Understanding innovation ecosystems: a biomimetic approach

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Abstract: This essay seeks in the original concepts of ecosystems derived from Biology, to expand the knowledge of the innovation ecosystems field, from Biomimetics. Using this approach, it was possible to offer a set of original findings and answer some criticisms in the management literature. Among the current criticisms is that there is no difference between the approach of innovation systems, for that we approach the origin of the term "eco" and learn that an innovation ecosystem is formed by agents and economic relations (biotic elements), as well as non-economic parts, such as technology, knowledge, laws, culture, etc. (abiotic elements). In other words, an innovation system deals only with the "biotic" part, while the study of ecosystems becomes more complex. Another current criticism refers to the limits of the phenomenon for management studies. From biomimetics, we learn that the limit of an ecosystem is given geographically (physical space) and must understand the identification of the different set of actors it comprises (biotic) and how they interact with the non-economic (abiotic) elements in that space. The mainstream has also proposed some ecosystem life cycle assessments and we propose that dynamics of roles and forms of action evolve according to the life cycle of the ecosystem, which follows a process of co-evolution, and we also discovered what guarantees can build, maintain or shatter na innovation ecosystem. And finally, we emphasize that Innovation Ecosystems can be created, but they need forms of governance to guarantee their evolution, as a way to face criticisms about the impossibility of creating innovation ecosystems in different spaces.

Key words: Innovation Ecosystems; Ecosystems; Biology; Biomimicry; Management; Research Opportunities.

Résumé: Cet essai cherche dans les concepts originaux des écosystèmes issus de la Biologie, à approfondir la connaissance du domaine des écosystèmes d'innovation, à partir de la Biomimétique. En utilisant cette approche, il a été possible de proposer un ensemble de résultats originaux et de répondre à certaines critiques dans la littérature de gestion. Parmi les critiques actuelles, il n'y a pas de différence entre l'approche des systèmes d'innovation, car nous abordons l'origine du terme «éco» et apprenons qu'un écosystème d'innovation est formé d'agents et de relations économiques (éléments biotiques), ainsi que parties non économiques, telles que la technologie, les connaissances, les lois, la culture, etc. (éléments abiotiques). En d'autres termes, un système d'innovation ne traite que de la partie «biotique», tandis que l'étude des écosystèmes devient plus complexe. Une autre critique actuelle fait référence aux limites du phénomène pour les études de gestion. De la biomimétique, nous apprenons que la limite d'un écosystème est donnée géographiquement (espace physique) et nous devons comprendre l'identification des différents ensembles d'acteurs qu'il comprend (biotique) et comment ils interagissent avec les éléments non économiques (abiotiques) de cet espace. . Le courant dominant a également proposé des évaluations du cycle de vie de l'écosystème et nous proposons que la dynamique des rôles et des formes d'action évolue en fonction du cycle de vie de l'écosystème, qui suit un processus de co-évolution, et nous avons également découvert quelles garanties peuvent construire, maintenir ou briser un écosystème d'innovation. Enfin, nous soulignons que des écosystèmes d'innovation peuvent être créés, mais ils ont besoin de formes de gouvernance pour garantir leur évolution, afin de faire face aux critiques concernant l'impossibilité de créer des écosystèmes d'innovation dans différents espaces.

Mots-clés: Écosystèmes d'innovation; Écosystèmes; Biologie; Biomimétisme; Gestion; Opportunités de Recherche.

Introduction

Just over two decades after the introduction of the concept of ecosystems in the field of management (Moore, 1993), researchers began to use this term with great frequency. Academics contributed to the development of the theme considering the concept of business ecosystem (Moore, 1993) and advancing to developments such as innovation ecosystems (Adner, 2006). In the literature, innovation ecosystems have gained prominence as they seek to understand that innovation, whether perceived as a process or as a result, increasingly depends on a dynamic of robust interaction between the various actors present in a context (Ritala; Gustafsson, 2018).

The innovation ecosystems approach, as well as the concepts of industrial districts, clusters and innovation systems, converge, of course, in the central axis of the complementarity of the organization's resources with its external environment. However, the literature on innovation ecosystems differs among other theories on collaborative innovation arrangements because it "borrows" from ecology the concept of "ecosystems". Defined as the system that results from the integration of all living and non-living elements of a given environment. Tansley (1935) precisely complements the concept of ecosystem, indicating that “eco” implies an environment and “system” implies a complex interdependence interaction.

Thus, when using such ecological metaphors, the approach to innovation ecosystems aims to highlight and problematize some forgotten or largely silenced dimensions in the mainstream of innovation management studies. Thus, concepts such as diversity, collaboration, complementarity, interdependence and balance, addressed in a very marginal way in the classic studies on innovation systems gain central relevance in elucidating why some innovation environments have significant differences in evolution and performance.

