# Negation of Negation Is the Metalogic

— All Other Logics Are Sub-logics of It

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**Abstract**

Based on the Zhu-Liang theoretical chain (Holism Theorem, Truth Degree Determination Theorem, Recursive Nesting Theorem, MPD, SODS), this paper demonstrates a metalogical proposition: **negation of negation is the metalogic, and all other logics (classical logic, intuitionistic logic, modal logic, relevant logic, etc.) are sub-logics of it**. Negation of negation is not an optional law of dialectics but the metalogical form of self-foundation and self-transcendence for any self-referential system. Through the natural isomorphism $G \cong \mathrm{Id}$ between the double-negation functor $G = F \circ F$ and the identity functor, and the terminal coalgebra $\Omega = \varprojlim G^n(1)$, we prove that for any logical system $\mathcal{L}$ there exists a unique coalgebra homomorphism $h_{\mathcal{L}} : \mathcal{L} \to \Omega$ mapping $\mathcal{L}$ into the truth space $\Omega$. Since $\Omega$ is constructed solely by infinite iteration of negation of negation, every logic is a substructure of $\Omega$, i.e., a sub-logic of negation of negation. This paper also provides an elementary set-theoretic model and systematically critiques the fundamental fallacy of reductionist generalization — exposing its essence as pseudo-logic, pseudo-consensus, futile involution, and pure entropy increase, while clarifying the abuse of Gödel's incompleteness theorems. This thesis unifies the millennia-old debate between logical monism and pluralism, offering an ultimate mathematical foundation for the philosophy of logic.

**Keywords:** negation of negation; metalogic; sub-logic; double-negation functor; terminal coalgebra; recursive unit; logical pluralism; critique of reductionism; Gödel's theorems; entropy increase

# Contents

# 1 Introduction: The Dilemma of Logical Pluralism and Monism

Two opposing positions have long existed in the history of the philosophy of logic:

- **Logical monism**: There is a single, universally correct logic (usually taken to be classical logic).
- **Logical pluralism**: There are multiple equally correct logical systems applicable to different domains or purposes[7].

Monism struggles to explain why intuitionistic logic, modal logic, relevant logic, etc., are equally effective in mathematics and computer science; pluralism faces an infinite regress of "which metalogic to choose" — if many logics are correct, which one serves as the basis for justification?

This paper proposes a fundamental solution: **negation of negation is the metalogic, and all other logics are its sub-logics**. This claim both acknowledges logical plurality (multiple sub-logics coexist) and maintains logical unity (the metalogic is unique), thereby sublating the traditional debate.

# 2 The Metalogical Status of Negation of Negation

## 2.1 Negation of Negation as the Metalogical Form of Self-Referential Systems

Negation of negation is not an optional law of dialectics but the metalogical form of self-foundation and self-transcendence for any self-referential system. Hegel in his *Science of Logic* already deeply revealed the central role of negation of negation as the "absolute method"[6]. Its metalogical nature arises from:

1. **Self-reference**: For a system to know and transcend itself, it must be able to negate itself and rebuild upon that negation.
2. **Recursiveness**: Negation of negation is not a one-time act but an infinite recursive process.
3. **Immanence**: The driving force of negation of negation comes from within the system, requiring no external first mover.

**Definition 2.1** (Negation of Negation as Metalogic)**.** *Let $\mathcal{L}$ be a logical system. If $\mathcal{L}$ is to characterize its own negation and reconstruction, it must contain an operation $\neg$ such that $\neg\neg A$ is in some sense equivalent to $A$ yet carries new information at a higher level. This operation is formalized by the double-negation functor $G = F \circ F$, where $F$ is the negation functor (dualization). When $G \cong \mathrm{Id}_{\mathcal{C}}$ (natural isomorphism), negation of negation returns to itself while each iteration expands the domain.*

## 2.2 Natural Isomorphism of the Double-Negation Functor

In the Recursive Nesting Theorem[1] of the Zhu-Liang theoretical chain, we constructed the cognitive category $\mathcal{C}\wr\}$ and the negation functor $F$. Define the double-negation functor $G = F \circ F$. Since duality of duality is naturally isomorphic, there exists a natural transformation $\eta : \mathrm{Id}_{\mathcal{C}\wr\}} \Rightarrow G$ whose components are canonical isomorphisms $\eta_A : A \to G(A)$. Hence $G$ is naturally isomorphic to the identity functor.

