6_ANNEXES

ANNEX 0_ GLOSSARY AND DEFINITIONS

A0.0_THE DEFINITION OF COMPLEX AND COMPLEXITY

Currently the terms *Complex* and *Complexity* are used in many different fields, coexisting also very different definition proposals for both [sometimes even within the same field].

This is the first obstacle that must be solved for a unified theory, because defining a term [or explaining the concept it refers to] is equivalent to setting the first premise[1] from which we infer the statements of the theory; **different definitions equate to different premises and necessarily lead to different conclusions.**

Therefore, as the first step for the present theory, it is necessary to arrive at a definition of those terms which must have two qualities:

- Be based on a sufficiently solid basis, which allows justifying the choice of such definition instead of others possible[2].
- Being able to embrace -and explain- the different utilizations of the term within the theories or fields of knowledge that are intended to 'unify'. All of them should be able to be conceptualized as particular cases of the general definition.

And we will be able to achieve it by reviewing the etymology of the two terms:

A0.0.0_OF 'COMPLEXUS' AND 'SIMPLEX'

The term **'complex'** is incorporated to English language from the French complexe, which in turn adopts it from the Latin complexus, with the meaning of:

> "a surrounding, encompassing, encircling, embracing, embrace…" [Lewis, 1879]
>
> "union, link, chain, encircle, ..." [Segura, 2014]
>
> "embrace, link, chaining…" [Coromines y Pascual, 1996].

How has it evolved from the original meaning of *complexus* [mainly as "embrace"] to its different uses today? To understand it, we need to deepen both into the etymology of *complexus* and its subsequent evolution.

The term complexus is the past participle of **complector** which means:

> "to link, to embrace, to wrap, to surround..." [De Miguel, 1879]
>
> "to grasp, clasp, seize, encircle, surround, compass, enclose" [Lewis, 1879]
>
> "to embrace, to encompass, to grasp…" [Coromines y Pascual, 1996]

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[1] [Carnap, 1945:397] proposes that a definition is "an equivalence statement". In certain way, it can be interpreted as the first 'axiom' on which a theory is based.

[2] Simply choosing one definition of the existing ones [or proposing a personal definition] would be an arbitrary act that may exclude from conclusions of the present text all those theories based on different definitions.

And the etymology of *complector* brings us in turn to the conjunction of two Latin terms derived from Proto Indo European [PIE] roots:

Cum, com:

from *kum [PIE]*: "Beside, near, by, with" [AHD 1992; Roberts & Pastor 1995].

"with, together" [De Miguel 1879; Klein 1966]

plecto, plectere, plexi, plexum:

from *plek [PIE]*: "to braid, to fold" [Roberts & Pastor, 1995]; "bend, fold, braid, twist, weave…" [Shipley, 1894].

"to bend, to fold, to link, to interlace" [De Miguel, 1879]

"to fold, to bend, to interlace, to link, to braid, to weave" [Segura, 2014]

We arrive to identifying *complector* with *interlace, braid or fold together* and *complexus* as *that which is interlaced, braided or folded together*, i.e., forming a unit or entity. The term **complexus refers** therefore **to the idea of different elements that come together composing a bigger entity without losing their individuality.**

Importantly, the original meaning of complexus significantly contrast with the concept of 'complicated' for which the Latin has a different term [complico,-are][3].

And it will be starting from SXVII that the term complexus incorporates the meanings of "complicated and intricate" [ODEE 1996; Harper 2014] and from SXVIII that it starts to be used to refer also to "not easily analyzed" issues [Harper, 2014].

There are two reasons for this *extension* of the meaning of the term 'complexus':

- On one hand, the prefix 'com' can refer to 'what is together' but also can imply an *intensification* of the term which accompanies [De Miguel 1879][4]. I.e.; 'com' can designate what is "woven together" but also what is "very woven"[5].
- Moreover, although Latin has a different term to designate what is *complicated*, its etymology is coincident with that of *complex*; both use the prefix 'com' accompanied by two terms 'plicare' and 'plecto' derived from 'plek'.

It is noteworthy that the term complexus expands its meanings in SXVII/SXVIII without deleting any of its previous meanings. Since then, it may designate that which is 'woven together', 'composed of many interlocking elements' or 'not easily analyzable'.

