimate. Physics is built upon two fundamental models: general relativity and quantum mechanics. We do not know how to harmonize these two divergent pictures of reality. General relativity offers a geometrical theory of gravitation, where the idea of relativity of all inertial frames of reference is generalized to cover accelerated frames of reference. It has led to the formulation of covariant equations whose sophisticated mathematical expression -through the language of tensor calculus- has given us the finest, deepest, and most rigorous description of the large-scale structure of the cosmos. According to this, gravity emerges as the effect of the geometry of space-time, as the result of the curvature produced by the presence of a density of energy and momentum.

However, for the understanding of the three remaining fundamental forces of nature, quantum mechanics has proven uniquely powerful. Unlike

general relativity and its geometrical image of force, quantum mechanics recapitulates our understanding of the physical world through a theory of fields in which the force is mediated by a set of elementary particles of bosonic nature.

The 20th century has therefore seen a formidable extension of the unifying power of the human mind. Major advances in the domain of the physical sciences have stemmed from the epistemological questioning of their basic concepts. Neither the work of Einstein nor the developments in quantum physics can be fully grasped without the examination of this profound immersion, with vivid philosophical resonances, into the fundamental categories of physics and the logical criteria required to stipulate a meaning for our notions about the objects of experience. With Einstein, ideas like space, time, simultaneity, and privileged states of motion underwent an exhaustive interrogation. This reflects a search for concepts that could be unambiguously assigned to the properties observed in the course of experiments. An analogous comment can be made about Heisenberg, whose famous uncertainty principle (a humbling truth for humankind) is the fruit of a careful revisiting of the meaning of basic kinematic and mechanical concepts.

This criticism of our intuitive notions has triggered key theoretical –and therefore also practical- advances, propitiating the fusion of pure thought and empirical knowledge. It constitutes the most faithful reproduction of the intimate functioning of a human mind in its restless quest for unification.

Biology, the science that tries to understand the world of life, bestows upon us a wonderful unifying tool: the theory of evolution. This model unifies ecological, morphological, and genetic knowledge about living beings. Through the lenses of evolution, the elucidation of the history of life allows us to delve into the structure and present functioning of biological entities.

Neuroscience is on its way to developing a unifying instrument of immense power and amplitude: the scientific understanding of mind. From the level of the nervous cells to the sphere of the activity of the brain as a whole (the synchronization of its different regions), progress has been firm, though insufficient. As soon as we understand how the mind works, the origin of its abilities and the scope of its capacities, we shall be ready to unify the domain of the Humanities, a goal which until very recently seemed unattainable for science, as if it were fragmented in irreconcilable approaches and inimical cultures. Through a neuroscientific theory of mind

we will be able to examine the source of the human being's symbolic creations. This task will contribute to building the neuroscientific foundations for the study of society, law, religion, and art.

2. Conservation, selection, unification

One of the neuralgic principles of reality elucidated by the physical sciences refers to the idea of *conservation* of certain quantities in the processes experienced by the objects of nature. According to Noether's theorem, we know that any differentiable symmetry is associated with a law of conservation. The most important concept used to express this principle of the working of nature is *action*, perhaps the most relevant and profound of all physical categories. Invariance under time translation yields the principle of conservation of energy; invariance under space translation yields the principle of conservation of momentum; invariance with respect to rotation yields the principle of conservation of angular momentum. In quantum physics, a gauge symmetry related to the conservation of charge has also been discovered. In summary, physics has unfolded principles of conservation which, from the realm of subatomic particles to the domain of thermodynamic systems, are capable of establishing laws of apparent inviolability (the status of the principle of conservation of energy in a cosmological scale is under discussion).

In biology, the category of *selection* is as important as the concept of *conservation* is in physics. Transmitted through the power of replication that living beings possess, variability is selected by the environment in accordance with its reproductive efficiency.

If we ascend in the scale of material complexity and we reach the universe of human consciousness, is it possible to identify a principle endowed with similar theoretical power? I believe that such a principle is the idea of *unification*. The conscious mind unifies the perceptions which it receives. The result is the integration of data susceptible to subjective assimilation. With the exception of some sensory systems (like the visual system), we do not know the precise mechanisms through which this phenomenon occurs, but we do know that the human mind holds the unusual privilege of unifying the multiplicity of the world through the filter of its rationality. This unitary grasping of reality (Kant's "unity of apperception" in the *ich denke*) means the insertion of nature into logic

patterns that consciously revert to the subject. It is one of the most remarkable progresses in the long path of evolution, for it represents the dawn of knowledge as the most powerful force of life and the pinnacle of its activities. Knowing involves unifying, connecting, integrating that which is different on the basis of shared relations. Behold the most genuine meaning of the Greek term *logos* and the philosophical scope of the verb *legein* since Thales and the pre-Socratics.

