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ARTICLE

From conceptual plurality to School consensus: circulation and stabilization of the concept of “Life” in light of Fleck’s epistemology

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ABSTRACT:

This paper examines the definition of life as a plural problem in biology and as stabilized content in biology teaching. In light of Fleck's epistemology, we understand definitions as scientific facts situated in collectives and styles of thinking, and describe the traffic between esoteric and exoteric circles. We reconstruct five styles that underpin canonical characterizations of life: evolutionary-historical, physical-chemical, systemic-organizational, thermodynamic self-organization and complexity, and metatheoretical-operational. We argue that plurality is operational in the esoteric, but tends to be erased in circulation through simplification, selection, and reordering, producing didactic consensus and apodictic statements. Finally, we indicate implications for teaching and teacher training: making the limits of lists explicit, reintroducing history and controlled controversies, and using borderline cases to teach life as a controversial and fertile concept for socio-scientific questions. The study is theoretical-epistemological, based on the systematization of canonical and educational literature, without claiming empirical exhaustiveness in this analytical section.

Key words:
Fleck's epistemology; Scientific controversies; Concept of life

Da pluralidade conceitual ao consenso escolar: circulação e estabilização do conceito de “Vida” à luz da epistemologia de Fleck

RESUMO:

Este artigo examina a definição de vida como problema plural na biologia e como conteúdo estabilizado no ensino de biologia. À luz da epistemologia de Fleck, entendemos definições como fatos científicos situados em coletivos e em estilos de pensamento e descrevemos o tráfego entre círculos esotéricos e exotéricos. Reconstruímos cinco estilos que sustentam caracterizações canônicas de vida: evolutivo-histórico, físico-químico, sistêmico-organizacional, termodinâmico da auto-organização e complexidade e metateórico-operacional. Argumentamos que a pluralidade é operacional no esotérico, mas tende a ser apagada na circulação por simplificação, seleção e reordenação, produzindo consenso didático e enunciados apodíticos. Por fim, indicamos implicações para ensino e formação docente: explicitar limites das listas, reintroduzir história e controvérsias controladas e usar casos-limite para ensinar vida como conceito controverso e fértil para questões sociocientíficas. O estudo é teórico-epistemológico, baseado em sistematização de

Palavras-chave:
Epistemologia de Fleck; Controvérsias Científicas; Conceito de Vida

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literatura canônica e educacional, sem pretensão de exaustividade empírica neste recorte analítico.

De la pluralidad conceptual al consenso escolar: circulación y estabilización del concepto de “vida” a la luz de la epistemología de Fleck

RESUMEN:

Este trabajo examina la definición de vida como problema plural en biología y como contenido estabilizado en la enseñanza de la biología. A la luz de la epistemología de Fleck, entendemos las definiciones como hechos científicos situados en colectivos y estilos de pensamiento, y describimos el tráfico entre círculos esotéricos y exotéricos. Reconstruimos cinco estilos que sustentan las caracterizaciones canónicas de la vida: evolutivo-histórico, físico-químico, sistémico-organizacional, termodinámico de la autoorganización y la complejidad, y metateórico-operacional. Argumentamos que la pluralidad es operativa en lo esotérico, pero tiende a desaparecer en la circulación por simplificación, selección y reordenación, produciendo consenso didáctico y enunciados apodícticos. Por último, indicamos implicaciones para la enseñanza y la formación docente: explicitar los límites de las listas, reintroducir la historia y las controversias controladas, y utilizar casos límite para enseñar la vida como un concepto controvertido y fértil para cuestiones sociocientíficas. El estudio es teórico-epistemológico, basado en la sistematización de la literatura canónica y educativa, sin pretensión de exhaustividad empírica en este recorte analítico.

Palabras-clave:
Epistemología de Fleck; Controversias científicas; Concepto de Vida

INTRODUCTION

The definition of life is a perennial problem in the biological sciences. On the one hand, it seems to cut across different research traditions, from evolutionary biology to molecular biology, from systems approaches to thermodynamic formulations and debates in astrobiology (Bich & Green, 2018). On the other hand, when we examine reference texts and canonical syntheses, we notice that “life” rarely appears as a univocal concept.

Instead, the specialized literature mobilizes heterogeneous definitions and characterizations, linked to distinct problems: life as population history and differential reproduction (Kuzawa, 2007); life as physicochemical order and stability (Atkins et al., 2023); life as autopoietic organization (Meincke, 2019); life as a system far from equilibrium (Gecow, 2025); life as the target of a universal definition for purposes of search and detection (Benner, 2010). This plurality expresses different ontological, epistemological, and methodological commitments, characteristic of specific scientific collectives and their thought styles (Fleck, 2010).

However, when we consider Biology Teaching, the scenario changes. The educational literature and the analysis of teaching materials indicate a recurring tendency in which life often appears as a relatively pacified concept, presented in the form of a list of criteria, textbook definitions, and stabilized explanations, with little historical or epistemological problematization, as highlighted by Ferraro (2009; 2019). What, in the specialized sphere, remains a disputed question tends, in the school space, to be converted into neutral and consensual content. The contrast between these two regimes (conceptual plurality in the esoteric scientific circle and didactic stability in the exoteric educational circle) constitutes the starting point of this article. The term “consensus” is used in this work in a descriptive sense, to indicate the didactic stability resulting from the circulation of knowledge, and not as an epistemological judgment about correctness or conceptual completeness.

We maintain that this deviation, between the esoteric portion of the scientific circle and the exoteric educational one, should not be understood as a pedagogical failure, a naïve simplification, or a deficit in teacher education. We propose, instead, that it can be interpreted as a structural effect of the circulation of knowledge.

To develop this hypothesis, we draw on the epistemology of Ludwik Fleck (2010), particularly the concepts of Thought-Collective, Thought-Style, and Traffic of Thought between esoteric and exoteric circles.

For Fleck (2010), scientific definitions are not merely correct answers to questions; they are scientific facts stabilized within specific scientific communities, whose coherence is sustained by shared problems, instruments, languages, and validity criteria. When these facts circulate into other contexts, such as teaching, science communication, and school materials, they tend to be recontextualized, losing part of the controversies and tensions that gave rise to them, while at the same time gaining stability and an appearance of neutrality (Fleck, 2010).

In light of the above, this article aims to reconstruct, in a comparative key, a set of definitions and characterizations of life present in canonical works of biology and philosophy of biology, understanding them as expressions of different thought styles. Furthermore, we seek to interpret, in the light of Fleck's epistemology, how and why these conceptual tensions tend to be attenuated when "life" circulates into the teaching space, where the concept often takes the form of a basic and apparently consensual definition.

Although other epistemologies, such as those of Kuhn or Lakatos, can be mobilized to analyze dynamics of controversy and scientific change, as, for example, in the discussions developed by Silva and Laburú (2010) and Cunha et al. (2025), the choice of Fleck is justified because his concepts of traffic of thought, thought collectives, and thought styles make it possible to analyze not only the production of knowledge, but also its reconfiguration in teaching and in genres of circulation of the exoteric circle (textbooks, schoolbooks, and science communication).

From this, we are guided by the following research questions: (i) Which thought styles underpin the main canonical definitions of life in the biological literature? (ii) How does Fleck allow us to explain the transition from controversy (esoteric circle) to didactic consensus (exoteric circle) in the case of the concept of life? (iii) How can the discussion developed here contribute as an element for the discussion of socioscientific issues in Biology Teaching?

Although Fleck's epistemology has already been mobilized in several studies in Science Education (Lorenzetti, Muenchen & Slongo, 2013; Santos, 2017; Fioresi & Silva, 2022) and although there are studies that discuss the concept of life in teaching materials and in teacher education (Ferraro, 2009; 2019), an articulation between the plurality of styles present in the biological literature and the manualization that favors school stabilizations, as well as didactic implications that operate as borderline cases and public decisions, in dialogue with approaches to socioscientific issues, remains little explored.

