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Nature, Critical Geography, and Complexity: An intradisciplinary dialogue

Natureza, Geografia Crítica e Complexidade: Diálogo intradisciplinar

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Abstract

Despite significant epistemological discussions within geography regarding the concept of nature, the persistence of dichotomous discourses and practices that separate human beings from nature are still observed. This study aimed to analyze the concept of nature from both the perspective of critical geography and the conception of Complexity, seeking to establish a dialogical approach between these two frameworks. Dialogics, as advocated by Complexity theory, seeks to build a complex associative relationship—which can be complementary, concurrent, or even antagonistic—between different theoretical perspectives. The research revealed that, despite the inherent particularities of their theoretical presuppositions, both Complexity thinking and Marxist thought (partially fundamental to critical geography) offer a significant problematization of the human being/nature dichotomy. Implementing a dialogical perspective proved to be a fruitful path for the epistemic and practical advancement of geographical science. Methodologically, the study was conducted through extensive bibliographic research, involving representative authors from both approaches. The results highlighted both the divergences and convergences between Complexity and critical geography, especially when analyzing notions such as totality, production, irreversibility, and autonomy and dependence. The primary focus of this analysis was the critique and overcoming of dichotomous interpretations of nature, proposing a more integrated and relational view.

Keywords:
Dialogic, Epistemology, Marxism, Complex Systems.

Resumo

Apesar dos movimentos epistemológicos da Geografia terem discutido amplamente o conceito de Natureza, ainda observamos a persistência de discursos e práticas dicotômicas que realizam uma separação entre Ser humano e Natureza. Este trabalho propôs-se a analisar o conceito de Natureza tanto na perspectiva da Geografia Crítica quanto na concepção da Complexidade, buscando estabelecer uma abordagem dialógica entre essas duas vertentes. A dialógica, conforme preconizada pela Teoria da Complexidade, visa construir uma relação de associação complexa – que

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pode ser complementar, concorrente ou até mesmo antagônica – entre diferentes perspectivas teóricas. A pesquisa revelou que, apesar das particularidades inerentes aos seus pressupostos teóricos, tanto o pensamento da Complexidade quanto o marxista (que fundamenta parte da Geografia Crítica) oferecem uma problematização significativa da dicotomia Ser humano/Natureza. A implementação de uma perspectiva dialógica demonstrou ser um caminho para o avanço epistêmico e prático da Ciência Geográfica. Metodologicamente, o estudo foi conduzido por meio de uma pesquisa bibliográfica, envolvendo autores representativos de ambas as abordagens. Os resultados evidenciaram tanto as divergências quanto as convergências entre a Complexidade e a Geografia Crítica, especialmente ao analisar noções como totalidade, produção, irreversibilidade, e autonomia e dependência. O foco principal dessa análise foi a crítica e a superação das interpretações dicotômicas da Natureza, propondo uma visão mais integrada e relacional.
Palavras-chave:
Dialógica, Epistemologia, Marxismo, Sistemas Complexos.

I. INTRODUCTION

Considering the epistemological movements present in the history of geography, it is necessary to delve deeper into the concepts of the discipline influenced by Historical-Dialectical Materialism, as the concepts of First and Second Nature arising from Marxist theory have been central to the discussion of nature in human geography for the last 50 years. According to Marx and Engels (2001), nature was initially seen as "virtuous" and subject only to incipient technical interventions, where eventual appropriation changed its use value to exchange value, thereby becoming an object of exploitation by the capitalist system since, in the logic of capital, the natural is subjugated to the interests of social relations of production. In this context, "The limited relationships between men condition the limited relationship between man and nature, precisely because nature is still little modified by history" (Marx; Engels, 2001, p. 25, translated from Portuguese).

Both concepts, present in geographical analyses, are sometimes expressed in a physical/human geography dichotomy, with the concept of "first nature" present in physical geography and that of "second nature" in human geography. Although the concept of "metabolism" between the parts (human-environment) aims to overcome the nature/society divide, some 20th-century Marxist academic production treated nature as a stage (in physical geography) and appropriated by society (in human geography). Even with attempts to include the human element as part of nature, the discourse of the authors addressing the phenomena maintained a dichotomous subject/object relationship, and consequently, a certain "objectification" of nature by human beings, treating it as an object of appropriation, whether social, cultural or economic.

In the context of nature in complex thought, this is expressed from what Morin (2016) calls "restored physis", an approach that integrates different processes and scales within a single organizational dynamic.

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Nature is understood as a complex system that encompasses chaos, instabilities, transformations, non-linearities (organizational recursion), and emergences. Complexity theory questions the limits of the simplifying paradigm of traditional science and seeks to establish a dialogue with other epistemic perspectives such as dialectics, phenomenology, hermeneutics, etc.

Complexity theory problematizes the traditional view of nature that positions humans as merely external or as appropriators of nature. Instead, the complex perspective conceives humans as complex systems that are intrinsically part of a complex metasystem. In this context, the dialogic paradigm emerges as an approach that seeks to understand reality from its fluid and multifaceted dimension. Dialogue permits the coexistence of complementary, competing and antagonistic perspectives, offering a framework for integrating anthroposocial dynamics.

Furthermore, Complexity theory incorporates, at its core, the crucial notion of self-organization. This notion recognizes the inherent capacity of systems, whether natural or social, to generate and maintain their own internal structure and dynamics. This idea resonates with what Maturana and Varela (2001) conceptualized as autopoiesis – the ability of a system to self-reproduce and create its own parts. Their reflection on self-organization and autopoiesis emphasizes the role of subjectivity of the subject in the process of knowledge, challenging the classical scientific premise of subject/object separation. Thus, by integrating self-organization and subjectivity, Complexity offers a way of thinking about the concept of nature from a more relational and dynamic perspective, paving the way for a connection with critical geography, which also seeks to break with traditional dichotomies.

From this perspective, we intend to analyze the concept of nature used in both critical geography and Complexity Theory, establishing a dialogical relationship between these two frameworks, focusing on the dialogue and application of Complexity in geography. The debate about the need for a dialogue between these approaches is an outcome of this conflict. Therefore, the objective is not to present a new definition of nature, but rather to question the most conventional interpretations within geography from the standpoint of Complexity, with the intention of discussing a definition of nature for geography that allows a dialogical connection between the two perspectives.

This paper begins with a brief contextualization of the concept of nature in Complexity Theory and some of its applications in geography, followed by a discussion of how nature is conceived within critical geography. To this end, a brief critical analysis of Schmidt (1978), one of the most influential names in the interpretation of nature in Marx, will be carried out, indicating some of the mistakes made by this author and how he influenced

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the interpretation of geographers towards a staged conception of first and second nature. In order to critique this perspective, "second-stage" ecosocialist authors will be used for a more plausible interpretation of Marx's concept of nature, largely emphasizing the idea of the metabolism of nature as an interpretation that escapes the subject/object dichotomy. In addition, it will explore how nature is interpreted by authors in critical geography. Finally, a dialogical exercise will be carried out to bridge the approaches of geography (critical and complex), highlighting their divergences and convergences based on notions such as totality, production, autonomy and dependence, and irreversibility. The purpose of this exercise is to critique the dual interpretations of nature and present a way to integrate multiple perspectives in geography.