[3] *Complicare*: to fold, to bend, to twine, to screw. For instance, '*Complicata notio'* refers to a 'complicated idea' [Segura, 2014]

[4] This reference to the intensive nature of the term 'com' is also found in AHD 1992 and Harper 2014.

[5] This will be the dominant meaning in the *Sciences of Complexity*. For example, Gell-Mann [1994:22] proposes conceptualizing Complexity/what is complex as that which is "totally woven"

And if we divide into three areas the current use of the term 'complex' [Epistemology-Philosophy, Sciences of Complexity and unscientific use] their analysis shows us that each of these areas will choose [or at least 'prefer'] one of its possible meanings:

- Epistemology and philosophy will be making an ample use of the term that supports nearly all its possible meanings, preferring that linked to its etymology; **which is woven together**.
- The sciences of complexity will prefer the conceptualization of the complex as those **entities composed of many elements interacting in a not easily way to understand**, approaching the concepts of structure and network.
- The unscientific use of the term will mainly conceptualize it as **difficult to understand.**

However, while the etymological meaning of complex as 'that which is woven together' underlies all its possible uses, its other meanings do not.

Any complex object from the perspective of sciences of complexity or unscientific use of the term is also complex from the etymological perspective, but on the contrary is not the case; **an *embracing* is something complex -two people woven together- that 'is not made up of many elements interacting in a non-easy way' nor is 'difficult to understand'[6].**

Image 62: The dance *[Matisse, 1909] a picture essentially complex in the etymological sense. However, in the sense of the Sciences of Complexity or unscientific use of the term, it would hardly be designated as 'complex'.*

The unscientific and sciences of complexity uses of the term do not consider as 'complex' objects that are complex in the etymological sense of the term. They restrict the meaning of the term deleting its original meaning [which we can relate to its PIE roots -approximately 7,000 years old] and limiting it to meanings incorporated in the last three centuries.

And a Unified Theory must necessarily be built on a definition compatible with [or underlying] all its uses, which forces us to go to the original meaning of the term [**complex** as that **which is woven together**] that allows us to conceptualize its more restricted uses as 'particular cases':

- The sciences of complexity will refer to a particular case of 'complex objects with many elements and relationships that make difficult to understand them and predict their futures states'.
- The unscientific use of the term will refer to objects whose 'complexity' generates 'comprehension and analysis difficulty, leading to a difficulty of assigning them a truth value'.

[6] And an embrace let us highlight another issue that we have championed in the text. An embrace is not more embrace when the number of people involved increases, but when it is most intense. In systemic terms when interaction between the parts makes the global identity to more clearly emerge. The complexity of an embrace is less related to the idea of *organization* and more to the idea of *emergence*.

However, the above definition can be difficult to relate to the conceptualizations of the sciences of complexity that allude to a greater or lesser number of parts and relationships. Therefore, we propose a definition of **complex** slightly adapted as that **'which identity or meaning emerges [nonlinearly] from the interaction between its parts'[7].**

This definition will be broad enough to allow us its use referred to objects that go from something etymologically complex [e.g.: an embrace] to something complex as per the sciences of complexity [e.g.: a society]; including real objects [any of the above] but also conceptual objects [e.g. text or idea] that allow us to understand its unscientific use.

Thus we see that this definition will allow us to encompass all uses of the term, and also keeps a 'reasonable' resemblance to some dictionary definitions:

Complex [Drae, 2014]:

> "Composed by various elements"
>
> "Whole or union of two or more things"

And the term **Complexity** designates the "quality of complex" [Drae, 2014; Moliner, 2007]. It refers to the degree to which an object is complex, i.e., the object as a whole embraces, surrounds and braids its parts.

We thus identify *Complexity* as the **quality of those objects whose identity or meaning emerges from the interaction between some parts that make up a unit or entity without losing their individuality[8].**

Moreover, it is interesting that the term **plecto** means both 'to fold' as 'to braid' because both meanings involve subtle differences:

If we **interpret it as 'to fold'**, complexity would be referring to the idea of iteration as a rule to generate a global identity, approaching several concepts frequently used in the systemic perspectives [already reviewed in the text]:

- To fractal structures generated by indefinitely iterating a pattern through a self-similarity relation.
- To chaotic systems whose unpredictable behavior can be modelled as the iteration of simple formulas.
- To hierarchical structures and holarchies considering that each inclusion relation is equivalent to a nonlinear aggregation of information; i.e.: a 'fold'.