In bringing the metaphor of innovation ecosystems to the study of innovation environments, we must go far beyond the institutional and apparent elements of classical innovation systems approaches. Evidently, the institutional characteristics of national, regional and sectoral innovation systems are elementary for innovation processes and results. However, increasingly, world-class innovation environments, unequivocally present “eco” elements.

Despite the term being borrowed from Biology, efforts reveal that there is a lack of theoretical consistency in relation to the terminology, which tends to produce a fragmented and diversified theory, which makes it difficult to consolidate knowledge (Oh et al., 2016; Scaringella ; Radziwon, 2017). In management, we are prodigious at borrowing concepts from other áreas of knowledge without proper contestualization. We use them as metaphors without contextualizing them, which leaves the concepts fragile. In this sense, the question then arises: what can we learn about ecosystems with biology to be able to better manage and study these innovative environments? In order to advance this understanding of innovation ecosystem management, we use a biomimetic approach. Biomimicry is an emerging discipline that explores how nature works and how we can learn from nature to solve human problems. The word itself, "biomimetics" comes from the Greek bios (life) and mimesis (imitation). Thus, we recover the biological concepts of ecosystems and all their elements and then present proposals that can serve to improve the understanding of the phenomenon of innovation ecosystems. We are talking about the management of innovation ecosystems, because more and more, public policy makers have been concerned with these environments to promote the competitive differentials of their territories and, what is perceived is that little is known about how to manage these environments and promote their development. In this sense, we believe that we can learn or create more solid bases from ecological knowledge. In order to facilitate the understanding of these concepts, we will provide examples alongside of this essay.

Our ambition to better understand the phenomenon of innovation ecosystems from a biomimetic approach, allowed us to create 6 propositions related to the limits of the phenomenon, the levels of analysis, as well as evolution and life cycle. Although biomimicry allows us to advance the understanding of the phenomenon and provide answers to the most common criticisms in this field, we know that there are differences between natural sciences and social sciences that will not be addressed in this essay.

1. The concept of ecosystem: from biology to business

Moore (1993) was the first to adopt the term ecosystem from biology. Inspired by anthropologist Gregory Bateson, who described the coevolution of interdependent species in a continuous cycle, and biologist Stephen Jay Gould, who noted that new ecosystems are able to establish themselves from the collapse of natural ecosystems in the face of radical changes in environmental conditions, Moore (1993, p.2) formulated the concept of business ecosystems, where companies "co-evolve their capabilities around a new innovation: they work cooperatively and competitively". The author wanted to understand the strategic logic behind the change and how executives could anticipate management challenges to drive complex business communities with a focus on innovation.

For Moore (1993), faced with events such as the emergence of high-tech companies, a new understanding was needed for these issues that were still seen as problems companies faced in an industry. That is, companies needed to be seen as part of a business ecosystem that spans a variety of sectors. Thus, "in a business ecosystem, companies coevolve capabilities around a new innovation: they work cooperatively and competitively to support new products, satisfy customer needs, and eventually incorporate the next round of innovations" (Moore, 1993, p. 2).

Moore (1993) goes on to explain in his article that the ecosystem approach takes the focus off individual companies, leading to competition between business ecosystems, which includes the role of a variety of actors in order to drive change. However, an interlocution is not built with what biology means by ecosystem and what, from that, it is possible to add to the area of management, which goes beyond the traditional systemic approach and which justifies the inclusion of the prefix "eco".

From the concept developed by Moore (1993), the use of the term ecosystem began to gain importance in management research to refer to a network of interconnected organizations that normally operate around a focal company. Adner (2006, p. 98) based on what Moore (1993) had called the business ecosystem, coined the term innovation ecosystems and defined it as "the collaborative agreements through which companies combine their individual offerings into a coherent solution customer-oriented ". Therefore, an ecosystem goes beyond the idea of a management system, not only being the "set of actors" (Nelson, 1993; Lundvall, 1992), but the "dynamics of the complex relationships that are formed between the actors" (Jackson, 2011 , p. 2).

From this, several authors started to describe the field of innovation ecosystems from different perspectives, defending the use of Eco (Adner; Kapoor, 2010; Jackson, 2011; Thomas; Autio, 2014; Oh et al .., 2016 ; Gomes et al. 2016; Adner, 2017; Scaringell; Radziwon, 2017; Ritala, 2017; Wang; Zhai, 2019). Gomes et al. (2018), in a systematic literature review, between the years 1993 and 2016, with a hybrid methodology of bibliometric and content analysis, differentiating the two terms - business ecosystems and innovation ecosystems -, attributing to the first the function of capturing value , while in innovation ecosystems the main focus is value creation. However, the author makes the analysis based on the articles of his bibliometrics, without seeking a dialogue with the biology area.