II. Materials and Methods

This work includes research and bibliographical analysis on three main fronts, according to the research objectives: (1) the concept of nature within Complexity Theory, (2) the concept of first and second nature within critical geography, and (3) the convergences and divergences between those.

As the first objective is to present the concept of nature within Complexity Theory, the considerations will be based on authors of complex thought, such as Morin (2002), Prigogine (1996) and Maturana & Varela (2001). Based on the known principles of Complexity, the point of the discussion will be to bypass dualities and seek understandings that foster dialogue between the intra-disciplinary perspectives of geography. From this perspective, nature is conceptualized as a complex system, characterized by a diversity of domains. This means that it is not a monolithic entity or easily reducible to a single type of manifestation or understanding.

Secondly, the idea of nature as presented in critical geography will be investigated, considering its individual and philosophical roots, and elaborating on this notion through its main authors. Since this course is based on Marxist work, a critical analysis of the works by Alfred Schmidt (1978) will be made, as he is both one of the most influential thinkers on the study of Marx's concept of nature and is also widely cited by influenced geographers. By critiquing the author, the ideas of Smith and O'Keefe (2017) and the perspective of the production of nature will be exposed, as well as those of proclaimed the "second-stage" ecosocialists such as Foster (2005), Burkett (2001), and Saito (2021). These latter bring a vision of Marx's concept of nature that challenges the humanity/nature dichotomy considering the perspective of the metabolism of nature.

Lastly, how this Marxist influence is expressed in the work of critical national geographers Casseti (1991), Santos (2006), Porto-Gonçalves (2006), and Suertegaray (2021) will be uncovered. The focus will be on the relationship between the social domain and natural dynamics, that is, the differences, similarities and

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connections between first and second nature and their repercussions on geographical studies. In this phase, the convergences and divergences of such understandings, with the considerations of Complexity, will be identified. Therefore, based on the discussions of the aforementioned fronts, we seek to unite the convergences and criticisms of the two former perspectives, and align them with the principle of the dialogic paradigm of Complexity.

III. Results and discussion: Nature within Complexity and Geography

According to Edgar Morin (2005), Complexity can be fundamentally understood as that which is "woven together" (complexus). This implies that a complex system is made up of heterogeneous elements that are inseparably associated, forming a whole that is simultaneously one and multiple. In this intricate fabric, several dynamics work in tandem: actions (events that occur), interactions (reciprocal influences among elements), feedback (where the effect of an action or interaction results in either a positive or negative feedback loop), and even disorder (randomness). The choice of these notions — actions, interactions, feedback and disorder — is necessary because they represent the dynamic elements that give shape and movement to complex systems, revealing that reality is not simplistic.

The necessity to overcome dual notions became evident with advances achieved by scientists in the 20th century, particularly the formulation of the Theory of Relativity, the development of Quantum Physics, the emergence of Systemic Theories and the reflections made in Analytical Philosophy on the limitation of mathematics as an absolute source of knowledge, Chaos Theory, Catastrophe Theory, Biology of Knowledge, etc, were all important factors to this paradigmatic change. Notably, it is worth highlighting here that this change in scientific thinking is also related to the studies carried out on complex dynamic systems and Complexity. The advances arising from these fields were systematized around the notion of Complexity and its basis being the General Theory of Systems - GST, Information Theory and Cybernetic Theory (Morin; Le Moigne, 2000) (Figure 1).

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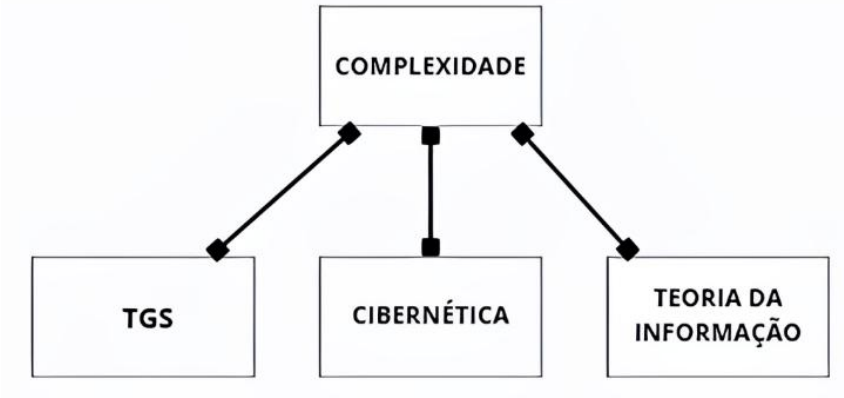

Figure 1 – Theoretical Tripod of Complexity (Source: The authors).

These theories were the main support for scientific work in the 20th century. Probably the most renowned among them, GTS provided important concepts and operations in several sciences. Although these theories are fundamental to many of the principles developed by Complexity, this does not mean that they do not have their distinctions. Complexity uses the precepts of these theories to guide its way of thinking, but it is not limited to them.

Complexity theory proposes an integrated and non-dichotomous view of nature. Unlike traditional approaches that separate the human being (social, cultural, and subjective dimensions) from the physical reality (natural and objective), Complexity emphasizes a circular and interdependent relationship between these domains. This means that mankind and the natural are not isolated, but participate in the same system of systems, in constant interaction and conformation. This perspective challenges the simplifying and dualistic principle of modernity, which historically separated humanity and nature, subject and object. In its place, a dialogical perspective is proposed, in which the interaction between the physical and anthroposocial is not only possible, but necessary to understand reality (Morin, 2016).

Nature is viewed by Complexity as a circular relationship of mutual dependence between anthroposocial reality and physical reality. Thus, it is this circularity between realities that distinguishes this concept from the simplifying principle and the man/nature dichotomy; that is, the circular vision rejects monistic reduction and leads to an epistemic dialogue between the physical and the anthroposocial (Morin, 2016). The main conceptualization of nature in complex thought is from the notion of restored physis. The notion of restored physis is nature thought of as the "daughter of chaos" (due to the order/disorder relationship) and, furthermore, in accordance with the systemic vision, the object is not seen as independent of the subject:

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> In effect, every system observed in nature is linked to a system of systems, which is linked to other systems of systems and, little by little, joins the organized physis or Nature, which is a polysystem of polysystems [...] the observer is also part of the definition of the observed system, and the observed system is also part of the intellect and culture of the observer-system (Morin, 2016, p. 177-178, translation from Portuguese).

Following this assumption, there is no subject/object dichotomy. In reality, the subject is integrated into observation and self-observation because it is also a system. In other words, the human being is a system that is part of another system (a metasystem), and the system that is observed (object) is part of the social environment of the observer-system. Complexity seeks to establish a dialectic between the defense of a systemic concept and the need to problematize it in its incompleteness, thus it seeks to overcome the simplification of most systemic discourses that reduce all beings (biological, social, human, institutional, etc.) to the notion of a system. Thus, although systemic analysis seeks to overcome mechanistic reductionism, its totalitarian/holistic character is admittedly insufficient to analyze all of reality (Morin, 2016).