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[7] Actually, we have already seen that both *Emergence* [Lewes, 1875] and *Interaction* [von Bertalanffy, 1968] definitions involve nonlinearity. Therefore we put it in brackets indicating that it might actually be removed from the definition. We maintain this redundancy [or perhaps 'pleonasm'] to better clarify the idea.

[8] This allows us to state that from an etymological perspective "there cannot exist non-complex systems" [Alvira, 2014a].

Image 63: Paper Fractal. *Origami accomplishes by performing successive folds [ie dividing a paper in 'parts'] the emergence of a global identity not present in the parts.*

But we can also do some parallels with the idea of Ever-Increasing Complexity [without limits] of Adaptive Systems; if we had an infinite paper, there would not be a limit to the number of folds that we could do.

If we **interpret it as 'to braid'** it refers to the idea of interaction between two elements that limits its possible configurations, in turn generating a global form or identity.

- To the concept of System as organization of elements by a relationships structure that limit their possible states, defining their global identity.
- To Evolution as successive addition of rules that intertwine [interact] among them, shaping 'organisms' and 'behaviors/conducts'[9].
- To the ideas of *interdefinition* [elements give shape -or define- each other], *recursiveness* [the part shapes the whole, but the whole shapes the part] and *infiniteness* [no start and no end] present especially in the epistemological approaches to complexity.

Image 64: A basket *allows us to understand some of the qualities of complexity; how a global identity emerges from the intertwining of some parts [twigs] and in turn leads to three key ideas when reviewing complexity:*

- *Recursiveness: The twigs shape the basket, but the basket shapes the twigs.*
- *Interdefinition: The elements re-shape themselves due to their interaction with the other elements*
- *Infinity: The edge of a basket has no beginning or end [as neither has an embrace]; we could indefinitely cross it.*

We have therefore defined the terms *Complex* and *Complexity*; definition that will be the first premise on which to build the unified theory, allowing to encompass the majority of utilizations of the two terms [as general or particular cases] and it is interesting to review also two terms frequently used as complementary terms: Simple and Simplicity.

The term **simple** comes from the Latin simplex that we can also decompose into two Latin roots that come from PIE language:

- **plex** [from *plek*] which meaning we have already reviewed.
- **sim** [from *sem*] which meaning is 'one, same as one' [Shipley, 1984].

And this second term introduces some 'ambiguity' because it supports two interpretations that lead to different definitions:

- On the one hand, we can interpret it as 'that which is folded once' [i.e., it is folded into two parts]

[9] This allows us to insist that it is not possible to separate 'Complexity of Reality' from 'Epistemological Complexity'.

- On the other hand, we can interpret it as 'that which is bent in one' [i.e., that is not folded].

The importance of this issue is that in the second case *simple* would be the opposite of *complex*, while in the first case it would not. However, considering the meaning of the term, the second consideration appears to be the correct one[10]; **simplex** as **that which it is not folded nor woven:**

> "Straight [no folds or knots]" [De Miguel, 1879]
>
> "Which is not folded" [Corominas y Pascual, 2002 citing Berceo]
>
> "Characterized by a single part", ca 1590 [Harper, 2014]

The etymological analysis leads us to **complex -that which is folded or woven-** as the opposite concept to **simple -that which is not folded nor woven-**. There is a binary separation between the two concepts; only that which does not interact will be simple and therefore *any object which emerges from the interaction between two or more elements is a complex object.*

However, we have seen that in the SXVII / SXVIII the term complex expands its meanings, and this leads to a change in the meaning of the term simple[11]. **In the areas in which *complex* is used to designate 'that in which a large number of elements interact' *simple* is going to designate objects that do not necessarily lack interaction, it is sufficient that 'only a small number of elements interact' or 'their interactions are easy to understand'.**

And the hue becomes very important for two reasons:

- The first is that the gap between simple and complex is *binary in the Etymological sense*, but becomes a *diffuse* separation in the sense of the *Sciences of Complexity* and *unscientific use of the term*. What was a well-defined limit becomes a border impossible to pinpoint: **it is not possible to set an exact point when an object goes from having few to many elements[12] or from easy to difficult to understand.**
- The second is that *the term simple in the sense of complexity science or non-scientific use can be used to designate objects that are complex in the etymological sense of the term* [e.g., an embrace or five people dancing in a circle].