In this sense, this article offers contributions by proposing a typology of five thought styles applied to the concept of life, treating reference works as epistemological documents, by making explicit a Fleckian stabilization mechanism associated with the transition between circulation genres, and by offering a bridge to socioscientific issues through borderline cases and through how different definitions entail criteria of evidence and practical decisions.

Although the discussion developed draws on specialized literature in philosophy of biology and epistemology of science, the aim of the article is not to demand that teachers or teacher educators master all the theoretical debates involved, but to make visible how different criteria for defining life entail distinct conceptual decisions and produce effects on the way knowledge circulates and stabilizes in teaching.

It is important to acknowledge that this article is not the first to identify thought styles associated with the concept of life. Bertoni (2012), in her doctoral dissertation, analyzed the construction of the scientific fact "life" from the perspective of Fleck's epistemology and identified four biological thought styles: Descriptive Biological Thought Style, Mechanistic Biological Thought Style, Evolutionary Biological Thought Style, and Genetic Manipulation Biological Thought Style.

This paper takes this antecedent into account but advances in three directions: (i) it broadens the scope to include styles more recently consolidated in the literature (thermodynamic of self-organization and complexity, and metatheoretical-operational); (ii) it explicates, for each style, the Fleckian analytical operators (central

problem, validity criteria, lexicon, self-evidences); (iii) it connects stylistic plurality to the phenomenon of didactic stabilization, analyzing the traffic between esoteric and exoteric circles as a mechanism for the production of school consensus. In this way, the article contributes by articulating a typology, a Fleckian analysis of circulation, and implications for biology teaching.

It is appropriate to delimit the status of the present study. This is a theoretical-epistemological article, based on the analysis and systematization of literature, and not an empirical and exhaustive work of primary field research or evaluation of teaching materials. The works mobilized are treated as epistemological documents, that is, as syntheses of problems, validity criteria, and conceptual commitments that characterize distinct thought styles, whereas the educational literature is drawn upon to describe, as an interpretive hypothesis, a pattern of stabilization of the concept of life already recognized in studies on teaching and textbooks. Thus, when we refer to teaching and teaching materials, we operate by synthesizing secondary literature, and not as an exhaustive diagnosis of contemporary teaching materials.

The structure of the article follows this movement: (i) we present Fleck's framework and its central concepts; (ii) we reconstruct canonical definitions of life and their thought styles; (iii) we discuss the stabilized presentation of the concept in biology teaching; (iv) we develop the Fleckian interpretation of the circulation and the attenuation of controversies in the passage from the esoteric to the exoteric; (v) we point out implications for Biology Teaching, proposing the concept of life as a privileged point for historical-epistemological problematizations and for the discussion of socioscientific issues in teacher education and practice.

THOUGHT-COLLECTIVE, THOUGHT-STYLE, AND TRAFFIC OF THOUGHT

For analytical purposes, we adopt a selection of Fleckian concepts, following the systematization proposed by Takahashi (2018), limiting ourselves to the elements strictly necessary for the aim of this article: thought-style, thought-collective, and traffic of thought.

According to Fleck (2010), scientific knowledge is constituted from some basic premises. The first of these is what the author calls thought-style, designated as historically situated modes of perceiving, formulating problems, accepting evidence, and producing explanations within an area. A thought-style involves a set of problems considered relevant, a set of validity criteria (methods, languages, instruments, and models), and a set of notions that become self-evident for the participants of that domain (Fleck, 2010).

Therefore, the same phenomenon can be perceived, investigated, and explained in different ways depending on the thought-style in question. For example, the phenomenon of life can be understood from an evolutionary, molecular, thermodynamic, etc. perspective; and each of these perspectives possesses a set of problems considered relevant, validity criteria, and self-evident assumptions.

The thought-collective is the community that shares and sustains a thought-style through practices, training, texts, and institutions. For Fleck (2010), there is no pure knowledge produced by an isolated subject; knowledge is constituted in a triadic relationship between subject, object, and state of knowledge, that is, a historical-cultural repertoire of concepts, methods, and values that makes certain questions and answers possible.

Within a thought-collective, Fleck (2010) distinguishes the existence of esoteric circles (specialized core, where conceptual production and dispute are more intense – research, debate, controversy, and refinement of concepts are developed) and exoteric circles (wider layers of participation, where knowledge circulates in more stabilized forms – handbooks, teaching, science communication, journalism, etc.). This distinction allows us to describe why life can be plural and disputed in the esoteric circle, but at the same time appear as a relatively consensual concept in the exoteric circle.

The ideas constructed and mobilized by collectives are dynamic; that is, they circulate and transform as they transit between people, texts, levels of initiation, and collectives. Fleck (2010) highlights that during the circulation path, the content tends to be polished, simplified, reordered, and often stripped of controversies. From an analytical point of view, we distinguish two movements: (i) intra-collective traffic, in which internal

circulation tends to reinforce the style itself (production of local consensus, consolidation of terms and problems); (ii) inter-collective traffic, in which circulation between collectives tends to produce shifts in meaning, translations, and recontextualizations. It is in this second movement that the passage from life as a plural problem to a consensual school definition becomes intelligible. This reading is supported by models that articulate Fleck with the notion of circulation and textualization, highlighting distinct epistemological functions for different types of text in the transit between circles and collectives (Fioresi & Silva, 2022).

Fleck (2010) also describes levels of production and diffusion of scientific knowledge, which can be understood as genres of circulation. This reading of "levels" as textual forms with an epistemological role is explored in detail by Fioresi and Silva (2022), who treat journals, handbooks, schoolbooks, and popular textualizations as constitutive pieces of knowledge circulation. The more fluid and provisional science associated with the production core (journal science) tends, as it consolidates, to be re-expressed in more apodictic and stable forms (handbooks, schoolbooks, and science communication). For this article, this passage is central because the schooling of a concept should not automatically be taken as a pedagogical error, since it is often a typical effect of circulation, in which controversies are attenuated for teaching, synthesis, and communicability. This, however, does not exclude the possibility of error when school recontextualization displaces the epistemological status of the content, for example, by presenting as "scientific theory" propositions that are not recognized as such in the esoteric circle (as occurs in attempts to include creationism in the Science and Biology curriculum when dealing with "theories about the origin of life").

METHODOLOGICAL PROCEDURES

This is a theoretical-epistemological study of a reconstructive and comparative character, guided by Fleck's epistemology (2010). For the constitution of the corpus, works from biology, philosophy of biology, and studies on life were selected, prioritizing texts that possess historical relevance and recognized circulation in the debate on the concept of life, that make explicit conceptual and methodological commitments, and that represent different research programs. Table 1 summarizes the corpus and the inclusion criteria:

Table 1 – *Corpus* of analyzed works and selection criteria.

Author(s)	Work (year)	Tradition
Dobzhansky (1973)	*Nothing in Biology Makes Sense Except in the Light of Evolution*	Evolutionary
Mayr (1982)	*The Growth of Biological Thought*	Evolutionary
Schrödinger (1959)	*What is Life?*	Physico-chemical
Monod (1970)	*Le hasard et la nécessité*	Molecular
Maturana & Varela (1980)	*Autopoiesis and Cognition*	Systemic-organizational
Capra (1996)	*The Web of Life*	Systemic
Prigogine & Stengers (1984)	*Order out of Chaos*	Thermodynamic
Cleland (2020)	*The Quest for a Universal Theory of Life*	Metatheorical-operational

The analysis of each work followed a protocol based on Fleck's epistemology, identifying:

- Central problem: what question about life does the text seek to answer?
- Validity criteria: what type of evidence, method, language, or model is privileged?
- Stabilizing lexicon: which terms organize the ineligibility of the phenomenon (e.g., selection, information, autopoiesis, dissipation)?
- Self-evidences: which assumptions operate as unquestionable within the style?
- Way of making life intelligible: does the style explain through narrative, mechanism, organization, flow, or epistemological critique?