The concept of nature through Complexity has been described as a "tetralogical circuit" in which order, disorder, interactions and organization are linked in competing, antagonistic and complementary ways (Morin, 2016). The tetralogical circuit demonstrates that interactions require disorder/agitations that produce encounters, with organization and order also dependent on interactions. Organization, for example, is fundamental to the concept of nature through Complexity, and links the idea of totality to that of interrelations. Despite the relationship between organization and order, it cannot be reduced to simple order, as it preserves the whole as something non-reducible to the sum of its parts, with emergent qualities that arise from the whole rather than from the individual parts.

The tetralogical circuit expresses that order, by itself, is not enough to explain the complexity of natural and social phenomena. Disorder, understood here as uncertainty, instability or agitation, is equally necessary for change, adaptation and the creation of new forms. Organization arises precisely from the tension between order and disorder, functioning as a principle of articulation between stability and transformation.

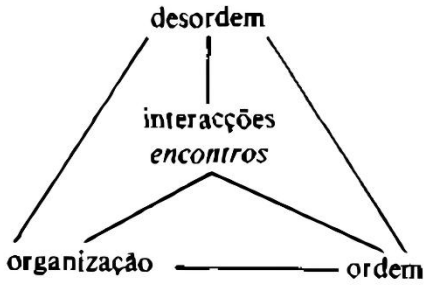

Figure 2 – Representation of the tetralogical ring, Morin (2016).

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The Theory of Complexity attributes organization as central to understanding living and social systems. Morin (2016) defines organization as the chain of relationships between components that form a complex unit, also called *unitas multiplex* — a unit that preserves internal diversity. Unlike simple systems, in which the whole can be understood by the simple sum of its parts, organized systems present emergent qualities, that is, properties that only exist when the whole is formed. Although often associated with order, organization goes beyond this notion. This is because it admits the presence of instability, transformation and even a certain degree of disorder, which is essential for the adaptation and evolution of complex systems.

One of the pillars of this understanding is the concept of self-organization, which describes the ability of certain systems to structure themselves internally without depending on an external authority or central command. In other words, order arises "from within", from the interactions between the system's own elements. In line with this concept, the idea of autopoiesis, developed by Maturana, Varela and Dos Santos (1995), defines living beings as autopoietic systems — capable of producing, maintaining and renewing their own structures. An autopoietic system is autonomous, or rather, it not only functions on its own, but also creates its own parts from its internal interactions.

From this perspective, nature is not conceived as something external, fixed, or purely material. It is thought of as a process in continuous transformation, in which human beings are deeply involved. Complex thinking, by rejecting the separation between subject and object, shows that human beings, as a living and social system, also participate in the process of self-organization of nature. The old division between mankind and nature is thus replaced by an integrative vision, in which both coexist within the same metasystem.

For Complexity, the separation between man and nature is illogical because the human being is a complex system that is a part of this metasystem; the socialization of physis and the physicalization of society are interdependent processes, in which nature acts as both an agent and a product of the dialogue between the anthropological, the biological, and the physical. The concept of organization articulates the anthroposocial sphere with the biological and physical spheres, causing the division between natural sciences and human sciences to end up hiding the physical reality of the human part and the social reality of the natural sphere. The human being is thought of as an open (relations) and closed (singularities) system that is part of an even larger system called society. And as mentioned, the social is in a relationship of circularity/circuit between the physical and biological reality.

The dialogue between Complexity and geography has not yet reached large proportions of dissemination in the Brazilian context, however, several scientific reflections on the topic have been conducted by both

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international and national researchers (Dutra-Gomes, 2010; Portugali, 2006; Manson; O'Sullivan, 2006; Malanson, 1999; Thrift, 1999). According to Dutra-Gomes (2020), complexity brought new understandings to dualisms in geography. Despite always seeking to converge methodologies, scales, epistemologies, and themes (physical and human geography), these attempts were not enough to prevent hegemonies in the discipline, such as that of the nomothetic/global approach, dominant throughout the history of geography. Thus, it is necessary to reflect on Complexity and its epistemological and practical approaches in geographic science as a way to problematize dualities in the perspective of nature.

The relationship between Complexity and geography was, for the most part, formed during and after the 1970s by quantitative geographers using theories, methods and techniques incorporating non-linearities into location-allocation models, such as the application of chaos theory techniques to urban models, or the creation of city models using fractal-based methods (Thrift, 1999). Geographical interest in gomplexity was specifically influenced by the emergence of Prigogine's theory of dissipative structures (1996), Haken's synergetic theory of complex systems (1983, apud Portugali, 2006) and Mandelbrot's fractals (1983, apud Portugali, 2006).

The first connections between Complexity and geography were established not by geographers, but by physicists such as Allen (1981, apud Portugali, 2006), who reformulated the theory of central place based on dissipative structures; and Weidlich (1987, apud Portugali, 2006), who applied Haken's synergetic theory to social and urban dynamics. Besides its technical use, Complexity also offers new opportunities for spatial researchers. Viewed by Thrift (1999) as "supernaturally spatial", complex thinking is not only concerned with the progression of time, but also with the processes linked to a spatial organization that produce emergences and multiplicities from internal dynamics. Within Complexity, rather than having rigid limits, scales are fluid and have interrelations, that is, the global and the local scales are related. According to Manson and O'Sullivan (2006), Complexity offers a new way of thinking about scales for geography, and in this way, instead of prioritizing just one type of scale, it highlights the importance of scale for both generalization and specialization.

Complexity in the context of geography is observed in various areas, such as in the methodologies proposed to quantify the chaos in the climate system and the unpredictability associated with climate change, offering significant direction for understanding the complexity of these systems. In geomorphology, these legacies are manifested in the relevance of the notion of equilibrium, a fundamental concept for Complexity. Equilibrium, in this context, refers to a macroscopic state that involves the maintenance of a stable material and

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energy balance, towards which, according to initial perspectives, the dynamics of geomorphological systems tend (Dutra-Gomes; Vitte, 2022).

Regarding biogeography and Complexity, biogeography is an interdisciplinary area that considers nature incorporated and recreated by humans. In much of Brazil, such as in the Caatinga biome, the direct relationship between the historical use and occupation of land and the plant landscapes found there is increasingly evident. In other words, in addition to the natural dynamics, there is a clear example of nature that was recreated by humanity (Souza; Souza, 2016). By exposing the dynamics of living beings, biogeography allows geography, which has traditionally privileged the study of relief, to use bioindicators to function as "thermometers" of the landscape. Furthermore, desertification in this biome and the geo-ecological predisposition of part of these lands to this type of degradation when subjected to certain forms of use, as highlighted by Ab'Sáber (1977), exposes the consequences of a new pattern of organization and self-organization.

In relation to urban themes, the relationship between Complexity and urban studies has its starting point when the city was used as a metaphorical example for the notion of dissipative structure among physicists. Allen (2012) was responsible for developing this metaphor and reformulating the Central Place Theory in terms of Complexity, with studies of cities as self-organized complex systems, giving rise to a new field of studies called "Complexity Theories of Cities" (CTC).