**Theorem 2.2** (Natural Isomorphism of Double Negation)**.** *Let $F : \mathcal{C}\wr\} \to \mathcal{C}\wr\}$ be the negation functor (dual layer and dual connection), and $G = F \circ F$. Then there exists a natural isomorphism $\theta : G \cong \mathrm{Id}_{\mathcal{C}\wr\}}$. In particular, $G$ preserves all limits and colimits.*

The philosophical meaning of this natural isomorphism: negation of negation is not simple "double negation elimination" (which would give $G = \mathrm{Id}$ as strict equality), but a natural isomorphism — at each level, $A$ and $G(A)$ are structurally identical but, as recursive units of different depths, carry different information. This is the core of truth recursive nesting: in $x = (x_0, x_1, x_2, \ldots)$, $x_n$ and $x_{n+1}$ are related by projections but are not identical.

## 2.3 Terminal Coalgebra and Truth Space

Since $G$ preserves $\omega$-limits, by the Adámek theorem[8] the terminal $G$-coalgebra exists:

$$\Omega = \varprojlim \big(1 \leftarrow G(1) \leftarrow G^2(1) \leftarrow \cdots \big).$$

$\Omega$ is called the truth space; its elements are recursive units $x = (x_0, x_1, x_2, \ldots)$. The structure map $\omega : \Omega \to G(\Omega)$ is an isomorphism (Lambek's lemma).

**Definition 2.3** (Truth Space)**.** *$\Omega$ is the terminal coalgebra generated by infinite iteration of negation of negation. It contains all possible recursive units and is the ultimate ground of logical space.*

## 2.4 Set-Theoretic Model: Metalogic as a Higher-Order Function

To more intuitively reveal the hierarchical relation between "negation of negation" and sub-logics, this section constructs an elementary mathematical model based on set theory and function mappings.

**Definition 2.4** (Universe of Logical Systems and Sub-logics)**.** *Let $U$ be the set of all possible logical systems. Each concrete logical system (e.g., classical logic, intuitionistic logic, modal logic) is a subset of $U$, denoted $L_1, L_2, \ldots$, and is called a* ***sub-logic****. For example:*

$$L_{CL} = \{\textit{all propositions obeying non-contradiction and excluded middle}\}.$$

**Definition 2.5** (Metalogic as a Higher-Order Function)**.** ***Metalogic*** *is not a concrete element of $U$ but a higher-order rule acting on $U$. Define it as a function $M$ that takes any sub-logic $L_x$ as input and outputs a new sub-logic $L'_x$:*

$$M : L_x \mapsto L'_x.$$

*This function describes how one logical system generates or transforms into another through a certain rule.*

**Definition 2.6** (The "Negation of Negation" Function)**.** *Let $M$ specifically denote the process of "negation of negation":*

1. ***First negation****: Critically sublate the input $L_x$, obtaining an intermediate state $\neg(L_x)$;*
2. ***Second negation****: Negate the intermediate state again, preserving the rational kernel and overcoming defects, finally outputting a new logical system $L'_x$.*

*That is,*

$$M(L_x) = L'_x, \quad \text{where } L'_x \text{ is the dialectical sublation of } L_x.$$

**Example 2.7** (Classical Mechanics to Relativity)**.** *Let $L_1$ be the logical system of classical Newtonian mechanics. The process $M(L_1)$:*

- *First negation: Reveal the limitations of $L_1$ at high speeds (near light speed) and microscopic scales (quantum), producing contradictions;*
- *Second negation: Sublate these contradictions, obtaining $L_2$ (relativity and quantum mechanics), which contains the correctness of $L_1$ at low speeds and macroscopic scales while transcending its domain of applicability.*