Despite the fact these concepts try to make an analogy with the biological concept of ecosystems, these analogies lack deepness with biological ones. According to Oh et al. (2016) e Scaringella e Radziwon (2017), it leads to a faulty analogy to natural ecosystems, and is therefore a poor basis for the needed multi-disciplinary research and policies addressing emerging concepts of innovation. Due to this lack of depth in this analogy with biological systems, it is necessary to bring to the business environment greater detail of biological concepts of ecosystems, ecological succession and how ecosystems evolve.

1.1 The origin of "eco"

The term *ecosystem* was first used by Tansley (1935, p. 299). According to Tansley, Clement´s concept of biome as the whole complex of organisms inhabiting a given area was not complete. One should not just investigate the organisms and how they interact among them, but the whole system. In this concept, the whole system includes not just the organism-complex but also the whole complex of physical factors forming the environment. For him, although our nature (as human beings) lead us to consider the organisms the most important part of these systems, we should consider the inorganic part also important, due to the fact that there is constant interchange of the most various kinds within each system, not only between the organisms but between the organic and the inorganic. These *ecosystems* are of the most various kinds and sizes.

Thus, we can define ecosystem as a system formed by all organisms (biotic element) that occur in a particular location, the nonliving environment (e.g. minerals, water, climate, landscape – abiotic element) and how they interact (Evert; Eichhorn, 2013). Thus, when management authors (Adner, 2006; Jackson, 2011) refer that the "eco" inserts in the notion of system the dynamics of complex relationships that occur between the actors to create value, it is necessary to emphasize that in these relationships the elements of the environment cannot be forgotten, because without them this notion of system is closer to biological communities than to ecosystems.

Thus, as well as in biology, other elements besides the actors (biotic elements), must compose the ecosystem, which we can call environmental elements (abiotic elements), for example: institutional elements (which were already considered in innovation systems), quality of life, climatic conditions, culture, history, technology, legislation, etc. Thus, it will be the relationship between the actors of the quadruple helix -

universities, individual companies/entrepreneurs, government and organized civil society (Carayannis et al., 2018), and of these with the elements of the environment, to create value, which will constitute what we propose in this essay as an innovation ecosystem. Jucevicius et al. (2016) when defining ecosystems as complex adaptive systems, he already drew attention to the elements of the environment, because according to the author, every innovation ecosystem is unique, historically evolved and incorporated into the cultural and institutional fabric of the region. However, what nature teaches us is that these elements are not just a background, but must be taken into account in the dynamics of the relationships of innovation ecosystems. In this sense, concepts such as diversity, collaboration, complementarity, interdependence and balance, addressed in a very marginal way in the classic studies on innovation systems gain central relevance in elucidating why some innovation environments have significant differences in evolution and performance.

When paying attention to the dimension of "quality of life" present in an ecosystem, when bringing to social and economic phenomena, it is essential to bring, in a complementary way, the studies of economist Amartya Sen, Nobel Prize in Economics in 1998. Sen (1998) makes a strong defense of the elements of freedom as central to economic development, that is, there will hardly be balanced and development environments without political and economic freedoms, social opportunities and guarantees of security and transparency. The study of ecosystems must take into account the dynamics of economic relations between the different sets of actors (governments, universities, companies and society), as well as the relationship between the set of actors and non-economic elements (technology, quality of life, freedom, culture, public security) in a given physical space (see figure 1). In this sense, we can summarize one of the first lessons learned from the biomimetic approach from biological ecosystems to innovation ecosystems:

(L1) An innovation ecosystem is formed by agents and economic relations (biotic elements), as well as non-economic parts, such as technology, knowledge, laws, culture, etc. (abiotic elements).

Studies that do not take these three aspects into account are studies that are looking at only parts of an ecosystem, but not the ecosystems as a whole. To better understand this, we present the hierarchy found in innovation ecosystems in the next section.

1.2 The ecosystem boundaries

The boundaries of an *ecosystem* can be the entire planet (in this case we refer to the global ecosystem as *Biosphere*), the Amazon forest, a city, a neighborhood, a company or as tiny as 1 square meter of soil with all the microorganisms and minerals that make up this soil. In other words, when one is studying how populations interact among them and with the abiotic element in a certain area, this area is set by the researcher (Evert; Eichhorn, 2013) . So to better understand it, the ecologists break it into parts to analyze it. One useful way to study *ecosystem* is to focus on the biological hierarchy. We understand that the same can be done if we think in terms of innovation ecosystems.