Unlike the notion of urban planning, aimed at identifying the dynamics of the city while solving urban problems, CTC is more interested in dynamics per se (how cities work). Although CTC has never made a very explicit criticism of classical urbanism, it is distinguished from this thinking because, while classical theories think of the city as a closed system that tends towards equilibrium, CTC states that the city is, essentially, an open system that is far from "equilibrium conditions" (Portugali, 2012).

THE CONCEPT OF NATURE IN CRITICAL GEOGRAPHY

One of the principle concepts of nature present in geography is its conception in critical geography. This epistemological movement, which has been discussed for more than half a century, is one of the main views present in Brazilian human geography and in physical geography, and is also representative. The nomenclature "critical geography" in this work serves to reference a movement that sought to problematize the dichotomies of traditional geography, valued the historical movement, and has, as the basis of its reflections, Marxist dialectical materialism, although not all critical authors were Marxists (i.e., Freirians, anarchists, Stalinists, etc.).

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According to Marx's (1818-1883) thought, there is no purpose for a nature that is separate from human beings, whether in a primordial form (biological) or in a socialized form (correlated with human activity). As mentioned, practically the entire Earth bears within itself the marks of human actions, reflecting human dependence on nature to meet its essential needs. Quaini (1979) states that although Marx recognizes the "priority of external nature", he claims that the distinction between a pre-social nature and a socially conceived nature only makes sense as long as man is considered distinct from nature (in the sense of a nature prior to human history).

First nature can be understood as external, as the realm of objects and the raw material from which society exists, while second nature is produced by human society, including the human and the non-human elements (Smith, 1988). It can then be said that in his writings Marx considers humanity as nature, with "first nature" including mankind biologically and, through the process of human socialization, transforming this primordial nature into a "second nature"; that is, when human beings become socialized, they in turn socialize nature. It is clear in the work "The German Ideology" that a nature prior to human history no longer exists (first nature) and what exists today is only a nature that was produced and appropriated (second nature):

> This differentiation only makes sense insofar as man is considered to be different from nature. Moreover, this nature that preceded human history is by no means the nature in which Feuerbach lives; it is the nature that today, with the possible exception of one or two recently formed Australian coral islands, exists nowhere, and which therefore does not exist for Feuerbach either (Marx; Engels, 2009, p. 39, translation from Portuguese).

Due to Hegel's influence on Marx, it is pertinent to mention that the separation between first and second nature appears earlier in Hegelian thought. The dual distinction of first nature as external to man and second nature as distinct from the first is something striking in his thought and is not necessarily and exclusively in Marx's work. The idea of nature for Hegel is an idea of reality cut into two parts and distributed throughout space/time. For Hegel, "[...] the idea of a second nature was connected to the idea of a designed nature. It was left for Marx to separate the concept from this teleology[...]" (Smith; O'Keefe, 2017, p. 33).

For Hegel, the idealists were right in considering nature as essentially created or derived from something, thus for Marx the separation of nature from this teleology occurs (Marx was not interested in nature as abstract and metaphysical). In Hegelian philosophy, nature did not contain its own means of its self-determination. It was regarded as the alienation that thought was compelled to submit to so that it could fully return to itself as spirit. Thus, nature was reduced to a mere mechanistic entity (Foster, 2005).

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One of the most relevant authors for the study of Marx's conception of nature is Alfred Schmidt (1978): "It is not necessary in the first place to scour Marx's entire collective works in order to isolate his different treatments of nature. This meticulous and ambitious project has already been carried out by Alfred Schmidt" (Smith, 1988, p. 48, translation from Portuguese). According to Schmidt (1978), there are two historical periods in Marxist dialectics: the pre-bourgeois and the bourgeois. In the first, the human being is identical to nature, and in the second period, with the bourgeoisie, the human being becomes universally master over nature.

In the concept of nature of Schmidt (1978), first nature is external to human activity and treated as the totality of things (the combination of first and second nature). Therefore, it is worth mentioning that Schmidt's (1978) interpretation of Marx's conception of nature brings some problems. "Schmidt tends to treat them as separate, and this allows him to discuss, among other things, the historical necessity of 'man's domination of nature'. That this accurately reflects Marx's conception of nature is doubtful…" (Smith; O'Keefe, 2017, p.33). Schmidt's interpretation suggests that, in Marx's thought, there is an intrinsic need for the domination of nature, characterizing him as anti-ecological. Furthermore, Schmidt accuses him of being utopian.

The theme of "domination of nature" has been constant amongst theorists of the Frankfurt School, of which Schmidt is a representative (Smith; O´Keefe, 2017). It is a concept that reinforces the man/nature duality by consistently placing human beings against nature. Thus, despite theoretical efforts to unite nature as the totality of all things, in practice, Schmidt manages to avoid this duality. Schmidt, in fact, accuses Marx of being "anthropocentrist", and consequently of being anti-ecological, because in his view, Marx transforms nature into an object of exploitation (Saito, 2021).

Thus, it is worth noting that the view propagated by Schmidt (1978) does not accurately reflect Marx's thinking on nature, despite his influence being notorious in geographical texts. This is expressed, for example, in the words of Moraes (2014):

> Marxism, for example, taken as a method, has its horizon of application circumscribed to the universe of manifestation of social phenomena and processes. In Marx's vast work, there is no systematic appreciation of nature and of natural phenomena and processes (Schmidt, 1976); these are always addressed by him as a 'nature for man', that is, as materials and means of production, in short, as 'resources' (potential use-values). Attempts to expand the use of his method to the field of natural phenomena resulted in positivist slips that contradicted some of the basic gnosiological foundations of his proposal (Moraes, 2014, p. 14, translation).

In this interpretation by Moraes (2014), Marxism as a method is limited to social phenomena and processes, and has an anthropocentric idea of "nature for man". However, what many thinkers, and even critical

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geographers, did was to reduce Marx's thought to Schmidt's interpretation, which, as mentioned, brought elements adjacent to Marx's view of nature, by establishing the theme of "domination of nature", like other thinkers of the Frankfurt School.

Because of this, the question arises: is it possible to truly see an elaborate concern about nature in Marx's thought that escapes this idea of domination? The "second-stage" ecosocialists present a different view of the environmental issue in Marx's thought, especially Burkett (2001), Foster (2005) and Saito (2021). These authors revisit Marx's works and invalidate the claim that Marx was not concerned with nature, revealing, based on these examinations, the presence of his ecological thought.

Based on his economic and philosophical manuscripts, Marx considers nature, from the moment it enters the history of human beings through production, as the "organic body" of humanity, that is, as an extension of the human body (Foster, 2005). This perspective, in addition to the society/nature relationship mediated by production, considers that there is an organic relationship that constitutes unity. Marx (2004), already in the first chapter of his economic and philosophical manuscripts (1844), treats the issue of the man/nature relationship as essential to the theory of alienation, that modern alienation is the result of a separation of the original unity between human beings and nature – thus the alienation of nature is a fundamental characteristic of capitalism. This means that the appropriation of natural and social conditions by capital intensifies the human alienation inherent in the socialization of capitalist production. As capital expands its control over the conditions of production, use value (the interaction between labor and nature to meet human needs) loses its primacy as the goal of production, becoming increasingly subordinated to the accumulation of value (Burkett, 2001).

