What is "Science" and Why Biology is an Autonomous Science?

To observe you have to learn to compare.
To compare you need to have observed.
Observation generates knowledge and
Knowledge is necessary for the observation.
He who does not know what to do with his observation
Is a bad observer.
For the apple tree, the fruit farmer has a more precise eye
Than the passer by, but he who does not know
that men are the destiny of mankind
Cannot see accurately.

Bertolt Brecht, 1934

INTRODUCTION

Although there is a multiplicity of writings in regards to the meaning of science, a comprehensive and pragmatic definition that includes the words of Bertold Brech, could be that science is the human intent of achieving a better comprehension of the world to change it by means of observation, comparison, experimentation, analysis, synthesis and conceptualization.

It also reaffirms that for a particular science to work (sciences are defined according to their object of study) we need, in turn, facts and hypothesis or theoretical concepts. For example, it is presently a well known fact that patients with acute myocardial necrosis show occlusive thrombosis in a coronary artery; this was described – at the beginning of the XX century – by James Herrick, among others, when he presented for the first time the clinical situation of acute myocardial infarction. However, only a few years ago the *hypothesis* (theory) of the thrombotic origin of myocardial necrosis was accepted as cause, when the *fact* of occlusion during the acute phase could be demonstrated. Hence, facts are only interpreted or comprehended within the conceptual elaboration of a hypothesis or theory that explains them.

What we call "science" today, is a relatively new word introduced by Whewell in 1840, as it was previously considered a branch of Philosophy and was called *Philosophy of Nature*.

HOW THEORIES ARE VALIDATED

But the question that follows immediately after is: why accepting certain theoretical hypothesis and not others? We could argue endlessly, but common people, and those not that common, such as scientists, accepts it if it works. None of us would hire an architect that claims to have a new theory on building houses faster and cheaper, if we knew that all his houses collapsed in a short time. We also accept the theoretical hypothesis of the various sciences, because in their specific fields they show that they work as predictors of facts or events. The thrombotic theory in acute infarction was accepted after 70 years of its formulation, and only after facts (as previously described) showed that the use of inter coronary fibrinolytic drugs that dissolved the clot *worked* for interrupting the symptoms and the progression of myocardial necrosis. It can be shown that they work, i.e. they can be verified in practice (*verifiable facts*) or it can be shown that they collapse, i.e. they are fake (*false facts*), from the philosophical point of view of affiliation*: to inductivism* or to *Falsificationism*.

SCIENTIFIC LAWS ARE NATURAL OR EXPERIMENTAL

If we accept that an activity that is beyond science, such as philosophy can assist us in defining what we call "science" we should discuss, briefly, which are the postulates or principles *a priori*, that we should accept in order to be able to say that the activity we carry out is science. The first fundamental question is: Are the laws, theories and models in science laws of nature? That was Alexander Pope's belief, when he inscribe in Newton's epitaph:

Nature and Nature's laws lay hid in night.
God said ¡Let Newton be! And all was light.

Then, is a law of nature an intrinsic and intimate property in the things and events of this world? Or is it just a knowledge elaborated in the mind of the individual and that, therefore does not exist in nature? Can we say that the laws of nature exist per se, even without the need of the existence of an actual person who knows them, or should it be said that the so called laws of nature are no more than models created by people?

We could try to easily solve this complex problem by saying that the law of nature is one thing and a very different one is the knowledge that men can extract from it.

According to this, a law that lays deep in the darkness exists permanently in nature, but the representation that scientists have about nature would change in accordance to the development of the particular science. It is said that when Einstein was asked to define science, he used a beautiful metaphor that was somewhat like this: we can imagine a clock which mechanism lies inside a black, unbreakable box, and we can only watch the clock hands move. Science are the hypotheses we elaborate to explain the clock hands movement; even when our explanations were true, we would never know for certain, as the real mechanism will remain forever unknown.

Even though I am fond of and fascinated by Einstein's metaphor, it is easy to believe that expiring scientific truths never would be able to guarantee that there will exist an underlying absolute truth of nature.

We learn from the history of sciences that the laws of scientific knowledge simply work, up to one day when they stop working because they cannot explain an event or yield a false result in a fact of nature. It can be shown that theories, even the broader and more expanded ones, are false but never will be possible to show that they are true because we will never know if a fact, not yet considered, would certify that they are false. In this sense, we can differentiate them from ideologies or beliefs, which are presumably truthful and therefore it is never possible to show that they are false. It is therefore irrational to try to use rational elements to show that a belief is false.