In biology the biotic part of an ecosystem is formed by a set of individuals from different species. The individuals of the same species that live in a particular location and can potentially interbreed and form a population. Following this, we can define *species* as a group of populations that can interbreed in nature. The next biological and highest level is the community. The community is formed by all the populations of an *ecosystem*. Community can also be divided into subsets of the whole, e.g. the bird community, the plant community or the microbial community. The community together with the physical environment (abiotic element) form the *ecosystem* (Evert; Eichhorn, 2013). In short, an ecosystem is characterized by its parts (biotic and abiotic) and how they interact with each other. But in order to set a limit, you have to identify who these components are. So in this case, you have to look at the community and the populations that comprise it. By identifying the populations it comprises and the physical space they occupy and how they interact with the abiotic elements in that space, you identify the limits of the ecosystem.

Transporting this knowledge to management, this division can be made according to Table 1. Individuals of the same species would be the actors of an ecosystem, for example, universities. The populations would be formed by the set of actors of the same type, like the educational institutions. Finally, communities would be formed by the set of populations of an innovation ecosystem, such as the population of educational institutions, the population of technology companies, the population of civil society organizations, the population of government levels (federal, state, among others - and is similar to studies of innovation systems. So, in order to limit an ecosystem, you have to look at the innovation system (community) that makes it up. By identifying the populations it comprises and the physical space they occupy and how they interact with the abiotic elements in that space – you have identified the limits of the ecosystem.

In the field of management, this issue has already been addressed by scholars who introduced limit parameters (Thomas; Autio, 2012; Autio; Thomas, 2014; Ritala; Almpanoupoulou, 2017). Some authors define the limits of the ecosystem around a Hub / focal actor firm (Adner; Kapoor, 2010; Adner, 2017), others around a platform of actors in a certain sector / technology, or even considering territorial limits, with examples from the Silicon Valley ecosystem, for example (Adner; Kapoor, 2010; Hwang; Horowitt, 2012). However, this is not so simple. And, it is for the sake of simplification that we end up running the risk of treating innovation ecosystems in the same way that studies linked to innovation systems do (which focus on communities) and not for their non-economic relations with the physical environment.

Elements of an ecosystem in biology	Biomimetical Learnings	Examples in management field
Individual. Eg: a bird of the specie *Vanellus chilensis*	Nature teaches us that ecosystems are made up of different individuals. In terms of management, innovation ecosystems are formed by different actors.	Actors such as: A hub firm or focal actor; The municipal government; A university; Civil society leadership
Population. Eg: Set of individuals of a species that inhabit a region	Nature teaches us that for an ecosystem to maintain itself, populations must be maintained, even if the individual does not remain (even if an organization is extinct).	Set of actors such as: Education organizations, organizations representing government at different levels, business populations - Comprises platform studies of actors in a given sector/technology
Community. Eg: Set consisting of all populations of all organisms in a region.	Nature teaches us that the set of populations that exist in an environment is known as a community.	Different sets of actors that can be found in one location: The complete mapping of actors in an ecosystem. The community refers to the innovation system.
Ecosystems. Eg: the ecosystem is formed by the populations of all organisms found in that region and the environment they inhabit and interact with.	Nature teaches us that to think in terms of the ecosystem it is necessary to take into account the biotic, abiotic elements and the relationships that are established between them.	Set of actors of the four helix + elements of the environment + dynamics of relationships between them to create value

Table 1: Biomimetical Learnings on Innovation Ecosystems
Source: authors.

Thus, in the final analysis, the great criticism of the analogy to the biological concept and use of the term "eco" is totally understandable, since current studies continue to study only the system and not the ecosystem. If what is being studied are merely the interactions between the actors, you are studying either the interaction between the members of a population or the interactions between populations. You are studying systems. When you put the prefix "eco", it means that you put the abiotic element (technology, quality of life, freedom, culture, public security) and all the relationships of the actors with it in your study. In other words, the study of innovation systems is limited to the study of the set of actors and their relationships in a given location, while the study of an ecosystem must also understand the relationship of these actors with non-economic elements. In this sense, we highlight the second learning from the biomimetic approach from biological ecosystems to innovation ecosystems:

(L2) The limit of an ecosystem is given geographically (physical space) and must comprise the identification of the different set of actors it include (biotic) and how they interact with the non-economic (abiotic) elements in that space.

The interaction between the actors of the ecosystem guarantees the flow of "energy" in the ecosystem and allows its development, as we will learn in the next biomimetic comparison.

1.3 Ecosystem as an energy flow

Back to Biology: in 1942, Lindeman proposed that the *ecosystems* are energy transforming systems and included the inorganic nutrients at the base of the chain. Lindeman (1942) proposed that energy flows through the *ecosystems* from one trophic level to another, forming a food chain in which all organisms are somehow connected to each other. This notion that *ecosystems* are emerging transforming systems provided a useful way to study them. According to Evert and Eichhorn (2013), as we have seen, living organisms require a constant supply of usable energy, and so we may consider the ecosystem as an energy-capturing and energy processing system. It can exist only if energy continuously flows through it. He chose the word "flow" to express the idea that all the energy captured by living organisms in the ecosystem will be dissipated in the form of unusable heat, for him, although energy can be stored in various forms (for example, as the starch in a potato tuber), sooner or later it must leave the system.