[10] *Simplex* shares etymology with *Duplex*, *Triplex*. *Duplex* is not what is folded twice [folded in three parts], but what is folded in two parts. *Triplex* is not what it is folded three times [folded in four parts], but what is folded into three parts, etc. The term Simplex refers to the idea of *folded in one*, i.e. 'un-folded'.

[11] The meaning of linguistic terms is shaped due to their interaction with the opposite terms [they interdefine]. So, when a linguistic term changes its meaning, the opposite term necessarily modifies it too. Saussure [1945] qualifies the 'language' as 'essentially complex'; as a set of rules and interactions between the different terms.

[12] This is why scientists from the Sciences of Complexity never agree to define when 'complexity starts'. It is not possible to set a sharp [exact] limit for a 'fuzzy' concept.

Apparently, according to the criteria above, we should propose a definition of simple that encompasses all its possible uses. However, a review of this issue from Spanish and English languages shows two different situations:

In Spanish both the use of term simple in the context of Sciences of Complexity as its unscientific use, can be perfectly replaced by term 'sencillo'.

> **Simple** [Drae, 2014]: which offers no difficulty

Therefore, there is no reason why the word 'simple' could not be used in the etymological sense.

However, English language has no term to differentiate what is 'simple' from what is 'sencillo'; both issues are designated by the same term: 'simple'[13].

Hence, in English a definition of 'simple' should encompass any of its possible uses, thus ‘simple’ may refer to which…

… Is not compounded or is composed of non-interacting parts
… Consists of a small number of interacting parts
… It is easy to understand

But proposing a definition of the term 'simple' in Spanish takes us to two options both presenting some drawbacks:

- Using the term 'simple' to designate also the 'sencillo' is unnecessary while it can lead to some confusion, since there are cases where both terms are used for different questions.
- Using the term 'simple' to designate only what is 'uncompounded' could lead to confusion when translating English-Spanish texts, thus missing the unifying interest of this proposal[14].

We see that the term simple is not going to allow us its use with a single meaning, but -especially in English- it will require us to admit an ample use and may designate 'which is easy to understand', coinciding with the Spanish term 'sencillo'.

The 'simple' may be or not the opposite to complex depending on the context, and therefore in a Unified Theory we do not differentiate between 'complex' and 'simple' objects but between non-complex and complex objects.

[13] Interestingly, the etymology of 'sencillo' goes back to the Latin 'singulus' [which in turn is also derived from PIE 'sem'], whose evolution in the English language leads to the term 'single', whose meaning 'considerably' differs from that of 'sencillo'.

[14] The unifying interest of this proposal does not arise only in relation to the joint understanding of the different conceptualizations of complexity; also in relation to communication between scientists.

A non-complex object will be that which does not fulfill the proposed definition of complex, i.e.: **which identity or meaning does not emerge from the interaction between its parts.** Another way to conceptualize it is as **'that which is not compound or is compound by addition or superposition of non-interacting [independent] parts'.**

Image 65: A dozen of eggs *is a 'non-complex' object in relation to its parts [the eggs]. The overall identity is the result of the sum or superposition of these parts; which do not interact between them.*

However, if we change the scale, each egg itself is a complex object; and it is almost sure that the price of a dozen eggs is lower than the sum of the price of each egg. This shows us the difficulty of finding real objects that are not complex in any scale or from some perspective.

And we can relate the above definitions with a statement that appears recurrently throughout the history of philosophy: **the whole is not the sum of the parts.**

The concept of interaction is associated with the idea of non-linearity; the generation of a global entity that is not resultant of the superposition or sum of the parts [Von Bertalanffy 1968; Simon 1962; Morin 1990], and this leads us to inextricably link the concepts of complexity and non-linearity:

- **Complex objects** are those in which two or more parts interact, that is, in which 'the whole is not the sum of the parts'; *the whole is not deductible as a superposition or linear aggregation of parts.*
- **Non-complex objects** are those in which their parts do not interact, i.e., in which 'the whole is the sum of the parts'; *the whole can be generated as a superposition or linear aggregation of parts.*

The criterion of non-linearity / linearity is established as necessary / sufficient condition for determining whether a phenomenon is complex or not; an object may or may not be complex but it will not be by halves.

Furthermore, if we review all definitions of complexus, we see several common characteristics:

- Braid, fold, embrace ... all involve a type of interaction between parts.
- Encompass, encircle, embrace ... all of them involve a global shape or identity.