*Thus $L_2 = M(L_1)$, and $L_1 \subset L_2$ (in the sense of model preservation).*

**Proposition 2.8** (Hierarchical Difference Between Metalogic and Sub-logics)**.** *Comparing the mathematical essence of the metalogic $M$ and sub-logics $L_x$ reveals their hierarchical difference:*

Table 1: Mathematical Comparison of Metalogic and Sub-logics

| Aspect | Metalogic (function $M$) | Sub-logic (set $L_x \subseteq U$) |
|---|---|---|
| Mathematical counterpart | Function (rule) $M : L_x \to L'_x$ | Set (object) $L_x$ |
| Activity | Active generative and evolutionary power | Passive object of operation |
| Stability | Eternal universal dynamic principle | Temporary system with finite scope |
| Relation | Produces, governs, and unifies all $L_x$ | Concrete manifestation of $M$ at a given stage |

**Theorem 2.9** (Unifying Power of Metalogic in the Set-Theoretic Model)**.** *The function $M$ (negation of negation), as a higher-order rule, acts upon and governs all sub-logics $L_x$. The sub-logics $L_x$ are concrete outputs of $M$ in the historical process, i.e., generated objects. Therefore, "negation of negation" as metalogic is higher and prior to any sub-logic.*

This elementary model is fully compatible with the categorical construction of the terminal coalgebra in Section 2.3: infinite iteration of the function $M$ corresponds to the inverse limit $\Omega = \varprojlim M^n(1)$, and each sub-logic $L_x$ embeds as a constant recursive unit or a specific projection in $\Omega$.

# 3 Other Logics as Sub-logics of the Metalogic

## 3.1 Definition of Sub-logic

**Definition 3.1** (Sub-logic)**.** *Let $\mathcal{L}_1$ and $\mathcal{L}_2$ be two logical systems, with semantics characterized by objects and morphisms in categories $\mathcal{C}_1$ and $\mathcal{C}_2$ respectively. If there exists a faithful functor $H : \mathcal{C}_2 \to \mathcal{C}_1$ preserving logical operations (conjunction, disjunction, implication, negation, etc.), then $\mathcal{L}_2$ is called a* ***sub-logic*** *of $\mathcal{L}_1$.*

## 3.2 Mapping Arbitrary Logics into the Truth Space

By the Recursive Nesting Theorem[1], for any cognitive object $A$ (including a logical system itself) there exists a unique coalgebra homomorphism $h_A : A \to \Omega$ making the following diagram commute:

$$\begin{array}{ccc} A & \xrightarrow{\eta_A} & G(A) \\ {\scriptstyle h_A}\downarrow & & \downarrow{\scriptstyle G(h_A)} \\ \Omega & \xrightarrow{\omega} & G(\Omega) \end{array}$$

Regarding a logical system $\mathcal{L}$ as an object in the cognitive category $\mathcal{C}\wr\}$ (objects are formulas, morphisms are derivations), there exists a unique truth function $h_{\mathcal{L}} : \mathcal{L} \to \Omega$.

**Theorem 3.2** (Logical Embedding Theorem)**.** *For any logical system $\mathcal{L}$ (classical logic, intuitionistic logic, modal logic, relevant logic, etc.), there exists a unique coalgebra homomorphism $h_{\mathcal{L}} : \mathcal{L} \to \Omega$ mapping each formula of $\mathcal{L}$ to a recursive unit in $\Omega$ and preserving logical operations (under appropriate semantics). Hence $\mathcal{L}$ is a sub-logic of $\Omega$, i.e., a sub-logic of the negation-of-negation metalogic.*

*Sketch of proof.* 1. Encode $\mathcal{L}$ as an object in the cognitive category $\mathcal{C}\wr\}$: the set of formulas is the state space, the derivation relation gives morphisms, and negation corresponds to the functor $F$. 2. By the Recursive Nesting Theorem, a unique coalgebra homomorphism $h_{\mathcal{L}}$ exists. 3. $h_{\mathcal{L}}$ is faithful because $\Omega$ is constructed as the inverse limit of $G$, and $G$ preserves logical structure. 4. Hence $\mathcal{L}$ embeds into $\Omega$, i.e., $\mathcal{L}$ is a sub-logic of $\Omega$. □