Albert Einstein thought that theories are not vanished forever, as when a new structure is built in the same place of an old one. It is similar, though, to the successive views that we have from a landscape as we climb a mountain. The higher we go, the wider the new view tends to become, thus allowing us to make unsuspected connections with the more reduced views that we had observed from below, but the new point of view does not eliminate the previous ones (Newton's mechanical theory was not eliminated by Einstein's relativity theory). Maybe using his metaphor we can add, as Wagensberg does in "Ideas for the impure imagination": (1) *"The landscape is the natural law and the view from the peak, its final representation. Knowledge is a mountain without a recognisable peak, to which we, however, can access as much as we want to. And the possibility of indefinitely approaching something suggests, with irresistible force, that that something exists. That is the Law of Nature. It is an idea similar to the idea of Perfection: perfection exists (because it is imaginable), but it is not perfect (because it is unreachable)".*

PRINCIPLES THAT SHOULD BE ACCEPTED TO DO SCIENCE

Science is not reality but its knowledge, i.e. it is only a finite representation of a piece of the infinite reality. But as knowledge it respects, minimum, three principles or non demonstrable theories: *intelligibility, objectivity and dialectic*.

Principle of intelligibility

Scientist, when making science, puts a leap of faith on the criterion that *nature can be understood*, and through this, that the world in *"intelligible*". And the world could be a random place, an unintelligible one, where two identical situations would have different results. In that given situation, science would not be possible, because the representation of a nature that is purely random could not be possible.

A representation of nature becomes intelligible when one complexity can be *compressed,* made more consistent that the representation. This capacity of *compression* in nature indicates the capacity of *comprehension* that we have about nature. For example, due to gravity a stone falls straight downwards; the description of this fact could be established with one thousand positions of the stone performed by one thousand observers (by the way, if reality is infinite, observations should be infinite); luckily, they can easily be reduced to the application of laws, expressed in simple mathematical equations developed by Newton, and to some initial conditions.

Science is reductionist, but knowing beforehand the result in the complexity of a River-Boca game[NT] would be impossible and it is not intelligible, there is no possible reduction, the most consistent way of obtaining the results are results themselves. If in science, a scientist does not arrive to the expected result and fails over and over again, he/she does not make excuses saying that the phenomenon is inexplicable for scientific knowledge, i.e. unintelligible, instead he/she tries again and again, because science is the only kind of knowledge that accepts the principle of unintelligibility as a non demonstrable principle.

Again, in the words of Einstein: *"What is most incomprehensible in Nature is that it can be comprehended by men".* (2)

Principle of objectivity

The second principle would be *objectivity*, which indicates the separation between the mind generator of knowledge and the entity which is the object of knowledge. According to Schrodinger, this is a principle equivalent to the *real world hypothesis*, the scientist detaches himself/herself from the world, turns into an external entity and non-involved in order to create universal knowledge. He/she tries to legitimate the fact that thought does not affect the status of that which is thought about, i.e. science is independent of what scientist experience. It is a principle that can generate much criticism, it can be accepted or not,

[NT] Reference to the historical rivalry between the two most representative soccer teams in Argentina.

science accepts that. It can be made more factual by saying that one is being objective when – confronting several ways of observing an object – we choose the one that least affects observation.

Dialectic Principle

The third criterion for defining science is the dialectic principle. The dialectic principle is used when scientific knowledge is exposed to the risk of being demolished by experience. This principle is the engine of scientific development, Karl Popper's principle of *falsificationism*, or Jorge Wagensberg's "dialectic" principle. The latter also affirms that *"knowledge is scientific when has the will to be so, i.e. when it achieves the maximum objectivity, intelligibility and dialectic… even if these maximums are meager. According to this, a mechanic in billiard balls is a scientific as well as a quantum mechanic. In this sense, a psychologist does not have to be less scientific than a physic… (Quite another thing would be that he/she explicitly renounces top be)"*. (1)

WHY IS BIOLOGY RELATED TO PHYSICS?