Within the range of interactions between groups of organisms and their environment, those involving energy exchanges are most useful in the study of ecosystems. The energy flows starts with the organisms that are capable of capturing usable energy and nutrients from the nonliving environment (abiotic elements) and use it to power their day-by-day activities (growing, physiological activities, reproduction, etc) and biomass production. These organisms are called primary producers, and they compose the first trophic level. The next trophic level is composed of animals (herbivorous) that eat plants and use its biomass as an energy source in the same way as the producers, and are called the primary consumers. Finally, the last trophic level is composed of the animals that feed on other animals (carnivorous). These animals use the biomass of other animals (herbivorous or carnivorous) as na energy source, and they are called secondary consumers. An important aspect of the energy flow through the trophic levels is that not all the energy produced in one level is transmitted to the next one (Begon, Townsend; Harper, 2006).

Nature teaches us that the lower the energy loss, the greater the efficiency of the ecosystem. If we think in terms of the innovation ecosystem, we can compare these energy flows to resource flows. Thus, if the government invests, for example, financial capital for the formation of intellectual capital and, the ecosystem is not able to retain the trained talents, we will waste resources and decrease the efficiency of the ecosystem. Thus, the greater the interdependence between the actors in an innovation ecosystem, the greater the dynamics of resource exchanges. In this sense, we learned that:

L (3): The resources flow through the actors (universities, industries, companies and civil society), reflection of interdependence between actors, can build maintain or shatter innovation ecosystem.

In Figure 1, we present a configuration of an innovation ecosystem including the economic (biotic) and non-economic elements (abiotic) and their interdependencies relations, that guarantee the continuity of value creation.

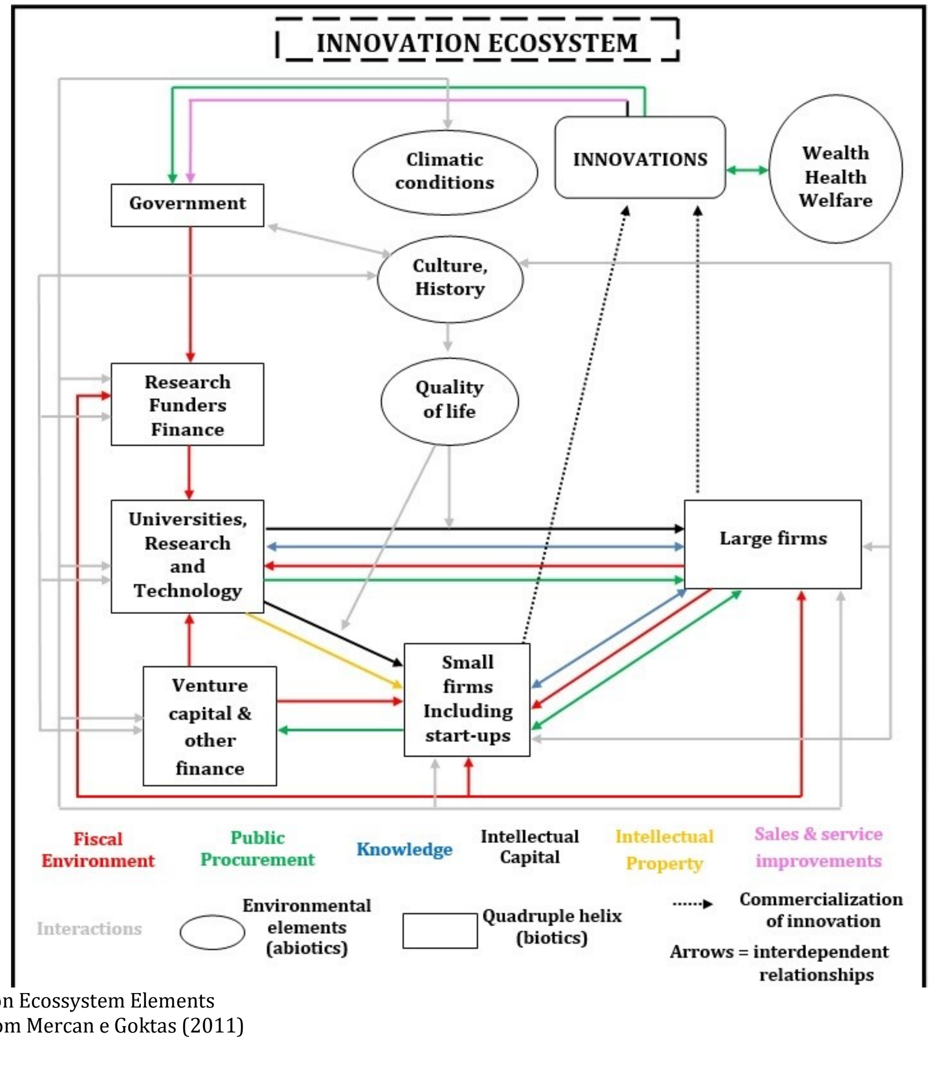

Figure 1: Innovation Ecossystem Elements
Source: Adapted from Mercan e Goktas (2011)