According to Saito (2021), Marx's analysis of alienated labor sheds light on the unfree modern reality, in which it is not possible to pursue labor as an end in itself. Instead, labor is related to a process of dehumanization and impoverishment. For Marxist thought, the way to overcome the alienated reality of this modern society is through the dissolution of capitalist private property, as it prevents a freely happening relationship between human beings and nature through labor.

This means that in modern bourgeois society, property has been transformed into an object, a non-personal domination accompanied by alienated labor. Due to the commodification of land, workers have lost their direct connection with it. By being separated from their original means of production, they can no longer have a relationship with nature as an extension of the human body. With the advent of capitalism, there is a rupture in the original unity between human beings and nature (Saito, 2021). According to Burkett (2001),

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capitalism possesses a metabolism with nature, but it is a metabolism based on the duality of man-nature, thus, solutions to environmental crises need to be anti-capitalist.

Thus, for "second-stage" ecosocialists, the fundamental concept for understanding the ecological exploitation of capitalism is the metabolic integration between human beings and nature. Foster (2005) comments that the criticisms made of Marx's materialism, as if he emphasized a domination of nature and a utilitarian anthropocentrism, occur because these critics fail to recognize the material interrelations between human beings and nature (metabolic relations). Thus, the main category of Marx's theoretical analysis of nature is the German word "stoffwechsel" (metabolism), which is something that directly implies its structured elements and processes of biological growth and decay (Foster, 2005). In other words, metabolism in Marx's work is seen as a continuous process of organic exchange of old and new compounds that undergo assimilations, combinations, and exclusions so that the organic continuum remains.

According to Foster (2005), the origin of the term metabolism (stoffwechsel) dates back to 1815 by German physiologists, but it received a broader application within Liebig's work from 1842, called *Animal Chemistry*, for whom metabolism is this incessant process of organic exchange as mentioned. Thus, Liebig is one of the influences on Marx's thinking on metabolism. It is important to mention that Schmidt (1978) emphasizes the importance of the concept of metabolism, but it is not the same as the Marx-Liebig metabolic concept.

Consequently, by failing to understand metabolism in the terms that Marx actually applied, hends up losing sight of the materialist dialectics applied in Marxist thought, concluding, then, that Marx would have become a prey to his materialism and emphasized a domination of nature (Foster, 2005). The problem is that Schmidt infers that Marx's thought is influenced by Moleschott's explanation of metabolism (physiologist) and not the metabolism proposed by Liebig. Moleschott had a view in which humans function only as an element of the cycle of matter, and the metabolic relationship between humans and nature received no theoretical or practical attention, instead, it is an abstract and ahistorical cycle that matter experiences – a radical materialist view (Saito, 2021). It is therefore worth problematizing the influence of Schmidt's thinking on geography as an interpretation of Marx's conceptualization of nature and how this interpretation serves to maintain a dual thought, and furthermore, how the concept of metabolism is expressed in the work of geographers as an interpretation of Marx's thought on nature.

Highlighted in our analyses are several Brazilian critical geographers who have extensive discussions on the concept of nature: Casseti (1991), Santos (2006), Porto-Gonçalves (2006), and Suertegaray (2021). These names were chosen because of their significant roles in both Brazilian and critical geography and the relevance

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of their discussions on nature with Marxist influence. The idea is not to create a detailed study of these authors, but rather to explain some of their thoughts on the issue of nature.

Gonçalves (1978), arguing in favor of critical geography, states that nature cannot be thought of as an ahistorical element, but that its meaning is historically evidenced through the mode of production and be seen as an use value. Furthermore, he also states that to understand the imbrication of the human-nature relationship it is necessary to understand it in capitalist social formations. Finally, he clarifies that it is not possible to make a distinction between the history of nature and the history of society, because nature is socially produced – a second nature (Gonçalves, 1978). There is, therefore, a clear influence of Marx's thought in his work, affirming the production of nature.

In the book "Os (des)caminhos do meio ambiente" (The (mis) directions of the environment), Porto-Gonçalves (2006) reflects on how, in modern Western thought, there is a logic of domination of nature. "Man is nature that becomes aware of itself, and this is a truly revolutionary discovery in a society that forgot about this when it put forward the project of dominating nature" (Porto-Gonçalves, 2006, p. 9, translation). For the author, the expression "dominating nature" only makes sense if we consider that human beings are not part of nature. By recognizing that human beings are nature, speaking of domination also implies domination over human beings themselves, which brings several additional problems and contradictions. In light of this, as mentioned, it is indicated that there is a logic in modern society in which nature is treated as an object to be dominated by human beings/subjects.

Also present in his "Os (des)caminhos do meio ambiente" is an important influence of complex thinking. Porto-Gonçalves (2006) uses Complexity to first challenge the atomistic-individualistic paradigm, and second to criticize the reductionism inherent in systemism, arguing that atomistic-individualistic reductionism focuses on the individual, whereas the new reductionism focuses on the whole, in the form of a holistic system.

Furthermore, by using Complexity, he questions the simplistic thinking that dominates Western society, which considers nature to be the place where the "Law of the Jungle" operates, or alternatively, nature is seen as a place of harmony. In view of this, quoting Edgar Morin, "nature is neither chaos nor a perfectly ordered and organized cosmos. It is, in Morin's words, a chaosmo" (Porto-Gonçalves, 2006, p. 74, translation). In other words, he uses Complexity in an epistemic way to question the principles of modern thought and to develop his perspective on nature as complex. Thus, Porto-Gonçalves, one of the most influential names in Brazilian geography on environmental issues and a critical author, demonstrates the possibility of establishing a dialogue

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between complex thought and Marxism to expose a critique of modern thought and achieve a broader view of nature.

Another important name in the discussion about nature in Brazilian geography is the critical geographer Dirce Maria Suertegaray. The author's academic career focused on the study of sand deposits in the southwest of Rio Grande do Sul, a process that led to her doctoral thesis (1987) entitled: "A trajetória da Natureza: um estudo geomorfológico sobre os areais de Quaraí–RS" (The trajectory of Nature: a geomorphological study on the sand deposits of Quaraí–RS). With this thesis, she became the first geographer-geomorphologist to question her research object from a critical perspective. In this work, based on her studies in the municipality of Quaraí, she contested the idea that what was occurring in RS (which she called arenization) was of anthropic origin.

The method chosen by the author was Historical-Dialectical Materialism. Utilizing a historical perspective, it was possible to determine that the sand deposits were of natural origin – records of the evolution of the landscape from a recent semi-arid or semi-humid climate to the current more humid climate. Another Marxist concept that guided the author's investigation was Praxis: Through the understanding of a mode of knowledge production focused on reality, the author showed that the construction of the problem of arenization emerges from dialogue with society, revealing the struggles waged by the media, education and social movements (Suertegaray, 2010).