We carried out an in-depth reading of each work, identifying representative passages for the five elements above. Next, we proceeded to the comparison between works, grouping those that shared central orientations (similar problems and validity criteria) into stylistic families. The grouping resulted in the proposal of five thought-styles, aware that boundaries are not rigid and that the same work may engage with more than one style. Table 2 (presented in the comparative synthesis) organizes the contrasts between the styles based on the analytical operators.

The five styles do not exhaust all the bibliography available on the concept of life, but constitute an analytical selection sufficient for the objectives of the article: to demonstrate conceptual plurality in the esoteric circle and to analyze its attenuation in the circulation into teaching.

LIFE AS A SCIENTIFIC PROBLEM: THOUGHT-STYLES IN BIOLOGY

Based on Fleck's epistemology (2010), we do not seek "the" correct definition of life; rather, we trace how different thought-collectives stabilize facts and criteria of intelligibility through thought-styles. For this reason, we treat certain works as epistemological documents, not because they exhaustively represent their fields, but because they function as influential syntheses that articulate problems, lexicons, and criteria of validity, with strong power of circulation and textbookization.

As mentioned in the introduction, Bertoni (2012) identified four thought-styles concerning life in his analysis. In this sense, the present article reinscribes itself within this perspective of Fleckian research on the concept of life. Unlike Bertoni (2012), whose analysis focused on identifying the styles present in materials of broader circulation, our focus falls on the contrast between stylistic plurality in esoteric literature and the process of didactic stabilization in the exoteric circle. In addition, we expand the repertoire with two more recent styles, the thermodynamic and the metatheoretical-operational, and make explicit, for each style, the Fleckian analytical operators, according to the protocol described in the Methodological Procedures.

Before detailing each of the styles, it is worth clarifying that the reconstruction presented here is neither rigidly classificatory in character nor intended to offer an exhaustive overview of the literature on the concept of life. This is an analytical delimitation, guided by the problem of the circulation of knowledge, whose aim is to highlight contrasts among criteria of intelligibility of the living, rather than to exhaust or hierarchize approaches. The reading of this section should therefore be understood as comparative and instrumental, and not as a definitive cartography of the field.

Evolutionary-Historical Style

In what we call the Evolutionary-Historical Style, the intelligibility of the concept of life is constructed from the idea that biological phenomena only acquire meaning when situated within processes of change over time, that is, within historical/evolutionary processes.

Evolution operates as an integrating principle, capable of transforming a collection of descriptions into an explanatory framework. Dobzhansky (1973, p. 129) formulates this emblematically when he states that "seen in the light of Evolution, Biology is [...] intellectually the most satisfying and inspiring science. Without that light it becomes a pile of sundry facts". This passage is relevant because it characterizes a criterion of validity typical of the style: evolutionary theory is valued for its integrative power, for its capacity to give explanatory unity to the diversity of living beings.

At the level of the object, the concept of life appears here as linked to organic diversity and to its historical nature. Dobzhansky (1973) asks about the intelligibility of the variety of forms and modes of existence and maintains that the only explanation that makes sense is that organic diversity evolved in a context of changing environments over time; he further describes the relationship among ecological challenges, adaptive genetic changes, and the possibility of extinction as a possible fate of lineages over time.

According to Fleck (2010), we are dealing with a style that selects as central problems the question of diversity, variability, adaptation, fossil species, and so forth, and organizes responses through a set of its own

vocabularies and causal schemes, such as selection, genetic change, extinction, and geological time, among others.

Mayr (1982) reinforces the same orientation by characterizing biology as a domain in which laws in the classical sense have less explanatory yield than historical narratives. He states that, in evolutionary biology, the concept of law is far less productive than that of historical narratives (Mayr, 1982). This point is decisive, since in this style, explaining involves reconstructing trajectories, contingencies, and inheritances, rather than merely deriving atemporal regularities.

One consequence of this is the centrality of "why?" questions, that is, evolutionary explanations, in contrast to "how?" questions, that is, proximal causes. Mayr (1982) observes that, historically, the demand for "why-questions" grows as a search for final causes, that is, historical-evolutionary causes, and argues that, without this level, descriptions remain incomplete (Mayr, 1982). Although proximate causes are useful for describing how processes and mechanisms operate, in the Evolutionary-Historical Style, they do not play an organizing role; the decisive intelligibility of the living comes from the why, from narratives of lineages, contingencies, constraints, and selections that explain why certain functions became stabilized and not others. In this sense, the phenomenon of life is understood primarily as a historical reality, not so much through the question "how does life function?", but rather "why does life function in this way?", and this "why" refers to the evolutionary axis.

Mayr also makes explicit a methodological/conceptual trait typical of this style. In biology, much of the progress comes less from the accumulation of facts than from the introduction of new concepts. He exemplifies this with the point that phenomena now explained by natural selection were known before Darwin, but did not make sense until the concept of populations composed of unique individuals was introduced (Mayr, 1982). Here, an internal mechanism of stabilization of the style emerges, in which certain concepts come to function as conditions of intelligibility for what counts as a problem and what counts as an explanation.

Dobzhansky (1973) delimits a relatively stabilized core, evolution as a historical process, and a zone of controversy around mechanisms and explanatory models. In Fleckian terms, disagreement is not an external noise, but part of the functioning of a thought-style; it is concentrated at the research frontier, while the integrative framework remains operative as a condition of intelligibility.

In general terms, what we are calling the Evolutionary-Historical Style, considering Dobzhansky and Mayr as synthetic expressions of this movement, sustains a way of treating life as a scientific problem in which evolution functions as an integrative framework that gives meaning to biological diversity. Explanation privileges history/narrative and final causes, without dispensing with proximate mechanisms. The intelligibility of the idea of life depends on concepts that stabilize what counts as explanation, and controversies do not disappear, but are managed by communal dynamics of knowledge production and evaluation, as described by Fleck (2010).

In Fleckian terms, the Evolutionary-Historical Style selects diversity, variation, adaptation, and extinction as central problems. Its validation criteria include historical narratives, population evidence, and phylogenetic comparisons. The stabilizing lexicon comprises terms such as natural selection, genetic drift, geological time, and lineage. The self-evidences that operate in this style include the premise that all organic diversity has a historical explanation and that explanations in terms of final causes, that is, evolutionary causes, are not only legitimate, but necessary for the full intelligibility of the living. Life, in this style, becomes intelligible as a historical reality, whose meaning emerges from the narrative of lineages and contingencies.

Physico-Chemical Style

In what we call the Physico-Chemical Style, "life" appears less as a historical-evolutionary category and more as a problem of the physico-chemical explanation of organization. In What is Life?, Schrödinger (1959) formulates this program already as a guiding question: "How can the events in space and time which take place within the spatial boundary of a living organism be accounted for by physics and chemistry?" (Schrödinger, 1959, p. 3). The initial response is the rejection of a vitalist conclusion, even if the physical and

chemical phenomena that govern life are not yet fully known. Thus, the delimitation of the "living" is shifted to how matter is organized; that is, Schrödinger (1959) states that the decisive point lies in a fundamental difference in structure between living matter, the physico-chemical constituents of living beings, and inanimate matter, the objects usually treated by physicists and chemists.

This structural difference is exemplified by a figure that would become canonical in Molecular Biology: the chromosomal fiber. Schrödinger (1959, p. 5) argues that this is the most essential element of the cell, characterizing it as an "aperiodic crystal" ["an aperiodic crystal" (Schrödinger, 1959, p. 5)]. The emphasis therefore falls on material bearers of stability/regularity, crystals, whose non-periodicity opens the way to thinking biological complexity and specification within physico-chemical laws. The author himself makes explicit the ontological step of this wager when he says that such a crystal would be, in his opinion, the material of life (Schrödinger, 1959).