3. The unity of nature

These three notions (conservation, selection, and unification) are not strictly discontinuous. Any hypothetical tripartition of the universe in matter, life, and consciousness obeys instructive and epistemological schemes, not reality as such, independent from the judgement of human intelligence. Along its history, nature has been capable of rising on its own from one level onto another, and this suggests a profound ontological continuity between all realms of reality. It is in fact possible to draw a narrow analogy between a principle like the law of stationary action in physics (the action integral of a particle will manifest extreme values – i.e. maximal or minimal-, so that the value of action may be stationary) and the idea of natural selection, a mechanism that seeks an optimal point in the relationship between genetic variations and the surrounding environment. Also, to unify, the act of integrating perceptions in a unitary consciousness of external and internal reality, can be contemplated as a simultaneous optimization in the value of the information coming from the world and the information elaborated by the subject, with the goal of reducing the boundless multiplicity of phenomena into the unity of the conscious being. An entity capable of extracting, from the copious concatenation of stimuli, information of greater value, more profitable and meaningful, is certainly more conscious of the world and its own being.

The reduction of chemistry to physics has been accomplished thanks to the quantum theory of orbitals. Our deep understanding of how electrons are distributed in atoms is illuminated by quantum principles like Pauli's exclusion principle. Physics has therefore conferred upon human rationality an appropriate tool for understanding the periodic table of elements and the organization of chemical elements. The almost infinite universe of inorganic and organic reactions can be harmoniously inserted into the scientific view of the world that emanates from the physical sciences, from its small but powerful elenchus of laws and fundamental forces. This is one

of the most admirable achievements of quantum mechanics: the complete explanation of the atomic structure of elements and the justification of their principal physic-chemical properties. With no need to incorporate theoretical principles of substantive newness, or principles that cannot be easily deduced from basic laws, physics has allowed for a fluid integration of the vast domain of chemistry.

Evolutionary biology covers a new semantic field of science: life. Of course, it is based upon the fundamental laws of physics, mediated through chemistry (specifically, organic chemistry, which elucidates the structure of compounds like amino acids and nucleic acids). However, it assumes a series of concepts which are virtually absent in the domains of physics and chemistry. These notions are essential for our understanding of life and its development. They are crystallized in the theory of evolution, a model of exceptional explanatory power. We should not forget, however, that we lack a complete theory of evolution. Research in the fields of genetics and epigenetics could actually lead to a substantial revision of some fundamental concepts of evolutionary biology. Nevertheless, as a paradigm, the evolutionary frame has not been surpassed, and it is highly improbable that it will be substantially overcome in the future, at least in its capital aspects. But just as classical physics was not suppressed by 20th century physics, which rather showed the limits of its approach and expanded its theoretical power, future progress in biology can actually broaden the scope of this science and enlarge its categories.

The thread behind the transition from physical chemistry into biology has not been entirely elucidated, for we do not know how life flourished from inert organic matter. However, it is legitimate to hope that we shall soon solve this intricate problem. It is reasonable to think that life on Earth appeared by virtue of a set of chemical conditions which facilitated the creation of molecules susceptible to replication, whose increasing degrees of autonomy from the environment allowed them to induce certain metabolic reactions in the interior of cells. But in the absence of a fully convincing itinerary as to how inert matter conquered the domain of life, we still have to distinguish physics from evolutionary biology, even if a congruent framework with the scientific view of the universe clearly points to the existence of profound coherences and continuities between the inert and the living worlds.

The impossibility of reducing the biological level to the physical-chemical level does not stem from an intrinsic prohibition but from the overwhelming complexity of the system. As soon as we unveil the origin of life, there is no *de iure* interdiction forbidding the unfolding of the fine

thread connecting the world of chemistry and the realm of biology. Of course, the complexity of biological systems is not the sole result of their intrinsic elements but of a factor which becomes extremely relevant for biology: the effect of contingencies. The study of life demands knowing the prolix historical itinerary through which organisms have passed. History contains necessity but above all it is permeated with contingency. Only Laplacian intelligence could have foreseen the arrival of a meteor whose devastating consequence for most of living species triggered the massive Cretaceous extinction. Also, we know that there are unsurmountable uncertainties in the quantum scale. Therefore, the integration of knowledge cannot seek to eradicate any trace of contingency or to reduce every explanation to a physical proposition, but rather serves to expose the inextricable imbrication that binds all domains of reality. This goal highlights the power of the human mind to perceive the fundamental principles behind the unity of such heterogeneous spheres.