In addition to the dynamics of the exchange of resources (energy), the roles and relationships between the actors must also be considered in the process of evolution of the ecosystem, as we will see in the next section.

1.4 The ecosystems evolution

Understand how the energy flow in ecosystems is important, but it´s not all that matters. Ecology is the study of ecosystems and an important part of it is the interactions among the elements of the ecosystem. A common view in ecology is that everything is connected. In other words, no organism exists in isolation (Evert and Eichhorn, 2013). The interactions of the organisms among each other and with the environment is responsible for the natural selection postulated by Charles Darwin in his classic book *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life* (1859). According to Darwin, the organisms, in one population, that possess traits that allow them to better survive will produce more offspring and, as a consequence, new organisms possessing that trait will become more numerous. According to Darwin, the population posses a pool of characteristics that will be selected or not by the environment. So, those organisms, in the population, that posses the most favorable traits to allow them to survive the changes in the environment will be selected and will produce more offspring. This will lead to an increase in the number of organisms with that trait and, as a consequence, will lead to changes in the characteristics of the population. This is how species evolve in an ecosystem.

Since the interactions among organisms and of them with the environment is ultimately responsible for the selection of the fittest organisms in a population, it´s important to talk about some types of interaction that happens in a ecosystem: consumer-resource, mutualism and competition. The first type of interaction is the consumer-resource. In this type of interaction, consumers obtain their energy from the resource. Consumers refer to either a herbivorous or carnivorous population that feeds on their prey (plants and other animals, respectively), or a plant population that draws its resources from the environment (minerals, water, light). In turn, resources refer to those individuals (animals and plants) that serve as food for others, as well as to the mineral resources used by plants in their nutrition. It´s said that consumer-resource interaction explains the energy flow from one trophic level to another and how this flow is organized. Observing this type of interaction, one can notice that the resource population controls the size of the consumers and vice-versa. It happens due the fact that the resource population is limited in size by the predation made by consumers, and, likewise, the availability of resources limits the consumer population to a level that can be maintained with these resources. Here populations evolve due to the rise of new traits that allow consumers to more efficiently locate and explore the resources (e.g. eyes that can view with more definition or objects that are far from them, noses that can perceive smells from higher distances), or allow the resources to better avoid being consumed (e.g. auditory systems that perceive the consumer approach more efficiently). These new traits will be selected and will be more present at the population in the next generations(Ricklefs, 2008).

The second type is the mutualism. Here the interaction produces benefits for all organisms involved. According to Begon, Townsend and Harper (2006, p. 381), the mutualism involves the direct exchange of goods or services (e.g. food, defense or transport) and usually results in the acquisition of novel capabilities by at least one partner. Here the agent of selection is the relationship among the organisms. The characteristics that favor this relationship, making it more efficient, will be positively selected and become more common in the next generations. This is the type of relationship that we seek to highlight in an innovation ecosystem, an interaction in which the actors co-evolve in harmony with the elements of the environment. The notion of co-evolution, which unites the actors over time, was pointed out by Moore (1993), to define the business ecosystem.

The third one is the competition. In this interaction, two or more organisms from different species compete for the use of the same required resource that is available in limited supply. Here required means that the organisms need the resource in order to survive, and limited means there is a fixed supply of the resource. Experimental data that shows if two or more organisms compete for a resource is that (1) without one of the competitors, the remaining ones will perform better (grows faster, produces more offspring) and (2) when this improved performance is shown to be due to the organism's having access to resources that would otherwise have gone to its competitors. The competition is one of the main forces that drives the natural selection. Here traits that increase the efficiency to obtain the resource will be favored and thus selected (Evert and Eichhorn 2013, p.31-10).

This last type of interaction reminds us that even in nature there is competition. Thus, in an innovation ecosystem, although cooperative relationships are very important to increase the potential for creating value for innovation, what happens is what we call coopetition. A variety of actors with common goals integrate innovation ecosystems (Brusoni; Prencipe, 2013), which interact in a complex way, sometimes cooperating, sometimes competing with each other (Shaw; Allen, 2016). One reason for this is that each actor in the ecosystem has its own network, with individual characteristics and objectives. However, the success of an innovation ecosystem cannot be defined through the individual performance of an actor, but through solutions found together and the creation of value generated by interaction (SONG, 2016). Thus, the innovative performance of a given business environment depends on behavior, especially in the interactions between the actors of the quadruple helix (Carayannis et al., 2018; Carayannis; Rakhmatullin, 2014).