In Monod, the same style reappears in a more informational vocabulary and is guided by a mechanism already fully situated within molecular biology. In discussing the impact of molecular theory, Monod (1970) delimits the phenomenon of life through a double anchoring: a physical/experimental basis, the chemical structure of the genetic material and the information it carries; and a processual basis, the molecular mechanisms through which this information is expressed and realized in the organism. From this perspective, the central dogma of molecular biology is presented as the general basis for an intelligibility of the living, not because it directly deduces all complex structures and functions, but because it offers an explanatory basis that makes such complexities treatable in terms of information, regulation, and mechanisms. In contrast to Schrödinger, whose argument emphasizes above all the problem of material stability and structural specificity, Monod shifts the focus to the articulation among structure, information, and the operation of mechanisms.

From the point of view of the "concept of life," Monod (1970) combines this informational-molecular core with an organizational property that he calls teleonomy. In discussing functional adaptations, he states that it is indispensable to recognize, as a fundamental property of living beings, that they are objects endowed with a project, that is, objects that represent a project in their structures and realize it in their performances. At the same time, he adds a caveat: teleonomy is a necessary condition for characterizing living beings, but it is not sufficient as a discriminatory criterion, because it may also appear in artifacts produced according to a project (Monod, 1970). The distinction, therefore, is not abandoned; it changes place. Rather than separating the living from the non-living solely by the presence of purpose, Monod suggests that the differential feature of the living lies in the mode of constitution and maintenance of organization, that is, in systems whose form and functioning emerge from internal processes, such as self-construction and reproduction, and not from external imposition, as in artifacts. The proposed solution returns to the structural register: distinguishing artifacts from living beings as systems whose form results from internal interactions, suggesting the image of machines that self-construct. Here, the "living" is once again described through a grammar of material organization, program, and information, and internal mechanisms.

These texts, by Schrödinger and Monod, may be read as epistemological documents of the same physico-chemical family, insofar as they reject vitalist explanations and seek to anchor the intelligibility of the living in material bases treated by physics and chemistry. However, they express distinct emphases within this family. In Schrödinger, the specificity of the living is formulated above all as a structural problem, related to biological stability and complexity, which required a material bearer with singular physico-chemical properties, capable of sustaining regularity and variation. In Monod, the focus lies on an informational and mechanistic reading, in which genetic material is central not only as structure, but also as the support of information and as part of a system of mechanisms of expression and regulation that realize a program, teleonomy. Thus, the convergence between the authors does not lie in the same specific property of definition, but in the common commitment to locating the living being within a physico-chemical basis, while they diverge as to what is taken as the explanatory core: a structure bearing stability, in Schrödinger, and information and mechanisms for teleonomy, in Monod.

This internal divergence does not require postulating distinct thought-styles. For Fleck (2010), a thought-style is not a homogeneous doctrine, but a relatively stable set of orientations that defines what counts as a relevant problem, which criteria of validity are accepted, and which forms of explanation are considered

intelligible within a collective. In this sense, both authors remain within the same grouping because they share a central commitment: the rejection of vitalism and the requirement to anchor life at a physico-chemical level, treating the specificity of the living being as something that must be explained by material properties and by mechanisms compatible with this register. Thus, the divergences may be read as intracollective variations and refinements, shifts of emphasis and vocabulary that emerge as new problems, instruments, and research programs are consolidated, without breaking with the common horizon of intelligibility that characterizes the style.

In light of Fleck (2010), the Physico-Chemical Style selects as central problems the explanation of material stability, heredity, and biological functioning on physico-chemical grounds, rejecting any appeal to external vital forces. Its criteria of validity include molecular structure, controlled experimentation, mechanistic analysis, and, progressively, the notion of genetic information as an explanatory operator. The stabilizing lexicon is composed of terms such as aperiodic crystal, genetic code, central dogma, information, molecular mechanism, and teleonomy, the latter, in Monod, operating as a bridge between mechanistic description and the recognition of functional purposiveness. The self-evidences that operate in this style include the premise that every biological phenomenon is, in principle, reducible to or explicable by physico-chemical processes, and that vitalism does not constitute a legitimate explanation.

Life, in this style, is intelligible as a problem of material and informational organization: the living is that whose order and functioning can be described by physical and chemical laws, even if these laws are not yet completely known. The specificity of the living being does not reside in a special substance or force, but in the way common matter is arranged, informed, and regulated.

Systemic-Organizational Style

In what we call the Systemic-Organizational Style, “life” ceases to be sought as the result of a historical-evolutionary process or as a property-structure-function, and comes to be treated as a type of organization, a pattern of relations and processes capable of constituting a unit and maintaining its identity. The central problem is not what matter the living being is made of, but what type of organization makes a system recognizable as living, independently of the materials that realize it.

In Autopoiesis and Cognition, Maturana and Varela (1980) explicitly shift the explanatory focus from the properties of components to relations and processes. In announcing their approach, they state that, in explaining the organization of living systems, they will deal with the relations that components must satisfy to constitute the system, and not with the identification of these components; they also assume that there is an organization common to all living beings, whatever their components may be.

This movement becomes more operational with the distinction between organization and structure. The authors define organization as the set of relations that defines a machine or system as a unit and determines its possible dynamics; structure, in turn, corresponds to the actual relations among concrete components that realize that organization (Maturana & Varela, 1980). Thus, life is characterized less by a substance than by a relational pattern that may be embodied in different material arrangements.

The main point is the definition of an autopoietic machine. They describe it as a machine organized as a network of processes of production, transformation, and destruction of components that, through their interactions, continuously regenerate the very network of processes that produces them and, in doing so, produce the concrete unit itself, that is, they generate and maintain the boundary itself and the components that realize it (Maturana & Varela, 1980). In this sense, life appears as organizational self-production: not merely a system that remains in operation, but an organization closed upon the production of itself, in which the operation of the system has its own constitution as its product.

This emphasis helps explain why the definition does not automatically apply to machines and computational systems; although they may exhibit self-regulation and operational continuity, in general they do not produce their own material components or their constitutive boundary, depending instead on external fabrication, maintenance, and replacement, which brings them closer to allopoietic organizations, systems that

do not produce themselves and depend on external elements for their creation and operation, than to autopoietic ones. Thus, this style privileges evidence of circularity/organizational closure, a network that maintains itself; criteria linked to the constitution of unity and boundary, the system delimiting itself as a unit; and explanations in terms of relations among processes, rather than in terms of intrinsic properties of isolated parts.

In The Web of Life, Capra (1996) systematizes this vocabulary for a systemic synthesis of the living. He states that he follows Maturana and Varela in the definitions of pattern of organization and structure, in which the pattern is the configuration of relations among components that determines the essential characteristics of the system, while structure is the physical embodiment of that pattern (Capra, 1996). Capra (1996) adds a third axis, process, to account for the dynamic character of the living: in living systems, the embodiment of pattern in structure is not static, but occurs as a continuous process, such as growth, metabolism, and replacement of components, so that pattern-structure-process form interdependent perspectives for describing life.

In taking up autopoiesis, Capra reinforces the central point of the style, in which the focus lies on organization. He cites the formulation that the problem is living organization and that the interest is not in the properties of components, but in processes and relations among processes (Capra, 1996). He then makes explicit that autopoiesis is a network of production processes in which each component participates in the production and transformation of the others, so that the network makes itself, and he reproduces the phrase: in a living system, the product of its operation is its own organization (Capra, 1996).

In the Systemic-Organizational Style, life is treated as a problem of organization. The main problems are: what pattern of relations and processes must be present for a system to be a living unit? How does this unit maintain itself through autopoiesis, generating and regenerating its own components and boundaries? This produces a definition of a different type from those previously presented: not a definition by listable properties, but by organization, that is, network, closure, autonomy, and process.

Thus, in light of the Fleckian perspective, the Systemic-Organizational Style selects as its central problem the question of the organization that defines a system as living, shifting the focus from the properties of isolated components to the relations and processes that connect them. Its criteria of validity include the identification of organizational patterns, the analysis of networks of processes, operational closure, autopoiesis, and the system's capacity to produce and regenerate its own components and boundaries.