In considering history, we cannot override the shadow of contingency. However, we can understand the human constants that pervade spaces and times. Thanks to the scientific study of mind, it is possible to understand human motivations, their logic and –why not?- the seeds of their admirable creative capacity. This yields a fundamental framework for understanding great civilizations and the most sublime productions of the spirit. Even without exorcizing the specter of contingency, it is still feasible to identify the fundamental axes around which human action gravitates. In our days, this knowledge comes from the neurosciences.

It is not utopian to dream of an explanation for the neurobiological bases of consciousness. Again, this goal does not exhaust the understanding of every specific consciousness, because this power of *Homo sapiens* is nurtured by sustained interaction with both the external and the internal environments. It is utterly impossible to reproduce every single detail that forms the vivid experiences of conscious subjects (we would need a rigorous replication of every physical and psychological condition in which this capacity is manifested, as if we were trying to draw a 1:1 scale map). But this deep obstacle does not prevent us from uncovering the neuroscientific foundations of consciousness, which probably lie in certain anatomical structures responsible for connecting perceptual and associative areas, like the claustrum and the superior longitudinal fasciculus.

4. The integration

Science is in possession of the most rigorous and universal language that the human mind has developed: mathematics. The progress of this discipline over the last few centuries, especially in the elucidation of its fundamental principles, its scopes and limits, has granted us an unsurpassed formalism for describing the structure and functioning of the universe. We know, however, that this depiction of reality cannot be complete for at least two reasons: first of all, these models tend to use the language of differential equations, while our knowledge of matter has revealed the discontinuity that exists in the fundamental levels of nature, in particular at a quantum scale. Secondly, the use of mathematical language compels us to draw a distinction between formal and material equality. When, in the field equations of general relativity we find number π and in the Schrödinger equation we contemplate the imaginary number i , it is clear that the notion of equality needs to be interpreted as the equivalence of pure objects of thought (abstractions which do not necessarily enjoy ontological independence in the realm of nature). The mathematical expression of physical categories represents the deepest and finest approach to the material universe conceived by the human mind, but only in an asymptotic limit, in whose ideality material objects fully converged with the pure objects of thought, would it be correct to say that one member of the equation is strictly equal to another.

The indubitable advantage of mathematical language resides in its versatility, for it is flexible enough to cover the practical totality of natural registers. The invention of new mathematical tools throughout history is the best proof of this fruitful plasticity. This is the reason why the limits of thought do not inexorably seal the frontiers of being. Against Parmenides' thesis, the realm of mind is eminently ductile and it can adapt itself, both in its language and its categories, to the pressing challenges posed by reality. We have even managed to expand the limits of our imagination. Before Cantor, it was generally accepted that infinity could not be properly scrutinized by reason. After Cantor, we have learned that different types of infinity exist and that we can have infinite sets which are numerable. The borders of thought have been wonderfully extended, helping us discover unexplored territories of both the real and the possible.

Beyond the difficulties, it is admirable to reflect on the achievements of our Promethean longing for knowledge, in our indefatigable desire of grasping the vastness of the universe in the lightness of the concept. Every act of cognition is guided by logic, whose premises and operative rules

articulate human reasoning. However, its quantitative expression has only reached an adequate expression in sciences like physics, chemistry and –to a lesser degree- biology. Attempts at extrapolating this language onto social studies have been successful only to a limited extent. But logic is equally applied regardless of the field of knowledge. A physicist's mind is not governed by different logical rules than the mind of a philosopher. Any advance towards the improvement of our logical categories and the unveiling of their possibilities, their elasticity and foundation, will provide the human intellect with new and more acute tools for apprehending realms of reality which until now have remained beyond the scope of our knowledge.

Of course, the struggle to integrate knowledge by founding the most complex realities upon the simplest ones cannot be claimed to exhaust our understanding of reality. The world will surely never cease to amaze us with unforeseen wonders, and blessings for our intellect. But the richness and inexhaustibility of the world does not prevent us from identifying the fundamental principles behind its vast and astonishing nature. Our mind, our logic, our intuition..., must be in a constant state of improvement through their interaction with reality, so that the deciphering of the basic axes of the universe will also unveil the true possibilities of human intelligence, of its logic and its language.