Thus, influenced by Marx's thinking, there is an interpretation made in the thesis of time as both an arrow and a spiral. For the existence of an analysis that considers the articulation of nature with society, it was fundamental to understand and apply time as an arrow/becoming. Beyond understanding movement as becoming, it is necessary to understand the process of socialization of nature and, consequently, the transformation of man/society itself as nature. In the author's thesis, this is evidenced in their search for the genesis of the object of research (sand deposits) that was supported by the notion of deep time from geology/geomorphology and the historical understanding of the appropriation of the space under analysis.

The author also implements the Marxist concept of a metabolic relationship in her works, based on the development of the concepts of territory of nature and the nature of territory. From the context of the appropriation of territory, that is, from the analysis of the process of connection between nature and society through labor, it is observed that nature constituted an extension of the human being and the human being also represented an extension of nature, thus evidencing the concept of a metabolic relationship (Suertegaray, 2023). Using other terms, the territory of nature is a territory in which organic relationships are established between the human being and nature, a metabolic interaction that is harmonious.

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In light of these contributions, Suertegaray (2021) demonstrates how much of Marxist literature throughout the 20th century treated nature as merely a material resource, and this perspective even had repercussions in geography by conceiving the nature-society relationship from the perspective of appropriation/exploitation. For the author, despite the concerns and reflections on the finitude of nature in the 1970s that brought the environmental issue to the fore, only a concern for a nature that is external to society is emphasized.

From these reflections and from the approach in geography of a biological perspective of nature as biotic and abiotic (concept of milieu), Suertegaray (2021) challenges these notions and develops the concept of environment for geography. For the author, nature should be seen as transfigured, in the sense of transformation from one figure into another, and such transformation occurs from subordination by processes of exploitation. Thus, the transfiguration of nature is different depending on the area and society, always establishing a situation of conflict, therefore demonstrating both the cultural dimension and historicity of nature. In the same vein, one can reflect on the human being as nature, and the transformation that it undergoes as a hybrid, since it is affected by the capitalist mode of production. Thus, the concept of environment seeks to overcome the naturalist perspective widely present in ecology and distinguish environment from milieu, since the latter has a biological inheritance (Suertegaray, 2021).

In this dialogical practice, it is also interesting to mention the influence of Complexity on Suertegaray's thought, because, despite using Historical-Dialectical Materialism as a method, she engages in a broad dialogue with complex thought. She uses Morin's epistemology (2015), Maturana and Varela's biology (2001), and Prigogine's irreversibility (1996) as references to support her critique of the duality of modernity and the need for articulation between nature and society. With regard to time, Prigogine (1996) contributes the idea of an irreversible movement, while nature is understood as autopoietic, having an interconnection between the subject and the object (Maturana; Varela, 2001), and it is acknowledged that "there is no way to escape the search for new methods that promote the articulation of natural and social elements and processes. The analysis of these issues is, today, thought about in terms of Morin's principle of complexity" (Suertegaray, 2017, p. 132, translation). Furthermore, the understanding of geographic space as both one and multiple was inspired by Morin's epistemology and his principle of that which is "woven together" (complexus) (Suertegaray, 2001).

Another relevant name for this discussion is Valter Casseti. Like Suertegaray, he has a broad interest in environmental issues and has a Marxist worldview. Casseti's thinking uses the division of nature into two historical moments, beginning with first nature, in which humans are present but use natural resources for their

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use value, with labor acting as a mediating element between humans and nature. At this moment, nature is a means of production without the need to generate surplus. The second moment is second nature, which represents a situation of exchange value, where nature is transformed into a tradable commodity that serves to accumulate capital, thus modifying the production of nature. For the author, the Marxist concept of nature should be understood not as something externalized, but as a social product (Casseti, 1991).

Casseti's thinking is strongly influenced by Smith's text (1988), which argues that, instead of adopting an idea of domination of nature, one should consider a more complex process of production of nature. The argument of domination offers only a one-dimensional and determined future. In contrast, the idea of production suggests a historical future subject to political forces, which can be changed, and not because of an inevitable technical necessity.

Furthermore, it is also worth mentioning the geographer Milton Almeida dos Santos, who was responsible for producing a profound theoretical work for geography. An important concept for understanding the conception of nature present in Milton Santos' thought is that of the technical-scientific-informational environment. Santos (2006) states that the history of the relationship between society and nature is one of the replacements of a natural milieu by one that is increasingly artificialized and instrumentalized, and this history can be divided into three stages: (1) natural milieu, (2) technical milieu, and (3) technical-scientific-informational milieu. The natural milieu is the period in which man chose from nature those aspects considered fundamental to the pursuit of life, while the technical milieu is the moment of emergence of a mechanized space, or the phase after the invention and use of machines, in which instruments are not extensions of the human body, but represent an extension of the territory. The technical-scientific-informational milieu is the period that begins practically after the Second World War. This is the moment when technical objects tend to be both technical and informational, as the intentionality of their production causes them to already emerge as information (Santos, 2006).

In short, the cited geographers went beyond the treatment of the domain of nature to the idea of a socially produced nature. Marx's influence is more present in Milton Santos, Suertegaray and Casseti than in Porto-Gonçalves (despite their dialogue with Marxism). In addition, Milton Santos, Suertegaray and Casseti explain the conceptualization of a first and a second nature. However, Suertegaray focuses particularly on the perspective of metabolism of nature in Marx and dialogues with ecosocialist authors such as Foster (2005). Suertegaray and Porto-Gonçalves converge by establishing an epistemological dialogue with Complexity.

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NATURE, COMPLEXITY AND CRITICAL GEOGRAPHY: INTRADISCIPLINARY CONVERGENCES AND DIVERGENCES

The Marxist and complex conceptualizations of nature have similar and distinct points, however the formulation of these points does not intend to overcome one theory by another, but rather to establish a dialogical relationship that reflects the multiplicity of geographical practice. According to Morin (2005), the dialogic can be defined as the complex association (complementary/competing/antagonistic) of instances necessary for the existence of an organized phenomenon.

Dialogic is linked to the hologramatic principle, which is responsible for demonstrating that the whole is in some way included in the part and the part is also included in the whole. Thus, the organizational complexity of the whole requires the complexity of the parts. In this sense, for the dialogical objective, some important notions are established to analyze the perspective of Complexity and critical geography: (1) totality, (2) production, (3) irreversibility and (4) autonomy and dependence. Thus, convergences and divergences will be indicated based on these notions.