It is accepted that the scientific revolution started in the XVI and XVII centuries, the theories from Galileo, Descartes, and Newton explained the phenomena of the world in relation to natural and secular causes; its two initial branches were mechanics and astronomy, which was the mechanic of the celestial objects. To Galileo, mechanics and geometry-mathematic explanations were the ultimate science, and continue to be so for centuries till the present time. Despite of the spectacular advances in biology with Darwinism, genetics, and molecular biology, it continued to be regarded as a branch of physics, at least reducible to physics from the conceptual point of view.

Vitalism and theology

It is obvious that biology, the science of the living beings, has other characteristics beyond those of the inanimate matter, and they could not be ignored reducing the organism, by means of mechanics, to a machine, as Descartes tried to do. Therefore, for more than two centuries many naturalists created an invisible force, such as Newton's principle of gravity, calling it *vis vitalis* and proclaimed themselves vitalists.

Another principle that some naturalists used was *teleology*, the idea that natural processes seem to automatically lead to a determined or defined end or achievement, the forth most important cause in Aristotle's explanation, which he called *causa finalis*.

Both, *vis vitalis* and teleology actually were not scientific principles and were never verified through any experiment, and therefore were not refutable as well. This discussion ended with the development of paleontology, genetics, and molecular biology, when it was shown that the genetic program and natural selection were able to account for these phenomena.

What does biology have from physics and what does not

There is a "functional biology" that is mechanicist and that is represented by the physiology of all the activities performed by the living organisms, which includes all the cellular processes and function of the genome, which ultimately can be explained in a purely mechanical fashion – and physics, answering the most frequently asked question: "how?" "How do b1 receptors work?" "How?"

But there is also a historical biology, indispensable to explain all the phenomena of the living world that includes the dimension of historical time, i.e. all the aspects of evolution – also known as evolutionary biology. It answers the question "why"; why are dinosaurs extinct?" "Why…?", and the answers do not emerge from experiments but from the methodology of historical narrations, tentative arguments by retroduction.

Physics principles that cannot be transferred to biology

There are principles in physics that –although presently used – can not be transferred to biology.

Essentialism **(different classes):** the physical sciences acknowledge, since Plato's hypothesis, that the vast and endless number of phenomena from nature is only apparent, as they actually are a limited amount of natural varieties (called essences, types or classes, according to the different eras), each one of them was included in a class, and the different apparent natural forms they belonged to. All rounded forms in nature respond to the fundamental characteristics of a circle (essence, type, or class) and are differentiated from the essential characteristics of a square and, besides, between the essence of a circle and a square there are no intermediate forms.

If we would apply biology typological thought, there would be no place for variation, but since Darwin we acknowledge that there is a *poblational thought*, but not the existence of types or variable essences, for example, among the species and even among the African, Asian, or Caucasian races – although there is racism involved which can not be supported by biology but by an ideology.

Determinism**:** the famous astronomer and mathematician Pierre-Simon de Laplace (1812) was proud to proclaim *"for an intellect that at any given moment could know all the forces that animate nature and the different positions of the beings included in it… nothing can be uncertain, and the future, exactly as the past, would be present in front of his eyes"*. As very well known today, studies on variation and *random* phenomena (genetic), are very important in biology.

Reductionism**:** physicists are "reductionists" because with inanimate objects, the problem of explaining a system was solved as soon as its analysis was broken down in its smaller components.

In biology, relations and interactions between the parts is of great importance and hence properties that are not present in the individual components may emerge; that is the reason why it is said that the whole is greater than the sum of the parts.

Universal natural laws*:* physics accepts that explanations, or its hypothesis if you will, are universal and these characteristics were described, in some historical moments as universal laws of nature.

Biology has a historical component, increased singularity of phenomena, variation, random and chance, thus for Ernst Mayr (3) most parts in biology theories are not based on laws but on concepts, such as the concepts of selection, species division, competition, population, bio-diversity and many others. Due to the fact that in biology the exception does not rule out – but confirms the rule; Karl Popper's falsificationism method cannot test biological theories by contesting them.

COMPLEXITY OF THE LIVING SYSTEMS COMPARED WITH INANIMATE OBJECTS

If we acknowledge three worlds according to their accessibility by human sensorial body organs, the micro cosmos (sub atomic world of elemental particles and their combinations) as well as the macro cosmos (world of cosmic dimensions) could be systems with relatively simple components, but the meso cosmos (from atoms to galaxies) where we, human beings live with our biological systems of macro molecules and cells is of extraordinary complexity, where new properties emerge at each integration level, hence the analysis provides almost always a better understanding about the systems but not their explanation.

