Explanatory Breadth Without Criteria Is Not Explanation:
A Case for Disciplined Generality in Scientific Theory Construction

Hye-Eun Yoon (Selly)

Independent Researcher, Bucheon, Gyeonggi-do, Republic of Korea

*** Corresponding Author:** Hye-Eun Yoon (Selly) selly@sellyes.org

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Abstract

Scientific theories are often perceived to be deeper when they apply across more domains, scales, or classes of phenomena. This inference is unsafe. A principle may travel widely because it captures a genuine common structure, but it may also travel widely because its terms are too under-specified to resist application.

This paper proposes **disciplined generality** as a methodological standard for broad theories and argues that explanatory breadth requires internal criteria. It reconsiders the question: *'When can a theory be regarded as having a scientific structure?'* A broad theory should specify the observational grounds from which its principle is derived, what follows and does not follow from that principle, what would count against it, and how its concepts behave across temporal emergence, cross-scale functional-structural equivalence, and perturbation.

The argument is developed through illustrative cases: free-energy and active-inference accounts, string theory, and evolutionary adaptationist explanation as exemplars of under-disciplined breadth, and plate tectonics and the periodic system as positive contrasts. Falsifiability is necessary but not sufficient: a theory may be formally open to refutation while leaving its concepts under-stratified and its criteria dependent on later interpretation. Formal coherence similarly does not establish realizability.

These cases show that theoretical breadth becomes scientifically disciplined only when a theory clarifies its level hierarchy, transfer rules, cross-level interaction variables, conditions of failure, constraints on realizability, and risks of misapplication. Without such discipline, explanatory breadth is not a theory, principle, mechanism, framework, or model. It is merely an illusory label that allows redescription to pass as explanation.

1 Introduction: Explanatory breadth and the risk of redescription

A recurrent temptation in scientific theory construction is to treat explanatory breadth as a sign of theoretical depth. A framework appears powerful when it can be applied across domains, scales, and kinds of phenomena. The wider the range of application, the more fundamental the principle appears. Yet this inference is unsafe. A principle may travel widely because it captures a real common structure, but it may also travel widely because its terms are too under-specified to resist application (Guest & Martin, 2021; Kuhn & Hacking, 1962/2012; Lakatos, 1970).

The problem is not generality itself. Science needs broad theories. Fragmented local models cannot by themselves explain how phenomena are related across levels, domains, and forms of organization. The problem begins when a broad principle expands without internal criteria for its own application. In that case, a theory may appear to explain a domain while merely redescribing it in its preferred vocabulary. Any phenomenon can be translated into the language of the theory, but translation is not explanation (Bechtel, 2008; Craver, 2007).

This problem becomes especially acute when a theory uses terms that are formally elegant but empirically elastic. Terms such as optimization, minimization, prediction, inference, adaptation, information, regulation, self-organization, and unification can illuminate complex systems. They can also blur important distinctions (Craver, 2007; Marr, 1982/2000; Newell, 1994). The same term may be used for a biological process, a cognitive operation, a physical structure, a developmental trajectory, or a social practice. Unless the theory specifies how the term changes across levels and contexts, apparent unity may conceal a loss of discrimination.

2 Explanatory debt in broad theories

The result is a distinctive explanatory debt. A broad theory may claim to unify many phenomena while leaving the actual work of specification to the researchers who apply it (Cummins, 2000; Guest & Martin, 2021; Lakatos, 1970). One domain must decide what the variables are. Another must decide what counts as evidence. Another must determine how levels are related. Another must distinguish mechanism from metaphor, model from ontology, and principled extension from post hoc redescription. The general theory then receives credit for unification while outsourcing the criteria that make its applications meaningful. This debt is most visible when the same vocabulary is used across heterogeneous domains without specifying how its criteria of application change (Craver, 2007; Marr, 1982/2000).

3 Illustrative Stress Cases for Disciplined Generality

The following cases are not intended as comprehensive evaluations of the theories discussed. They are used as methodological stress cases to show how explanatory breadth becomes disciplined or under-disciplined depending on whether a theory specifies its internal criteria, transfer conditions, and constraints of application.

3.1 Free-Energy and Active-Inference Accounts: Formal Breadth and Scope Pressure

Free-energy and active-inference accounts illustrate the problem in one of its most general forms. Their integrative ambition is valuable, and their formal vocabulary has generated important work across perception, action, learning, regulation, psychopathology, biological self-organization, and adaptive behavior (Buckley et al., 2017; Friston, 2010; Friston et al., 2017). Yet this breadth has also generated concern that the formalism may extend by redescribing heterogeneous systems in inferential terms without sufficiently constraining its scope (Raja et al., 2021). Such accounts must clarify the level at which the principle is applied, the target of explanation, the rules by which concepts transfer across domains, and the conditions under which the account would be insufficient or wrong.