Understanding how these relationships occur in biology, helps us to reflect on what characteristics need to be developed in populations so that they favor the evolution of an innovation ecosystem (which characteristics can improve the exploitation of resources or make the ecosystem survive in a changing environment). Thus, throughout the development of the ecosystem, the selection of the actors most adapted to the new environment is already taking place. When it reaches its climax, the actors are selected based on the characteristics that best enable them to interact with other actors. And, thinking in terms of the innovation ecosystem, the characteristics that best enable them to interact collaboratively to create value. In this sense, we highlight new learning from the biomimetic approach of biological ecosystems to innovation ecosystems:

L(4) An innovation ecosystem evolves due the relationships established by its actors (consumer-resource, mutualism, competition), as these relationships will select the actors that possess the most favorable traits that allow them to better interact among them and with the environment to create value.

Após entender como evolui um ecossistema de inovação e o papel das interações nesse processo, se faz fundamental a compreenção de alguns elementos dos ecossistemas naturais e dos artificiais.

1.5 Innovation ecosystems: natural or artificial ecosystems?

The formation of a natural ecosystem will start after the environment is disturbed (a burned forest, a coral reef destroyed by a hurricane, an island covered with volcanic lava) and ends when the environment reaches a final combination of populations of organisms. This combination is known as the "climax community". The process that leads to the formation of the "climax community" is called ecological succession, or just **succession** (Evert and Eichhorn, 2013; Ricklefs, 2008).

After the *habitat* is disturbed, a small number of species start to colonize it, acting as pioneer species. These are species adapted to the conditions of this new habitat. During the years this species modifies the environment and creates the conditions for a new species to develop and, after some time, succeed the pioneer ones. This process will continue until the climax community is reached. The exchange of one set of species by another is gradual, while one is going down the other is rising. During this process, a gradual increase in species diversity of that spot is observed. There are two types of succession: primary and secondary. The difference among them is related to where the process of succession take place. Primary succession is the establishment and development of communities in newly formed landscapes or in *habitats* that a recent disturbance removed all life. For its turn, the secondary succession is the establishment and development of communities in recent disturbed areas that only part of the species of the area were removed.

Considering this approach, we can also think that innovation ecosystems can be evaluated according to their stages of development (succession), considering the diversity of actors and sets of actors in the ecosystem. And this is a research gap recognized by authors like Spigel (2017) and Dedehair et al, (2018). These authors point out that it is necessary to adopt a dynamic perspective on how innovation ecosystems adapt to new contextual configurations. In this sense, we highlight a new learning from the biomimetic approach from biological ecosystems to innovation ecosystems:

L(5): Different stages of innovation ecosystem development can be assessed according to diversity of actors in an ecosystem.

After understanding how a natural ecosystem is formed and that during this process the diversity gradually increases in the ecosystem, we can now talk about the artificial ecosystems. Since the agricultural revolution, the capability of humans to manage and alter their environment has increased. Various natural ecosystems had been replaced by artificial or semi-artificial ecosystems (Wang and Zhai, 2019). Artificial or semi-artificial ecosystems are created by human intervention in the environment in which the natural ecosystem is partially (semi-artificial) or fully replaced (artificial) by exotic plants and constructions (Milliken, 2019). Due to this artificial ecosystem, less biodiversity than natural ones is presented. Compared to natural ecosystems that are in a state of dynamic equilibrium (Evert; Eichhorn, 2013; Ricklefs, 2008), artificial ones are not at equilibrium, and without human intervention they will perish (Milliken, 2019). In a farm, for example, the animal and plants species used in this system are not natural to that location. Thus they need human intervention for them to be sustained (food and nutrients for survival) (Milliken, 2019). Artificial ecosystems are created to fill our needs.

Concerning how they are formed, Wang and Zhai (2019, p.7) proposed that they are formed with the input of energy by humans to modify it in order to satisfy their needs.

> Ecosystem evolution should include succession and reconstruction. The former is the functional evolution of the ecosystem without structural change, and the latter is a new ecosystem that is reconstructed according to human's purpose and need. The evolution of an ecosystem is related to human economic purpose, its input–output ratio affects the goal of system reconstruction".

The disturbance in the environment caused by humans can be compared with the event that disturbs the environment and give rise to the succession process, but here what follows is not the formation of a natural ecosystem, but an artificial one. As natural ecosystems, this will be formed by the expenditure of energy. These artificial ecosystems can be 100% constructed (houses, buildings, roads, etc – abiotic elements), or can be formed by a mix of abiotic elements and biotic (natural or exotic fauna and flora).