Due to its complexity, biological systems show abilities that are absent in the inanimate systems, such as replication, reproduction, regulation, metabolism, adaptation, growth, hierarchical organization and many others that are part of the biological science and do not exist in the inanimate world.

The biological concept of evolution**:** as we already discussed, the inanimate world is formed by the classes – Plato's types and essences –; however, in the concept of bio population, each individual is unique, hence the mean statistical value of a population is an illusory abstraction (4). Even though two bars of any metal are identical, there are no two identical individuals in more than six thousand billion human beings. Populations do not differ in their essences, but only in their statistical averages, which in turn gradually vary in each generation. Therefore, the population thought and the populations are not "laws" of the classic physics, but "concepts".

Examples of concepts in the different biology branches are: territory, geographical isolation, sexual selection.

The double cause in biology**:** biological processes, in opposition to the purely physical, are not only controlled by the natural laws, but also by *genetic programs*. This dualism clearly defines the inanimate processes from the living. This is clear if we acknowledge that there is not one single process from the living world that is not partly controlled by a genetic program included in the genome.

Natural selection**:** after the variation of the living beings caused by mutation, recombination and environmental effects, in a second stage the variable phenotypes are selected according to the concept of natural selection, which is in fact a process of elimination of the least adapted whereas the most adapted are differentially reproduced. The concept of natural selection is the novel strength discovered by Darwin, which guides organic evolution, and is a completely unknown process in the inanimate world. This process allows explaining the apparent "designation" of the living creatures, so dear to the old naturalists who adopted "teleology", or to theologists who attributed it to the perfect design of God.

Evolutionary biology is part of the historical sciences**:** the origin of human beings, the evolutionary trends, as well as dinosaurs extinction are, to a large degree, singular phenomena that cannot be explained by laws or experiments. Hence, the new heuristic method to explain these phenomena is that of the historical narratives. As with any scientific method, an assumed historical narrative is build up, which is extensively tested afterwards in regards to its explanatory value, using the other observed factual events.

Although observation plays an important role in the physical sciences, as well as in the biological, and the experiment is the method mostly used in physical science and in a biology branch called functional biology, the historical narrative and the comparison of different facts form the most important methodology of evolutionary biology and of certain physical sciences such as geology and cosmology as well.

The holistic thought versus reductionism: rejection of reductionism in biology is not an attack to the analysis, as no complex system, such as the living system, can be understood if not by means of a rigorous analysis of it smallest parts. But if in physics this can explain all the system, in biology there are so many interactions among the parts that the full knowledge of the smaller parts provides only a partial explanation.

Nothing is so characteristic of the biological system as interactions, and the way in which the smaller units are organized into larger units is of essence for the new specific characteristics of those larger units. Thus, new characteristics are formed from the interactions of genes with the genome, genome with cells, cells with tissues, tissues with organs, organs with the organism, the organism with the inanimate environment and other organism with the echo system or the social group.

All these aspects were neglected by reductionism.

CONCLUSIONS

We tried to show that biology, one of the sciences that physicians use in his practice, is an autonomous science based primarily in the peculiar characteristics of the living world and non reducible to the physic sciences.

This occurs with biology because what matters in the study of a complex system is its organization, and even though the analysis allows certain explanations, at lower levels, the explanatory power of the precedent analysis can decrease. Even with inanimate systems, as pointed out by Thomas Huxley: to fragment, i.e. to analyze, water in its components of hydrogenous and oxigenous gas does not explain water emerging characteristic of “fluidity” when they combine. Another simple example of the inanimate world where new properties emerge is “the hammer” when both “head” and “handle” interact in combination; those new properties allow to pound nails into something, which would be impossible with the isolated head or handle. Molecular knowledge of the handle to figure out whether it is made of wood or plastic does not allow knowing which properties “emerge” from a hammer when they are together. This addition of interaction is what *constitutes* the crucial property of any emerging system, from the elementary particles to the superior levels. Also, biological systems store the information acquired historically in its genes, therefore modern “bio archeology” can tell us that all Native Americans descend from 10 to 20 brave direct ancestors who had the courage to cross the Bering Strait, or that all Europeans would descend from only seven women (Eve’s seven daughters).

It is fascinating to us, practical physicians, to learn that in the complex biological systems often times properties emerge that cannot be predicted by knowing the components of those systems.

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