The stabilizing lexicon is composed of terms such as autopoiesis, organization vs. structure, network of processes, closure, structural coupling, pattern, and unity. The self-evidences that operate in this style include the premise that organization defines the identity of the system independently of the material substrate that realizes it, and that life is not a property of isolated parts, but a relational and emergent phenomenon. Life, in this style, is intelligible as a self-producing network; that is, a system is not living because it possesses certain components, but because its components produce the very network that produces them, generating and maintaining a boundary that delimits the system as a unit. The question "what is the living being made of?" gives way to the question "how does the living being organize itself to produce itself?"

Thermodynamic Style of Self-Organization and Complexity

In what we call the Thermodynamic Style of Self-Organization and Complexity, life is treated as a particular type of physical organization that is maintained only because the system is far from equilibrium (Silva et al., 2021). In general terms, living beings are open systems that continuously exchange matter and energy with the environment, and it is precisely this continuous flow that makes it possible to sustain stable patterns of organization, that is, order, without violating the second law of thermodynamics, because disorder, or entropy, is, so to speak, "exported" outside the system. In this style, "complexity" is the emergence of patterns and collective behaviors, macroscopic coherences, from many local interactions, often involving feedback and instabilities. The central question, then, ceases to be "which components define the living being?" and becomes "how can flows, instabilities, and irreversible processes generate and sustain complex organization?"

At first glance, this style may sound close to the previous one, since both speak of organization and the maintenance of patterns. The difference lies in the point of anchoring: in the systemic style, the emphasis falls on organizational form, closure, network of processes, constitution of the unit, as the conceptual criterion of the living being, relatively independently of the substrate; in the thermodynamic style, by contrast, the emphasis falls on the physical-energetic conditions that make the emergence and maintenance of this organization possible, that is, on flows, dissipation, and irreversibility as the explanatory basis.

Thus, the style is organized around a few central ideas. First, the commitment to non-equilibrium, that is, the continuous presence of flows of energy and matter, as a source of order, or as a condition for producing and sustaining ordered patterns, thereby making flow productive. Second, the commitment to dissipative structures and organization through dissipation, in which, under far-from-equilibrium conditions, an open system may form local order, a stable pattern, precisely because it is dissipating energy and exporting disorder to the environment, instead of moving toward a uniform state of equilibrium (Prigogine & Stengers, 1984).

The third commitment is that, far from equilibrium, many processes become nonlinear, with small variations producing disproportionate effects, and the behavior of the system ceases to be a simple sum of causes and effects. For this reason, fluctuations cease to be merely noise and may be amplified, reorganizing the system. At certain moments, the system reaches critical points, bifurcations, at which it may follow distinct paths and deterministic prediction loses force, since the outcome depends both on the conditions and on the fluctuations that have been amplified (Prigogine & Stengers, 1984). It is in this sense that the authors speak of "order through fluctuations"; emergent organization does not appear despite variations, but may arise precisely from them.

In this style, life appears as an organization sustained by macroscopic coherence under non-equilibrium conditions. The program emphasizes that, in certain regimes, a new coherence emerges, a mechanism of communication among molecules, and observes that such communication seems to be the rule in the world of biology and may be considered the basis for defining biological systems (Prigogine & Stengers, 1984). In addition, life appears as a historical-contingent process, sensitive to conditions and selections. The structure that emerges depends critically on conditions of formation and on mechanisms of selection, which shifts the focus from universal laws of equilibrium to the production of singularities far from equilibrium (Prigogine & Stengers, 1984).

Finally, life appears as irreversible temporality. The radical novelty of the style is to link organization and time; the attempt to unify dynamics and thermodynamics leads to a conception of active matter, in which irreversible processes organize matter and biological systems (Prigogine & Stengers, 1984). In the thermodynamic style, life tends to be stabilized as a regime of self-organization in open systems far from equilibrium, in which order may emerge from non-equilibrium, the genesis of new forms involves instabilities and bifurcations with a stochastic component, and the very intelligibility of the living is grounded in macroscopic coherence and correlation, molecular communication, as a basis for definition (Prigogine & Stengers, 1984).

The presentation of these styles does not aim at the detailed reproduction of specialized debates in school contexts, but at making explicit that different research programs operate with different criteria for rendering the phenomenon of life intelligible. It is precisely this diversity of conceptual commitments that tends to be attenuated in the process of schooling, an aspect that will be taken up again in the discussion of the stabilization of the concept in biology education.

The Thermodynamic Style of Self-Organization and Complexity selects as its central problem the explanation of how open systems, far from thermodynamic equilibrium, can generate and sustain order, complexity, and macroscopic coherence without violating the second law of thermodynamics. Its criteria of validity include the analysis of flows of energy and matter, the identification of dissipative structures, the study of bifurcations and nonlinearities, and the understanding of the productive role of temporal irreversibility. The stabilizing lexicon is composed of terms such as non-equilibrium, dissipative structure, fluctuation, bifurcation, order through fluctuations, macroscopic coherence, irreversibility, and self-organization. The self-evidences that operate in this style include the premise that thermodynamic equilibrium is a state poor in information and

incompatible with life, and that the continuous flow of matter and energy is not a disturbance, but the very condition of possibility of biological order.

Life, in this style, becomes intelligible as a dynamic regime of self-organization in which order emerges and is maintained precisely because the system is "far from equilibrium," dissipating energy and exporting entropy to the environment. Irreversible temporality ceases to be a problem, as in classical physics, and becomes an explanatory resource; that is, life is a process that exists only because time cannot go backward.

Metatheoretical-Operational Style

In this fifth style, life appears less as an object to be captured by a definition and more as an epistemological problem: what does it mean to attempt to define life, with universal pretension, when our empirical sample is limited and when definitions have a specific logical status? In Cleland (2020), this leads to the following diagnosis: the question "what is life?" is not well answered by definitions in the classical sense, and insisting on them may even hinder the search for, or recognition of, life as we do not understand it.

Cleland (2020) begins by distinguishing what a definition is in the logical/nominal sense, which specifies the meaning of a term within language, from definitions in the real/empirical sense, that is, attempts to characterize a natural kind in the world and to establish criteria that distinguish it from other phenomena. When a scientist asks "what is life?", they want to know what distinguishes living systems from physico-chemical systems in any place and time. Cleland (2020) argues that analyzing the contemporary concept of life is unlikely to deliver a scientifically satisfactory answer.

At the metatheoretical level, that is, in the discussion of the limitations of defining life, rather than defining life directly, she anchors this difficulty in the distinction between human categories and natural kinds. If life is a natural kind, its extension is too open to be decided by necessary and sufficient conditions; if it is not, the program of a universal biology cannot be sustained, and we fall into radical pluralism. In both cases, the conclusion is that life cannot be defined in the logical sense of definition.

The second pillar of this thought-style is the focus on the epistemic limitations of biology when it attempts to generalize life beyond Earth. Cleland (2020) calls the "N = 1 problem" the central challenge: our empirical sample is limited because the entire set of known cellular life appears to share a common evolutionary history, often summarized by the hypothesis of a last universal common ancestor, LUCA. This does not imply that all possible life, or even all life that has existed on Earth, is reducible to LUCA; there may have been pre-LUCA cellular lineages that left no descendants, and there are entities of disputed status, such as viruses, whose history may involve multiple scenarios, including derivation from current cells, extinct cellular lineages, or trajectories that are still not well resolved. Even so, Cleland's (2020) point remains: with such a restricted sample, it is not logically safe to generalize the properties of what we know as life to all possible life, especially when seeking a universal characterization for astrobiology and the detection of extraterrestrial life.

The case of viruses illustrates this tension well. Depending on the thought-style mobilized, they may be excluded because they do not possess their own metabolism, or included according to informational/evolutionary criteria, such as replication, heredity, and population dynamics. For this reason, besides not resolving the N = 1 problem, they function as a borderline case that reveals how criteria of life vary according to the research program, precisely the kind of conceptual instability that Cleland (2020) seeks to prevent from being fixed by a rigid definition of life. The author emphasizes that this is not merely a matter of logical caution: there are scientific reasons to suspect that our sample may be unrepresentative and that the criteria of life are not trivial even on planet Earth. Cases such as viruses, prions, states of extreme dormancy, seeds and endospores, and radical dependencies, obligate symbioses and organelles, show that properties frequently listed as defining may appear in fragmented, distributed, or conditioned ways. In this context, extrapolation to other physico-chemical conditions, such as those investigated in astrobiology, only makes the risk of prematurely fixing a rigid definition even more evident. These examples reinforce the thesis that criteria vary according to the thought-style mobilized, making it prudent to avoid definitions that convert a local solution into a universal rule.