Answering the subtitle question: The innovation ecosystem is an artificial ecosystem, which is created from human intervention. However, like the artificial ecosystem in biology, it will assume some characteristics of the natural ecosystem, as we explained throughout the essay. What needs to be emphasized here is that in artificial ecosystems, as emphasized by Milliken (2019), human intervention is necessary so that the ecosystem does not perish. Thus, if we think in terms of the innovation ecosystem, the interdependence between the ecosystem participants highlights the relevance of paying attention to how ecosystems are coordinated and managed. In this case, human intervention can be understood as the governance mechanisms. It can be said that they are central to the health and stability of the ecosystem, as they boost collective performance, allowing and facilitating the creation of value and collective gains (Cusumano; Gawer, 2002; Autio; Thomas, 2014).

In addition, as explained in item 1.4 about natural ecosystems, we can say that artificial ecosystems also need their populations / organizations to maintain a constant search for the best characteristics / capabilities that are able to guarantee their adaptation to the environment in the face of constant changes. In this sense, we highlight new learning from the biomimetic approach of biological ecosystems to innovation ecosystems:

L (6): Innovation Ecosystems can be created, but they need forms of governance and also that the organizations keep a constant search for the best traits to guarantee their adaption to environment.

Conclusions

This essay looked at the original concepts of biology to expand the knowledge of the innovation ecosystems field, from Biomimetics. Using this approach, it was possible to offer a set of original findings and answer some criticisms in the management literature. We arrived at a set of six propositions (Table 2) that also made it possible to provide suggestions for future research. Highlights among the lessons learned that in order to advance in the studies of ecosystems in the area of management, it is necessary that researches take into account the relationship between the various actors in the ecosystem and between them and the elements of the environment. This was a first step towards reconnecting the areas of biology and management in search of greater rigor in the use of the term ecosystem, towards the suggestion of Ritala and Almpanopoulou (2017).

Biology	***Biomimicry: Learnings from Biology***	**Criticism of current studies / Research Opportunities**
The ecosystem is formed by all organisms (biotic element) that occur in a particular area, the nonliving environment (e.g. minerals, water, climate, landscape – abiotic element) and how they interact.	*An innovation ecosystem is formed by agents and economic relations (biotic elements), as well as non-economic parts, such as technology, knowledge, laws, culture, etc. (abiotic elements).*	Most studies on ecosystems are focused on "individuals". From this biomimetic approach, we perceive opportunities linked to different forms of studies, such as populations and even communities. It is necessary researches that deals with non-economic aspects in addition to the relationships between the actors. Due to this, there are research opportunities, for example, linked to quality of life, social capital and intellectual capital.
By identifying the populations that compose an ecosystem and the physical space they occupy and how they interact with the abiotic elements in that space - this done, you have identified the limits of the ecosystem.	*The limit of an ecosystem is given geographically (physical space) and must comprise the identification of the different set of actors it comprises (biotic) and how they interact with the non-economic (abiotic) elements in that space.*	This characterization can guarantee one of the most important arguments about the differences between ecosystems, networks, other forms of cooperation and environments that generate innovation. Empirical studies using this understanding could provide solid bases for comparative studies on the subject.
Energy Flow	*The resources flow through the actors (universities, industries, companies and civil society), reflection of interdependence between actors can build maintain or shatter innovation ecosystem.*	The use of the resources flow through the actors (universities, industries, companies and civil society) can be used to measure the efficiency of the ecosystem. Actors that produce more without losing quality with the same amount of energy would be more efficient.

Ecosystem Evolution	*An ecosystem evolves due the relationships established by its actors (consumer-resource, mutualism, competition), as these relationships will select the actors that possess the most favorable traits that allow them to better interact among them and with the environmen to create value.*	We realize here an important opportunity for research in the area of innovation ecosystems: Understand how happen the interaction among the actors and of them with their environment. Such studies can allow us to advance in the understanding of how an innovation ecosystem evolves and increases in complexity (greater set of actors).
During the succession process an increased number of species can be observed as it gets closer to the climax community.	*Different stages of innovation ecosystem development can be assessed according to diversity of actors in an ecosystem*	
Artificial ecosystem – man-made ecosystems taht need your Constant intervention in order to be maintained.	*Innovation Ecosystems can be created, but they need forms of governance and also that the organizations keep a constant search for the best traits to guarantee their adaption to environment.*	The understanding of forms of governance and their relationship with ecosystems of inactivation seems to be a very fruitful field in the studies of ecosystems. Studies on dynamic capabilities can contribute to listing the set of characteristics necessary for organizations to adapt to the environment.

Table 2: Summary of the learnings from the biomimetic approach and research opportunities
Source: autores.

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