3.2 String Theory: Mathematical Unification under Weak Empirical Constraint

String theory provides a second case. Its theoretical ambition is not merely local explanation, but unification across fundamental forces, particles, and spacetime structure (Dawid, 2013; Smolin, 2007). This ambition has produced a mathematically rich research programme, and its value should not be reduced to immediate empirical testability alone. Yet string theory also illustrates the risk that mathematical elegance and unificatory power may outrun the criteria by which a theory becomes empirically constrained (Dawid, 2013; Smolin, 2007; Woit, 2006). If the space of possible formulations becomes too large, and if contact with observation remains indirect or underdetermined, then breadth can begin to function as a promissory structure rather than as a disciplined explanatory achievement. The issue is not that unification is illegitimate. The issue is whether the theory specifies what would follow from its principles, what would not follow, and what observations would meaningfully constrain the range of admissible possibilities.

3.3 Evolutionary Adaptationist Explanation: Post Hoc Breadth and Just-So Risks

Evolutionary adaptationist explanation provides a third case. Natural selection is one of the strongest examples of a broad scientific principle, but adaptationist explanations can become under-disciplined when they are applied post hoc to traits, behaviors, or preferences without specifying the relevant selection pressures, alternative explanations, inheritance structure, population-level dynamics, and evidential constraints (Gould & Lewontin, 1979; Smith et al., 1985). In such cases, the explanatory vocabulary of adaptation may appear to clarify why a trait exists while merely redescribing its apparent usefulness. The familiar risk is the just-so story: an observed feature is treated as adaptive because a plausible function can be imagined for it (Gould & Lewontin, 1979). A disciplined adaptationist explanation must therefore distinguish genuine selection-based explanation from retrospective functional narration.

3.4 Plate Tectonics: Disciplined Breadth as a Positive Contrast

A positive contrast can be found in plate tectonics. Its explanatory breadth is substantial, but it is not merely redescriptive. The theory connects heterogeneous phenomena such as continental drift, seafloor spreading, earthquake distribution, volcanism, mountain formation, ocean trenches, and paleomagnetic patterns through constrained mechanisms and level-specific variables (Morgan, 1968; Vine & Matthews, 1963; Wilson, 1965). It specifies observational grounds, generates expectations about where geological activity should occur, distinguishes mantle dynamics, lithospheric plates, plate boundaries, and surface formations (Morgan, 1968; Vine & Matthews, 1963), and remains vulnerable to counterevidence if these patterns fail to align. Its breadth is therefore disciplined. Its generality is therefore constrained by convergent evidence rather than by semantic extension alone. It unifies without allowing any geological event to be redescribed arbitrarily as “tectonic” without specifying the relevant mechanism, level, and evidential pathway.

3.5 The Periodic System: Disciplined Classification and Predictive Structure

A second positive contrast can be found in the periodic system of the elements. Its breadth is classificatory and explanatory, but not arbitrary. The periodic system did not merely group chemical elements under a convenient vocabulary. It organized them through constrained relations among atomic weight, recurring chemical properties, and predictive gaps. Mendeleev’s system left structured gaps and generated expectations about the properties of undiscovered elements, including eka-aluminium, eka-silicon, and eka-boron (Mendeleev’s, 1871; E. R. Scerri & Worrall, 2001).

The later grounding of periodic order in atomic number further illustrates disciplined generality. The system did not remain a merely descriptive arrangement of chemical similarities; it became progressively constrained by deeper physical structure. Moseley’s work helped establish atomic number as the ordering principle of the periodic system, thereby reducing the arbitrariness associated with atomic-weight ordering and tying chemical periodicity to nuclear charge (Moseley, 1913; E. Scerri, 2006/2019).

This disciplined structure also helps explain why the periodic system could support standardized reference infrastructures such as the CRC Handbook of Chemistry and Physics: its categories were not merely nominal, but constrained by measurable properties, repeatable relations, and progressively stabilized physical interpretation (Haynes, 2017). In this case, breadth was not achieved by redescribing any material phenomenon as “periodic,” but by specifying a structured relation between observable chemical properties, theoretical ordering, predictive gaps, standardized measurement, and later physical grounding.