In this sense, the displacement typical of this style is to replace the search for a strict definition with strategies of theoretical construction. Cleland (2020) maintains that the question "what is life?" would be answered more fruitfully by a scientific theory capable of accommodating and explaining a broader range of examples, and that, while our sample remains limited, it is prudent to avoid premature confinement to a local ontology, that is, to a set of basic concepts shaped by a single empirical delimitation, which may block generalizations and the recognition of new cases. Along these lines, part of the heterogeneity surrounding the definition of life may reflect less a confusion about the phenomenon and more the limits of our conceptual frameworks.

Here, the point is not to circumvent the question "what is life?", but to reformulate what counts as a satisfactory answer. For Cleland (2020), lists of properties and rigid definitions rarely solve the problem because they function as rules of classification based on a narrow empirical delimitation and, for this reason, are fragile in the face of borderline cases and unsampled possibilities. Instead, the answer she considers properly scientific is a theory of life, an explanatory framework capable of integrating different realizations of the phenomenon, generating predictions, and indicating what we should or should not expect in new contexts. In this process, operational criteria and provisional ontologies would not evade the problem; they would function as research bases, enabling collective work without prematurely fixing the category. Thus, the style does not eliminate the question, but proposes an effort to explain and expand the domain of what may count as life.

The Metatheoretical-Operational Style constitutes a "second-order" thought-style, since its object is not directly the phenomenon of life, but the very act of defining life. It selects as its central problem the epistemological question: under what conditions is a definition of life valid or useful, especially when our empirical sample is limited, the N = 1 problem, and when rigid definitions may prevent the recognition of unforeseen forms of life? Its criteria of validity include logical coherence, the distinction between nominal and real definitions, analysis of the limits of the available empirical sample, LUCA, viruses, endospores, and heuristic capacity, that is, the definition must help guide research, not block it. The stabilizing lexicon is composed of terms such as natural kind, N = 1 problem, LUCA, Last Universal Common Ancestor, nominal vs. real definition, pluralism, heuristics, and theory of life. The self-evidences that operate in this style include the premise that definitions by necessary and sufficient conditions are inadequate for open scientific categories such as "life," and that the search for a universal definition is epistemologically premature while our sample remains restricted to a single evolutionary lineage.

Life, in this thought-style, is intelligible not as an essence to be captured, but as an open scientific problem, one that requires less a definition than a theory capable of explaining different realizations of the phenomenon. The style thus shifts the question "what is life?" to "what counts as a good explanation of the phenomenon of life, given our epistemic limitations?" This self-reflection on the limits of the concept itself is a distinctive feature of this style, which does not invalidate the others but contextualizes and relativizes them.

Comparative Synthesis of the Thought-Styles concerning the Concept of Life

In order to make explicit the analytical contrasts mobilized in the reconstruction of the thought-styles, we present here a comparative synthesis of the five styles discussed (Table 2). The main aim of the synthesis is to offer a reading instrument that makes explicit how different problems and criteria of validity structure distinct conceptions of life.

Table 2 – Thought-Styles and Criteria of Intelligibility of the concept of Life.

Thought-Styles	Central Problem	Criterion of Validity
Evolutionary-historical	How can the diversity and adaptation of living beings over time be explained?	Historical narratives, population evidence, evolutionary comparison, and natural selection.
Physico-chemical	How can matter sustain stability, heredity, and biological functioning?	Molecular structure, physico-chemical mechanisms, genetic information, experimentation.
Systemic-organizational	What type of organization distinguishes living from non-living systems?	Organizational patterns, networks of processes, operational closure, autopoiesis.
Thermodynamic style of self-organization and complexity	How does Biological order emerge and remain sustained far from equilibrium?	Flows of energy and matter, irreversibility, dissipative structures, and nonlinearity.
Metatheoretical-operational	Is it possible, or desirable, to define life universally?	Logical coherence, limits of the empirical sample, explanatory, and heuristic capacity.

In view of the table, we can observe, from the reconstructed styles, that the concept of life is not organized around a single defining criterion, but emerges from different explanatory programs, each of which privileges particular problems and forms of evidence. This plurality, functional within the esoteric circle of science, helps explain why the concept tends to be reordered and stabilized when it circulates into teaching, where the demand for communicability and assessment favors more closed delimitations. The comparison among the styles, therefore, does not aim at choosing a correct definition, but at making explicit the conceptual decisions involved. In this sense, the plurality discussed throughout the article is treated here primarily as an epistemological phenomenon, resulting from distinct styles and their criteria of intelligibility, and not as evidence of an intrinsic ontological indeterminacy of the phenomenon of life.

THE STABILIZATION OF THE CONCEPT OF LIFE IN BIOLOGY EDUCATION

This section does not present a primary survey of textbooks, classroom observation, or an exhaustive empirical analysis of materials. The argument developed here is explanatory and interpretive: it synthesizes findings already consolidated in the literature on Science and Biology Education concerning how the concept of "life" tends to be presented in school materials and practices, mobilizing these findings as a basis for a Fleckian interpretation of stabilization in circulation.

Based on this literature, life tends to appear recurrently less as an open conceptual problem and more as stabilized content, often introduced through lists of properties and attributes that would distinguish living beings from inanimate beings, with little explicit discussion of the historicity of the debate and of the internal disputes within the biological sciences. This tendency is neither universal nor absolute, but it constitutes a sufficiently recurrent pattern to be analyzed.

In Josephino, Santos, and Bastos (2023), in their analysis of textbooks published between 1930 and 1959, there already appears a stance that combines the recognition of the difficulty of defining life with the replacement of the problem by properties and characteristics. One example is the passage transcribed from Mello-Leitão: "It is much easier to define the science of life than life itself" (Josephino, Santos, & Bastos, 2023, p. 13, our translation). According to Emmeche and El-Hani (2001), there is a traditional view, associated with Mayr (1982, section "Special Characteristics of Living Organisms"), according to which life as such cannot be defined, defining life is not an important issue, the process of life can be differentiated by a list of properties, and this list is not a set of necessary conditions, viruses being a typical case; although physical, the phenomenon exceeds reduction to physics.

In analyses of more recent textbooks, the gesture is repeated; the term life is frequently circumvented by definitions such as "biology is the science that studies life, or, more precisely, the characteristics of living beings," and by enumerations, such as organization, metabolism, irritability, reproduction, heredity, evolution, and so on (Linhares & Gewandsznajder, 1998). In studies on teaching and pedagogical practice in Science and Biology, this pattern is related to a pedagogical common sense that privileges definitions and classifications to the detriment of problems, models, and controversies (Schmitt, Albiero Jr., & Carvalho, 2023). According to Delizoicov, Angotti, and Pernambuco (2018, p. 25), this common sense is characterized by

> […] little rules and recipes; taxonomic classifications; excessive emphasis on the systematic repetition of definitions, functions, and attributes of living or non-living systems; poor questions for equally impoverished ready-made answers; the indiscriminate and uncritical use of formulas and calculations in repeated exercises; tables and graphs that are disconnected or poorly contextualized in relation to the phenomena addressed; experiments whose sole objective is the 'verification' of theory… In short, teaching activities that only reinforce the distancing from the use of models and theories for understanding natural phenomena and those arising from human transformations, in addition to characterizing science as a finished and unquestionable product: a didactic-pedagogical work that favors the undesirable dead science" (Delizoicov, Angotti, & Pernambuco, 2018, p. 25, our translation).