Essentially complexity refers to the existence of a global form or identity that emerges from the interaction between parts; to a whole that relates nonlinearly to its parts.

The concept of 'complex' links to those of Organization [or interactions system between parts] and Emergence [of an identity or globally recognizable form] and becomes equivalent to the concept of 'system'.

A0.0.1_THE DEFINITION OF COMPLEXITY IN THE SCIENCES OF COMPLEXITY

The use of the term complexity by the *Sciences of Compl*exity is based largely on the sense in which it was used by Weaver in his article 'Science and Complexity' [1948][15].

Although Weaver does not explicitly define it, he uses it referring to 'being composed by many interacting elements in a way not easy to understand'.

And this conceptualization of the *complex* involves breaking the equivalence between the terms *complex* and *system*, and will be developed and reinforced by all scientists in the framework of the *Sciences of Complexity*:

- Simon [1962: 468] defines a complex system as "made up of a large number of parts that interact in a nonsimple way"
- Von Bertalanffy [1968] describes Auto-differentiating Systems as Systems of Ever-Increasing Complexity, suggesting that *systems' complexity* increases as their differentiation / amount of organization increases.
- The proposal itself of 'Complex Adaptive System' [Gell-Mann, 1994; Holland 1995] which adds the word 'Complex' to the name Adaptive System [Simon, 1962] confirms this breach of the equivalence between the terms complex and system[16].

In the framework of the Sciences of Complexity the possible meanings of the term 'complex' are restricted, thus eliminating both the 'epistemological' as the 'unscientific' use of the word[17].

This restriction of the meaning becomes clear when reviewing the dictionaries of universities linked to the world of the sciences of complexity, that have eliminated the meaning of **complex** as 'which is woven together' keeping only those that also imply having a large number of parts:

> "involving a lot of different but related parts" [CDO]
>
> "consisting of many different and connected parts" [OED, 2014]

And shifted the meaning of **complexity** from the "quality of complex" to

> "The state of having many parts and being difficult to understand or find an answer to" [CDO, 2014]
>
> "The state or quality of being intricate or complicated" [OED, 2014]

[15] It is at least curious the existing semantic parallelism between Proto Indo-European and Latin roots [plek / plecto] one of whose meanings is 'to weave' and the surname *Weaver*; i.e.: 'a person who weaves'.

[16] Therefore, in the framework of the *Sciences of Complexity* only those systems composed of many elements and relationships are considered complex.

[17] Apparently the use of the term complex by the Sciences of Complexity could be compatible with its non-scientific use as "difficult to understand", but it's actually not. There are many objects difficult to understand which are not complex as per the sciences of complexity [eg, any logical contradiction as the liar paradox; a surreal painting, etc…]

It is noteworthy that this restriction/modification of the meaning of the terms *complex* and *complexity* is not characteristic of the entire English-speaking world. The Dictionaries non related to the world of the *Sciences of Complexity* include its new meanings but retain the original meanings of the term:

Complex [TRHD 1967; AHD 1992; NWD 1995]:

> "Consisting of interconnected or interwoven parts; composite"
>
> "Composed of two or more units"

Complexity [TRHD 1967; AHD 1992]

> "The quality or condition of being complex"

This 'restricted' conceptualization in the framework of the sciences of complexity is an impassable barrier to any unifying theory since it does not support other possible meanings of the term which are necessary for understanding its use in other areas, such as epistemological and unscientific fields.

It is not possible to build a Unified Complexity Theory based on the definition of complexity by the sciences of complexity that have limited its meaning, proposing that not everything that is woven together is complex; only which also meets the condition of being composed of many elements and difficult to understand.

This explains, for example, that although certain epistemological proposals of Complex Thinking are accepted in the world of the Sciences of Complexity[18], they are not linked to the term *complexity* but considering them philosophical issues. And that 'complex issues' according to the unscientific use of the term are not considered complex in the field of *sciences of complexity.*

A unified complexity theory will only be possible if scientists in the sciences of complexity revise their definitions of *complex* and *complexity*, adopting the ones we have proposed, or other similar that shall be consistent with the other uses of the terms.

A0.0.2_REFERENCES EXCLUSIVE FOR THIS ANNEX

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[18] In part because without epistemology is not possible to do science, and in part because some ideas of *Complex Thinking* are re-elaborations of former systemic scientists' proposals [Von Bertalanffy, Wiener, Ashby, Von Foerster...]

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