3.6 Common Risk of Under-Specified Breadth and the Need for Criteria

These cases differ in scope, empirical maturity, and formal precision, but they reveal the same methodological issue. A theory can gain apparent explanatory power by extending a vocabulary faster than it specifies the criteria governing that extension. The problem is not breadth itself. Broad theories can be scientifically powerful when their generality is constrained by observational grounds, transfer rules, level distinctions, failure conditions, and mechanisms of application. The risk arises when a theory’s vocabulary expands across domains while the criteria that make each application meaningful remain underspecified. In such cases, the decisive question is not whether the theory can be applied, but whether it can say what is preserved, transformed, constrained, or ruled out when it moves from one domain or level to another.

The contrast between the negative and positive cases also suggests a historical criterion of theoretical robustness. The periodic system and plate tectonics are not merely broad because their vocabularies travelled widely; they endured because their conditions of application became increasingly constrained across changing historical contexts. By contrast, theories whose formal or explanatory vocabulary expands before its internal criteria are stabilized remain more vulnerable to the explanatory fashions of a given period. A similar point can be seen in philosophy: enduring figures such as Confucius, Plato, Aristotle, and Occam do not persist merely as historical vocabularies, but as recurring criteria through which later problems are repeatedly judged. Theories tied to historical fashion travel by vocabulary; theories that endure travel by criteria.

4 Specifications for disciplined generality

The conditions listed in this section are not external preferences added after theory construction. They are internal constraints on whether explanatory breadth can acquire theoretical status rather than remaining a redescriptive vocabulary.

A theory must justify its breadth through internal criteria:

- Specify the observational facts from which its principle is derived
- State what follows and does not follow from that principle
- State what would count as evidence against it (Guest, 2024; Lakatos, 1970; Popper, 1959, 1963)
- Explain how its concepts behave when the system is examined across **temporal emergence, cross-scale functional-structural equivalence, and perturbation or disruption** (Craver, 2007; Marr, 1982/2000; Newell, 1994).

For each explanatory test case, the theory must:

- Decompose and stratify how its principle applies (Bechtel, 2008; Craver, 2007)
- Identify variables involved in interactions among levels
- Specify the status of each variable during cross-level transitions:
    - **Anonymized** — continues to constrain the higher-level description without remaining explicitly identifiable, and is integrated with variables from other levels to form a cross-level structure
    - **Visible** — remains identifiable as an explicitly structured object and is integrated with variables from other levels to form a cross-level structure
    - **Eliminated** — variables that do not persist into the higher-level structure and are dropped during the transition

These distinctions clarify whether cross-level variables are preserved, transformed, integrated, or removed during explanatory transfer (Craver, 2007; Marr, 1982/2000).

The theory must clarify the status of each level (Craver, 2007; Marr, 1982/2000):

- Is it a derivative form of another level?
- An independently emergent organization?
- A relatively autonomous layer constrained by lower-level conditions?

This distinction matters because naming levels is not enough. A theory may claim to operate across levels while leaving unclear whether those levels are causally generated, merely redescribed, or introduced as convenient classifications.

The theory must specify how causal operation becomes observable at each level (Craver, 2007; Cummins, 2000):

- How the operation appears as a phenotypic expression
- How that expression functions as a transformed manifestation of the same variable
- Through what causal process the manifestation unfolds

Without this specification, the theory cannot distinguish genuine multi-level explanation from a mere change in descriptive vocabulary (Craver, 2007; Guest & Martin, 2021).

These criteria do not constrain theoretical ambition. They make ambition answerable. Put more strongly, a theory earns disciplined generality only when it can anatomize its own claims, subject them to systematic stress-testing from multiple directions, and still specify why, where, and under what conditions they remain robust.

5 Formalization, realizability, and constraint-first modeling

A related risk concerns the relation between formalization and realizability. Mathematical idealization can be scientifically valuable. It can guide model construction, enable counterfactual exploration, and reveal structures that are not immediately visible in ordinary description (Levins, 1966; Weisberg, 2007). Yet formal coherence does not by itself establish that a model is physically, biologically, or developmentally realizable (Smith et al., 1985; Winsberg, 2010).

Formalization should therefore not be treated as a substitute for internal theoretical discipline. It should be a downstream expression of such discipline. A theory becomes genuinely formalizable only when its internal criteria have become sufficiently stable to determine what can be formalized, what must be excluded, and under what conditions the formalism preserves the intended explanatory structure. If formalization is fixed in advance around a theory's preferred claim, the result may be a unicorn rather than a horse: formally coherent, internally nameable, and even imaginatively useful, but not necessarily realizable under the constraints that govern the target phenomenon.