This diagnosis is compatible with Fleck's (2010) idea of stabilization, in which the concept circulates in textbook form and plurality tends to be transformed into apparently consensual content. A strong marker of this attenuation of controversies is the way in which scientific facts and statements are presented at school: outside their context of production, without discussion of alternatives, methodological choices, interests, and history. Lemke (1990) describes this as part of the ideology of objective truth, in which scientific facts are presented as established without discussion of theoretical dependence, biases, and historical context. In the specific case of life, this dynamic may be translated into the conversion of an epistemological tension into a school statement of the type "life = set of properties."

In a study on the origin of life and undergraduate teaching students, Nicolini, Falcão, and Faria (2010) observe that, in their analysis, the textbooks examined did not present divergences among researchers, either regarding the sequence of events or regarding the details of the hypotheses. This finding is important because it empirically illustrates the mechanism of stabilization: even in themes marked by broad scientific controversy, didactic material may tend to present a unified narrative (Fleck, 2010).

Thus, the literature has described a historical persistence that extends from the first half of the twentieth century to more recent textbooks: life frequently appears as difficult to define and, for this reason, is often taught through lists of characteristics. In education, didactic procedures tend to prevail that reinforce science as a finished product, reducing the space for conceptual dispute. In addition, school discourse tends to present statements as incontrovertible facts, with little reference to alternatives, history, and conditions of production. There is evidence in the literature of the absence of divergences in textbooks even on controversial topics (Nehm & Kampurakis, 2013; Calado, Scharfenberg, & Bogner, 2016; Karat & Giraldi, 2019).

In light of the above, we do not claim that every didactic material or every school practice operates in this way, but rather that there is a pattern that can be interpreted in light of Fleck's epistemology, which makes it possible to understand why the conceptual plurality characteristic of the esoteric circle is often converted, within the school context, into an apparent didactic consensus.

CIRCULATION, STABILIZATION, AND ATTENUATION

As synthesized in Table 2, the criteria of intelligibility of the living vary according to the thought-style mobilized, which helps us understand why such tensions tend to be attenuated in the process of schooling. The plurality of definitions of life reconstructed from canonical works, evolutionary-historical, physico-chemical/molecular, systemic-organizational, thermodynamic/complexity, and the critique of universal definition do not appear, from the Fleckian perspective, as "noise" to be eliminated, but as a normal effect of the functioning of knowledge within thought-collectives and thought-styles. The decisive point is that

controversy is functional within the esoteric circle, but tends to be erased when knowledge circulates and is reformatted in the genres of the exoteric circle, such as manuals, textbooks, and scientific dissemination.

In the space of specialized production, Fleck (2010) describes journal science as a type of personal, fragmentary, innovative, and provisional discourse, which deals with delimited problems, hypotheses under verification, and results not yet fully integrated into the consolidated system. This science is marked by a "tone of humility and caution" precisely because recognition is negotiated within the collective of specialists.

Applying this to the concept of life, in the esoteric circle, "life" is often a research operator that must function within a program, such as evolution, information, autopoiesis, non-equilibrium, and so on. The tensions among definitions are, to a large extent, the way in which the collective delimits problems, decides what counts as evidence, and adjusts its criteria. Controversy here is an engine of internal differentiation and refinement.

The important Fleckian step is to show that between the controversy of journals and broad circulation, there is an instance of stabilization: textbook science. In textbooks, science appears in a systematic, impersonal, and assured form, as a well-articulated mosaic in which the incongruities of journals are combined to compose a coherent system. It is in this passage that what may be described as a stabilized scientific fact is consolidated: the textbook does not merely compile; it selects and orders, producing a conciliatory narrative that tends to present the development of knowledge while omitting the doubts and dilemmas of the process.

For Fleck (2010), this has a normative effect, since concepts "come to set the tone" and become imposed upon the specialist, defining what can no longer be thought otherwise and guiding where investigation should proceed with redoubled acuity. In the case of "life," this helps explain why certain definitions acquire the appearance of a "center": not because they definitively solve the problem, but because they become effective stabilizing syntheses for a collective and for the training of beginners.

When knowledge migrates from the center to the periphery, from the esoteric to the exoteric, Fleck (2010) describes a typical transformation: popular science, and, by extension, a large part of school science, is characterized by being simplified, illustrative, and dogmatic; simplified by the absence of details and, above all, of controversies; dogmatic through categorical evaluations and apodictic presentation.

In this displacement, thought tends to become dominated by emotional plasticity and to acquire the subjective security of religiosity or of the obvious, dispensing with the proofs and coercive rules that are central in specialized discourse (Fleck, 2010). In other words, the attenuation of disputes need not be read as a "pedagogical error," but as a structural mechanism of recontextualization. To circulate and function in other contexts, knowledge often needs to be closed into forms that are faster, more teachable, and more assessable.

It is in this sense that "life" appears as a list of criteria, reproduction, metabolism, evolution, and so on, often without historicity or dispute. The Fleckian reading allows us to affirm that this is not merely simplification; it is a mode of stabilization that reconfigures a controversial object into school content with a consensual appearance.

An important caution is that Fleck does not describe circulation only as a loss of meaning; he suggests a two-way path. The center-periphery flow simplifies, but the periphery-center flow offers background, linguistic and perceptual schemes, and bases of social legitimacy for specialized science itself. This is relevant because it makes teaching part of the circuit; the school is not only the "destination" of knowledge, but it also helps compose the conditions of intelligibility and public legitimacy of what science considers stabilized. The bidirectionality and legitimizing role of the exoteric domain are discussed in recent readings that articulate Fleck with processes of dissemination and textualization, emphasizing retroactive effects of the "popular" upon the specialized (Fioresi & Silva, 2022).

Lemke (1990) helps give discursive materiality to what Fleck describes sociologically. He argues that the language of the classroom, the textbook, and assessments constructs a pervasive and false opposition between a world of objective, authoritative, impersonal scientific fact and the ordinary world of uncertainties, values, and interests. Along these lines, he describes unwritten rules of "talking science" at school: preference

for the passive voice, erasure of agents, use of nominal abstractions, effects that make "people disappear from science," reinforcing the idea that science is something done by "scientists," that is, by "them," and not by "us."

In this sense, the school's "pacification" of life is not only conceptual; it is also generic and linguistic. The typical school form, definition → examples → exercises → assessment, rewards, closed statements. Lemke (1990) even shows how disputes may be cut short by appeals to authority, such as scientific "law," in classroom interactions, reinforcing the mystique of fact. Thus, Fleck (2010) explains why controversy tends to disappear when it circulates through school genres and routines that convert controversies into official answers, with a strong emphasis on authority and evidence as closure.

In light of the above, we emphasize that, in the esoteric circle, the plurality of "life" is operational, organizing problems and methods in distinct styles. In circulation, moving from articles to manuals, textbooks, and schools, a structural stabilization occurs, causing disputes to be silenced and transformed into definitions and criteria. Lemke (1990) shows that stabilization is also a discursive technology, since scientific speech at school favors impersonality, authority, and closure of the system, which may explain why the concept of life, so plural in esoteric circles, appears as a peaceful and consensual list of properties.

The Fleckian reading of the circulation of knowledge may be enriched through dialogue with the notion of didactic transposition (Chevallard, 1991) and recontextualization. Coutinho, Mortimer, and El-Hani (2007), for example, propose a "conceptual profile" for the biological concept of life, identifying different zones, mechanistic, vitalist, evolutionist, systemic, that approximate the notion of thought-styles adopted here. These authors problematize the idea that teaching should simply reproduce scientific plurality, arguing that the conceptual profile enables teachers and students to move among different ways of thinking according to the problem at hand.

This dialogue is productive because it reinforces that didactic stabilization is not necessarily an "error," but may be a stage in teaching that, at planned moments, reintroduces controversies in a formative way, without requiring learners to master the entire spectrum of scientific controversy.