The notion of totality (1) is fundamental to both Complexity and critical geography. For Complexity, totality is understood as a system in which the parts and the whole are in a relationship of interdependence. The whole are emergences, which are thought of as more than the sum of their parts. Critical geography, having a Marxist foundation, understands totality from a dialectical relationship. For Complexity, the whole must be understood as much more than just its global form, as it is the bearer of emergent qualities, which cannot be reduced to the elements that constitute them, since these qualities emerge from the relationship between the parts in the systemic whole. The whole, in this sense, is hegemonic in relation to the parts, and viewed in isolation as nothing more than a "void". In this sense, emergences as a totality alone can also be seen as insufficient to express the relationship between wholes and parts – because for Morin (2016) the whole is greater and lesser than the sum of its parts, just as the parts are greater and lesser than the wholes, with the wholes and the parts presenting a competitive relationship, antagonistic and complementarity, with both subjugation and autonomy in relation to each other. The reductionist view, on the other hand, limits the explanation of the whole to the parts, and the holistic (globalist) view that reduces the properties of the parts to the properties of the whole ignores the complexity of the global unity.

In accordance with this, Maturana and Varela (2001), regarding the functioning of living beings, explain that a living system is an organized unit that interacts with the environment, and the behavior of this system is determined by the system itself and not just by the relationships of the parts. Thus, when observing the totality

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of the system, it is not necessary to reduce it to its parts. In this sense, for Complexity, the notion of totality should not be totalizing; Complexity, unlike a simplifying holism, does not seek to privilege any totality to the detriment of its parts. Therefore, "the idea of totality becomes more beautiful and richer, as it ceases to be totalitarian, as it becomes incapable of closing in on itself, as it becomes complex" (Morin, 2016, p. 162, translation).

For critical geography, the notion of totality is related to the dialectical method, with the constituent elements only being understood in relation to the whole and its internal contradictions, reflecting space as socially produced. H. Lefebvre (2023) explains that dialectics strive to comprehend the concrete conditions of research and the concrete characteristics of reality, that is, after distinguishing the contradictory aspects, it remakes them in their unity. In the Marxist method, the reality achieved through analysis and reconstruction (synthesis) is a reality that is always in movement.

According to Santos (2004), the notion of totality serves geography because it is appropriate for the study of space, as it allows for a separation from concrete reality. Without the notion of totality, he says, how can one explain that some states are increasingly rich and others are increasingly poor? How can one explain that the surplus value resulting from overexploitation results in the number of unemployed individuals? In order to see this reality, it is necessary to consider it as a totality, in which there is interdependence between the parts. This notion of totality allows for the frameworks of inequality to be exposed. Furthermore, it allows one to escape from methodological positions that fragment reality.

In this sense, for Santos (2006), totality is reality in its entirety, a totality of existing states of affairs, in their relationships and movements. In other words, totality becomes more complex and dense because the historical process is a process of complexification. Totality is in constant movement, so that every totality is incomplete and always seeks to totalize itself at each moment of its evolution, being constantly subject to new metamorphoses.

The convergence between Complexity and critical geography lies in their shared view of totality as incapable of closing in on itself, as a movement always open to new thoughts and transformations. Both perspectives emphasize that the whole cannot be reduced to the sum of its parts and question the notion of a static totality. However, the approaches differ (divergence) because while Complexity focuses on reflection of systems, the dialectical approach focuses on contradictions, seeking to transform a condition of inequality, thus prioritizing historical analysis more. This perspective is of a concrete totality, or order as a result of social/historical relations. For Complexity, order is the result of interactions between the elements of the

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system, seeking to understand how interactions act in systems. Chaos, for example, for Complexity, is a permanent generic principle that is part of the totality of nature, mediated by the tetralogy disorder/interaction/order/organization (Morin, 2016). Thus, both perspectives contribute to the problematization of the part/whole dualism, by insisting on the inseparability between scales, dimensions and processes, although they do so based on different foundations — one centered on the critique of social relations, the other on the dynamics of organizational systems.

The notion of production (2) is also shared by Complexity and critical geography. For Complexity, the idea of production is related to the notion of machine-being, functionally as an "organizing physical being", or rather any physical being that indulges in labor, production and transformation can be considered a machine. Morin (2016) refers to the Marxist notion of production of nature and proposes an even more complex way of understanding this dialectical relationship based on the idea of recursion, since the relationship between nan and nature, in addition to being a relationship of dynamic exchange (dialectic), must be understood as a circuit in which transformations continuously feed back on each other.

From the perspective of the Marxist notion of production, it is understood that human beings transform nature and, simultaneously, are transformed by it. However, for Complexity, although this understanding is crucial, it needs to be expanded to capture additional nuances of reality. The main divergence between the approaches lies in the fact that, for Complexity, in addition to recognizing this reciprocal transformation, it is essential to consider the changes that accumulate over time, generating new and different levels of organization.

This accumulation of transformations is not just a sequence of events, but rather what Complexity calls cumulative evolution. This means that the interactions and continuous modifications in a system, over time, not only alter its parts, but also produce rearrangements and emergences that result in more complex structures or behaviors. It is a process where what was built at one level serves as the basis for the emergence of a new level of complexity and organization. For example, biological evolution is cumulative, where the sum of small adaptations over eons leads to the emergence of new species and entire ecosystems.

This cumulative evolution is intrinsically linked to organization. At each new level of accumulated transformations, the system reorganizes itself, acquiring new properties and capabilities that did not previously exist in the isolated parts. While the Marxist notion of production emphasizes the continuous manner of the mutual transformation between human beings and nature, Complexity deepens this view by highlighting that this interaction generates a process of constant reorganization, where past transformations lay the foundation

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for new and more complex forms of existence. The emphasis, therefore, shifts to the interactivity that produces these organizational and evolutionary leaps, drawing heavily on Organization Theory, which studies how systems are structured, maintained and evolve amid their own dynamics.

Critical geography frequently discusses and incorporates the Marxist concept of production in its reflections. Smith (1988) points out that the immediate appearance of nature is presented as a "material *substratum*" of daily life, possessing the domain of use-value rather than exchange-value. However, when this nature is placed in a historical context, material development is presented as a process of production of nature that merges use-values and exchange-values, and as a result of this production there is uneven development.

The distinction between a first and second nature can be questioned based on the notion of the production of nature: "The distinction between the first and second natures is obsolete [...] it became obsolete as soon as it no longer referred to the division between human and non-human society" (Smith, 1988, p. 99, translated from Portuguese). In this understanding, the classical division of two natures, which is not the way Marx thought of nature, divides a first nature (non-human world) and a second nature (the human world). However, this concept is obsolete because, with production focused on exchange, even the first nature is produced, since it is seen through an economic perspective. The notion of the production of nature, therefore, distinguishes itself from the idea of domination and exposes Marx's perspective of a metabolic relationship between human beings and nature.

Complexity not only considers Marx's view of production as important to its theoretical approach, but the possibility of dialogue between systems thinking and the concept of metabolism is also expressed in Foster's work (2005):

> Beginning in the 1840s down to the present day, the concept of metabolism has been used as a key category in the systems theory approach to the interaction of organisms to their environments. It captures the complex biochemical process of metabolic exchange, through which an organism (or a given cell) draws upon materials and energy from its environment and converts these by way of various metabolic reactions into the building blocks of growth (Foster, 2005, p. 226, translated from Portuguese).