A model may be mathematically well-defined and empirically serviceable as an approximation while remaining unrealizable once energetic, developmental, morphological, or material constraints are imposed (Smith et al., 1985; Waddington, 1957/2014). The point is not that idealization is illegitimate. The point is that idealization becomes scientifically disciplined only when the constraints under which the model could be implemented are specified. Without such constraints, "minimal" may become a purely formal intersection among successful descriptions rather than a criterion grounded in what can exist.

This distinction is especially important for broad theories that move across levels of organization. Methodological convergence among successful models does not entail mechanistic realizability (Craver, 2007; Winsberg, 2010). A set of models may converge on a formal structure, but that convergence does not show that the structure can be instantiated under the relevant physical or biological constraints. A theory that moves from formal computability to real-world realizability must therefore state what constraints mediate that transition.

Constraint-first modeling reverses the order of explanation. It begins not from the most elegant formal unification, but from non-arbitrary atomic facts and implementability constraints. This strategy may demand greater formal complexity at the early stages. However, once stabilized, it reduces projection and category errors by preventing the slide from “formally describable” to “computable,” and from “computable” to “realizable” (Winsberg, 2010). Disciplined generality therefore requires not only broad applicability and internal hierarchy, but also explicit constraints on what kinds of structures can actually be instantiated.

6 Falsifiability is necessary but not sufficient

The task is not to reject ambitious theories. It is to demand disciplined generality. A theory earns explanatory breadth only when it can say what follows from its principle, what does not follow, what would count against it, how its concepts transform across levels and perturbations, and how its variables are preserved, transformed, integrated, or eliminated during cross-level transition.

These criteria also expose a limitation in the familiar claim that a good theory is simply a falsifiable theory. Falsifiability is necessary, but it does not by itself guarantee conceptual discipline (Guest, 2024; Lakatos, 1970; Popper, 1959, 1963). A theory may be formally open to refutation while still leaving its central concepts under-stratified, its levels of explanation ambiguous, and its criteria of application dependent on later interpretation. In that case, the theory transfers part of its conceptual debt to future researchers (Guest, 2024; Guest & Martin, 2021).

A stronger criterion is needed. Building on recent discussions of theory quality, **a good theory** should satisfy at least five conditions (Guest, 2024). First, it should begin from a non-arbitrary atomic axiom: a minimal starting commitment that cannot be freely expanded or redefined to fit the phenomenon at hand. For example, a theory of developmental or historically organized systems may begin from the atomic axiom that organized change is temporally constrained and cannot be freely reversed. (Prigogine & Stengers, 1984; Waddington, 1957/2014). Second, it should establish a clear internal hierarchy among its concepts. Third, it should explain both ordinary and extreme cases without ad hoc expansion. Fourth, it should limit arbitrary projection by later researchers while still allowing principled development. Fifth, it should minimize the risk of misrecognition when applied to ordinary cases. A theory should not merely allow phenomena to be renamed in its vocabulary. It should reduce confusion about what is being explained, at what level, through which variables, and under what conditions.

In this sense, theoretical quality is not exhausted by falsifiability (Guest, 2024; Lakatos, 1970). A good theory must also be internally disciplined. It must define the scope, hierarchy, transfer rules, and failure conditions of its own concepts. Otherwise, falsifiability becomes a partial virtue attached to an otherwise under-specified explanatory structure.

7 Conclusion: from broad application to accountable explanation

The future of broad scientific theory does not require narrower imagination. It requires broader theories with sharper internal constraints. A theory should not be praised merely because many phenomena can be redescribed in its terms. It should be evaluated by whether those redescriptions produce new distinctions, new constraints, and new risks of being wrong. Without such discipline, explanatory breadth is not a theory, principle, mechanism, framework, or model. It becomes a form of protection: an illusory label that allows redescription to pass as explanation. Explanation begins not when a principle can be applied everywhere, but when it can tell us where, how, why, and under what conditions its application matters.

Occam's razor is commonly reduced to a preference for simplicity, but this reduction is itself a later distortion, originating largely from logical positivist appropriations of the principle (Sober, 2015; Thorburn, 1918). More fundamentally, it asks whether a theory begins from non-arbitrary atomic axioms or from explanatory labels that can be multiplied whenever the theory expands. The prohibition against multiplying entities beyond necessity has a structural analogue in theory construction: a theory that multiplies explanatory vocabularies beyond the criteria that govern their application violates the same principle. Disciplined generality is, in this respect, Occam's razor applied not to ontology but to theoretical structure. Was what Occam's razor sought to protect not simplicity itself, but resistance to redescription without criteria and a demand for theories with robust internal structure?

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Conflict of Interest

The author declares that there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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