IMPLICATIONS FOR SCIENCE EDUCATION AND TEACHER TRAINING

Taking "life" as a plural concept in specialized biology and, simultaneously, as a stabilized statement in education does not require concluding that schools are wrong or that teachers oversimplify too much. From Fleck (2010), we understand didactic stability as a typical effect of the circulation of thought and of the genres in which knowledge is expressed, such as textbookization, schooling, and assessment. The pedagogical issue, then, is not to correct schools and teachers so that they copy the esoteric circle, but to intervene consciously at the points where stabilization erases controversies that could be formative.

The implications discussed below do not presuppose that basic education teachers master the specialized controversies concerning the concept of life, nor that biology education should reproduce the esoteric circle of science. What we propose is to recognize when stabilized definitions fulfill legitimate didactic functions and when the controlled reintroduction of conceptual controversies may be formative, especially for the development of argumentation, justification, and the understanding of science as a historical and social practice.

Lists of characteristics, "textbook" definitions, and classificatory schemes fulfill school functions, such as introduction, rapid communication, assessment, and curricular organization. The productive intervention we defend is not to eliminate these forms, but to make their limits explicit, considering them as a starting point for problematization, in alignment with a perspective that treats life as an important socio-scientific issue in biology, as recommended by Reis and Galvão (2005), Martínez Pérez et al. (2011), and Ferreira et al. (2020).

In addition, if the typical sequence in classrooms is definition, example, exercises, and assessment, the concept tends to become an official answer. Small changes in routine, such as reflective questions, comparison of sources, short debates, and justification tasks, make it possible to reopen the concept without "disrupting" the curriculum. Concerning teachers, we do not intend that they master all scientific controversies, but that they

be able to recognize thought-styles and map what is lost and what is gained when a concept moves from the esoteric to the exoteric. In other words, we strongly recommend that Fleck's epistemology be more present in teacher education, a position already defended in other works, such as those by Lorenzetti, Muenchen, and Slongo (2013), Costa, Silva-Forsberg, and Oda (2015), Parreiras (2018), and Paixão and Paiva (2024). The focus thus becomes didactic-epistemological, centered on when and why to use a stabilized definition, and when and how to reintroduce tensions.

For example, in high school classes, the initial presentation of life as a list of characteristics may be followed by an activity contrasting borderline cases, asking students to justify, in light of different criteria, whether such entities should or should not be considered living. This strategy allows the expected curricular content to be addressed while simultaneously making explicit that different criteria derive from different thought-styles.

It is in this sense that we argue that teaching should be organized through contrasts among thought-styles. About the question of "life," developed in this work, one possible path is the elaboration of comparative maps with guiding questions, such as:

- Evolutionary-Historical Style: Does life make sense as a history of lineages? What changes when the explanation is narrative and contingent?
- Physico-Chemical Style: Is life a problem of order, information, and mechanisms? What counts as evidence here?
- Systemic-Organizational Style: Is life a pattern of organization/autopoiesis? What changes when the focus is on relation rather than substance?
- Thermodynamic Style of Self-Organization and Complexity: Life as a far-from-equilibrium regime? How do irreversibility, flows, and self-organization enter?
- Metatheoretical-Operational Style: Why might defining life fail? What can be done without a rigid definition?

These questions are not normative, but merely examples of how to operationalize this movement. This contrast does not need to be exhaustive; it is enough for it to operate as an organizer of intelligibility in relation to the problem. Other examples may be developed, such as the question of viruses, prions, dormant seeds, colonies, artificial systems, and so on, and projects searching for life beyond Earth function as borderline cases that can foster discussions about what each definition privileges. The objective is to show how the criteria change according to the thought-style in question.

To illustrate how the proposal may be operationalized in the classroom without requiring deep philosophical mastery, we present a brief example:

Table 3 – Example of Classroom operationalization of a borderline case.

Step	Activity	Estimated duration
1	Presentation of the list of typical characteristics of living beings, as found in textbooks.	10 minutes
2	Introduction of the vírus case: display of a diagram of viral structure and the question "Is a virus a living being? Justify using the list".	10 minutes
3	Small-group debate: different groups receive "style cards" – evolutionary: focus on evolution and replication; physico-chemical: focus on molecular structure; systemic: focus on autonomous organization – and must answer the question according to the criterion received.	15 minutes
4	Collective discussion: Conclusion that different criteria lead to different answers – the definition of life depends on the thought-style.	15 minutes
5	Closure: The teacher systematizes that science does not have a single answer and emphasizes the importance of justifying the criteria used.	10 minutes

This example seeks to show that it is possible to reintroduce controlled controversy without overburdening teachers or students with the full theoretical density of philosophy of science. The focus is on justification and comparison of criteria, not on the exhaustiveness of the styles.

In this way, we reinforce the importance of shifting the focus from "how teaching errs by simplifying content" to "how teaching stabilizes through circulation," and we can reopen the concept in a planned way. Thus, "life" ceases to be merely an introductory item and comes to function as a privileged point of historical-epistemological problematization and as an axis for socio-scientific discussions, without requiring teachers to reproduce the esoteric circle, but learning to engage in dialogue with it.

FINAL CONSIDERATIONS

In this paper, we have sought to demonstrate that "life" does not appear as a univocal concept in the canonical literature because different thought-collectives operate with distinct problems, criteria of validity, and vocabularies. By contrast, in education and in didactic materials, the theme tends to assume the form of a stabilized definition, frequently as a list of properties, because knowledge, as it circulates from the esoteric to the exoteric, is textbookized, reordered, and stripped of controversies, thereby gaining communicability.

Regarding our first question, we identified five stylistic axes, namely: i) evolutionary-historical, which considers life as a history of lineages, variability, and explanations by final causes, with the centrality of narrative and contingency; ii) physico-chemical/molecular, which defines life as a problem of material order, information, code, and mechanisms of expression, seeking explanation based on physics and chemistry; iii) systemic-organizational, which treats life as a pattern of organization, autopoiesis, a network of processes that produces and maintains the unit and its boundary; iv) thermodynamic/complexity, which defines life as a regime of open systems far from equilibrium, with self-organization, irreversibility, and dissipative structures; v) metatheoretical-operational, which treats life as an epistemological problem, privileging operational criteria and strategies rather than essences.

Regarding the second question, Fleck allows us to understand the circulation from controversy to didactic consensus as a structural effect of the traffic of thought. In the esoteric circle, controversy is functional: it organizes agendas, delimits evidence, and refines concepts within research programs. In circulation, a shift of meaning occurs, in which content is selected, simplified, and reorganized; tensions are reduced, and statements become more impersonal and apodictic. Regarding the third question, the discussion contributes by offering a comparative repertoire for working with "life" as a concept in tension, in which different definitions imply different criteria of evidence, boundaries, and public decisions. This supports approaches to socio-scientific issues by shifting teaching from the correct answer to justification and argumentation, by showing how conceptual choices have effects on detection, classification, and intervention, and by inserting historicity and dispute as part of the very functioning of science.

We recognize that the theoretical density mobilized may contrast with everyday school practices; however, it is justified by the effort to make explicit assumptions that are often naturalized in the circulation of scientific knowledge. By making these assumptions visible, the article does not intend to artificially complexify teaching, but rather to offer analytical instruments for more conscious didactic decisions about when to stabilize concepts and when to reopen controversies in a pedagogically conscious and productive way.

We understand that the styles identified respond to the delimitation undertaken; however, we believe that, for this work, they are sufficient. The main contribution is to interpret the plurality of the concept not as confusion to be eliminated, but as a normal product of thought-styles and of their conditions of validity. Rather than seeking a final definition, the article makes explicit what each definition makes possible and how circulation reconfigures the status of the concept. As a theoretical-epistemological study, the work did not carry out an exhaustive empirical survey of textbooks, classes, or teacher education contexts, nor did it intend to map the entire possible bibliography. Further developments of this work include empirical studies on how "life" is stabilized in materials and assessments, the design and testing of didactic sequences with maps of styles and

borderline cases, and an investigation into how teacher education may incorporate Fleck to plan when to use stabilized definitions and when to reintroduce controversies in a didactically productive way.

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