This suggests that perspectives considered antagonistic in geographical thought have a relationship of dialogue (point of convergence), with the notion of metabolism of nature having broad convergence with systemic theory based on the interaction of organisms with their environment. The conceptualization of nature within Complexity presents with greater approximation to the Marxist view of metabolism, these appearing more closely aligned than with the division of first and second nature. This view allows an expansion of the

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scope of production beyond human labor, including the dynamics specific to natural systems. Such an expansion, however, does not replace the critical analysis of specific forms of social production, but can provide an epistemological basis for understanding that the processes of territorialization, for example, that do not result exclusively from the conscious action of social subjects, but involve multiple causalities and levels of organization, thus challenging the dualism between intentionality and spontaneity.

Like the previous notions, the notion of irreversibility (3) is also relevant to Complexity and points of dialogue with critical geography. As Prigogine (1996) writes, science conceived of time in a reversible manner. An example is Newton's law, which is both deterministic and time-reversible. This means that, by knowing the initial conditions of a system subject to this law, all of its past and future states can be calculated. However, advances in studies on irreversible processes have corroborated the breaking of this temporal symmetry. Entropy, an essential element of the 2nd Law of Thermodynamics, pointed in this direction. In other words, the second principle of thermodynamics demonstrated that the energy of the universe is constant and that the entropy of the universe increases towards its maximum.

Through entropy, irreversibility is understood as an increase in disorder. However, developments in fields such as the physics of non-equilibrium systems have challenged this notion, proposing that the arrow of time may also be a source of order in the system, and that it is thanks to irreversibility that nature creates its new and differentiated structures and organizations, some of which can become increasingly complex. In other words, life is only possible in a universe that is far from equilibrium (Prigogine, 1996). The arrow of time, which symbolizes the unidirectional movement of time – from past to future – is a fundamental element in understanding the development of life and the complexity of systems.

In this sense, in line with what Prigogine (1996) wrote about natural science changing its view of time, considering an open and totally historical notion of time, Massey (2008), a Marxist geographer, uses this new consideration of the irreversibility of time for a conceptualization of space that challenges the traditional notions of a fixed space, arguing that socially constructed space is dynamic and fluid. The question of irreversibility, in the author's thinking, exposes how some spatial processes, when initiated, can lead to transformations that are irreversible, a produced space that carries within itself the marks of historical processes. For the author, irreversibility for geography can be thought of as a result of the capitalist production system and its reconfiguration in geographic space; however, it should not be understood as a change that is inevitable and without intervention, but rather a reflection on the lasting marks left by capitalism on nature.

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In other words, for critical geography, this idea of time as an arrow is evident in the capitalist system that promotes the exploitation of nature. Thus, the convergence between the approaches is expressed in the consideration by both that irreversibility is a fundamental feature of natural and social processes. The divergence is that, while Complexity views irreversibility as the driving force behind the emergence of order in open systems (organization far from equilibrium), critical geography links it to the structural marks left by the logic of capital, emphasizing that certain changes in space are irreversible precisely because they are the product of relations of exploitation. The incorporation of the notion of irreversibility into geographical thought allows us to break with a cyclical or deterministic view of history and nature, opening space for an understanding of time as a field of possibilities and not just repetitions or reproductions. This has important implications for territorial planning, the analysis of socio-environmental risks, and the critique of narratives of absolute control over nature, calling into question the modern dualism between order and disorder.

The notions of autonomy and dependence (4) can also be understood in a dialogical way between Complexity and critical geography. The notion of autonomy for Complexity can be thought of from the self-organization of a system – elements that have freedom of organization, but that continue to be part of the systemic whole.

Despite the autonomy/self-organization of some systems, there is also a relationship of dependence between the components. For Complexity, nature is this relationship of solidarity and dependence of systems intertwined with and through each other, a system of systems in series, a polysystemic whole. For example, the organism is a system of organs, which are systems of molecules, which are systems of atoms, and the living being is an individual system that participates in a reproduction system and an ecosystem. Following this reasoning, the idea of systems of systems breaks with the classical idea of a closed and self-sufficient object (Morin, 2016).

Critical geography also has implications for the notion of autonomy. For example, aiming to expand the conceptualization of the idea of territory and outlining an alternative conception of development that escapes economism, Souza (1994) makes explicit the issue of autonomous territoriality. For him, autonomy reconceptualizes the idea of development, which is seen as the process of self-institution of society for greater freedom and less inequality. In other words, an autonomous society freely manages the territory and seeks transformation with a view to social justice, as is visible in indigenous and quilombola societies.

Thus, for critical geography, the idea of autonomy is applicable, for example, in autonomous territoriality in which societies decide to act according to their own interests. As for the notion of dependence, one of the

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applications for critical geography is the unequal insertion of territories in global politics, for example, technological innovations leave peripheral peoples even more at the mercy of the center of power, making them dependent on imported technology (Santos, 2006). Thus, the convergence between the approaches occurs based on the mutual recognition that autonomy is relational and that there is no absolute independence. The divergence is that for Complexity, autonomy is above all an emerging phenomenon of systemic organization, while in critical geography, autonomy is linked to the struggle for self-determination and territorial justice. The interdependence between autonomy and dependence questions the dichotomy between freedom and domination. It is shown that autonomy is not the absence of dependencies, but the capacity to reconfigure them.

In this way, the dialogue between Complexity and critical geography seeks to dismantle the dichotomies present in geographical thought. By going beyond separations such as part/whole, order/disorder and autonomy/dependence, both approaches favor an integrated and relational understanding of Nature and society. This perspective improves theoretical analysis and opens paths for geographical practices that recognize the inseparability of phenomena, contributing to a complex knowledge of reality.

IV. FINAL CONSIDERATIONS

The Complexity perspective and critical geography converge in several aspects when addressing the notions of totality, production, irreversibility, and autonomy and dependence, but they also present divergences. Both recognize totality as something dynamic and more than the sum of its parts, rejecting both reductionism and holism. However, Complexity focuses on systems and their interactions, seeking to overcome mere systemism by integrating uncertainty and self-organization; while critical geography, based on Marxism, highlights the dialectic of social and spatial contradictions.

Complexity presents a nature that has instabilities, non-linearities, and emergences, demonstrating that the simplifying paradigm is not effective for analyzing a nature that is dynamic. Due to the presence of dualisms in geographical thought, Complexity shows itself as an epistemology that offers the unity (one) of geography and the singularities (multiple) for the problematization of duality.

Critical geography and its Marxist theoretical basis also offer many elements for problematizing the duality in the definition of nature in geography, especially when it goes beyond a dominated nature and offers the perspective of a produced nature. Furthermore, the organic idea of nature expressed in the concept of metabolism offers a relationship of circularity and movement between the human being and the natural.

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Beyond a division between first and second nature, the concept of metabolism and production of nature is closer to the conceptualization of nature in Complexity as a metasystem.

The dialogic relationship that was established allows for an understanding of the most evident points from each perspective, but despite their specificities, there is a search for a non-dual positioning on nature that is important for geographical theory and practice. The challenge now will be the recognition and practice of new works that dialogue with different perspectives for the advancement of science itself, thus contributing to the problematization of a definition of nature based on duality.

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