## 3.3 Classical Logic as a Sub-logic

Classical logic (law of identity, non-contradiction, excluded middle, double negation elimination) can be seen as the degenerate case of negation of negation under "no temporal evolution". When the tribulation object $\mathcal{K}$ is empty (i.e., no undecidable propositions) and the metabolic operator degenerates to the identity map, negation of negation collapses to strict equality: $\neg\neg A = A$. Then the recursive unit sequence degenerates to a constant sequence $x = (x_0, x_0, x_0, \ldots)$, and the terminal coalgebra $\Omega$ degenerates to the power set of the initial object 1. Classical logic is the formalization of this degenerate case.

**Proposition 3.3** (Classical Logic as a Sub-logic)**.** *There exists a faithful functor $H_{CL}$ :* **Classical** $\to \mathcal{C}\wr\}$ *mapping classical propositions to constant recursive units. This functor preserves all classical logical operations.*

### 3.4 Intuitionistic Logic as a Sub-logic

Intuitionistic logic rejects double negation elimination, i.e., $\neg\neg A \to A$ is not universally valid[9]. In the recursive unit framework, this corresponds to the non-degenerate case of recursive unit sequences: $x_n$ and $x_{n+1}$ are related but not identical. The truth value of a proposition can be interpreted as the "hierarchical truth" of recursive units: a proposition is true at level $n$ iff its double negation holds at a higher level.

**Proposition 3.4** (Intuitionistic Logic as a Sub-logic)**.** *There exists a faithful functor $H_{IL}$ : **Intuitionistic** $\to \mathcal{C}\wr\}$ mapping intuitionistic propositions to recursive units, where $\neg\neg A$ corresponds to a higher-level projection.*

### 3.5 Modal Logic as a Sub-logic

Modal logic adds necessity $\Box$ and possibility $\Diamond$ operators[10]. In the recursive unit framework, $\Box\varphi$ can be interpreted as "$\varphi$ holds at all higher levels", and $\Diamond\varphi$ as "$\varphi$ holds at some higher level". This perfectly matches the projection structure of recursive unit sequences.

**Proposition 3.5** (Modal Logic as a Sub-logic)**.** *There exists a faithful functor $H_{ML}$ : **Modal** $\to \mathcal{C}\wr\}$ where $\Box\varphi$ corresponds to universal quantification over the tail of the recursive unit sequence, and $\Diamond\varphi$ to existential quantification.*

### 3.6 Relevant Logic as a Sub-logic

Relevant logic requires the antecedent and consequent of an implication to share variables (relevance constraint)[11]. In the recursive unit framework, this corresponds to the requirement that morphisms exist only when two recursive units lie on the same projection chain.

## 4 Unification: Sublating Logical Monism and Pluralism

In the traditional debate, monism emphasizes a single correct logic, pluralism emphasizes multiple equally correct logics. The metalogical framework of this paper offers a third path:

- **Meta-level monism**: Negation of negation is the unique metalogic, constituting the ground of all possible logics. Any logical system must presuppose the recursive structure of negation of negation, otherwise it cannot handle self-reference and evolution.
- **Object-level pluralism**: Beneath the metalogic, multiple sub-logics (classical, intuitionistic, modal, relevant, etc.) can coexist, each suitable for different cognitive domains and reasoning tasks. The differences among these sub-logics arise from different projections or different equivalence relations on the recursive unit sequence.

**Theorem 4.1** (Unification Theorem)**.** *Let $\mathcal{L}$ be any logical system. Then:*

1. *There exists a unique metalogic $\mathcal{M}$ (negation of negation) such that $\mathcal{L}$ is a sub-logic of $\mathcal{M}$.*

2. *Differences between $\mathcal{L}_1$ and $\mathcal{L}_2$ arise from different projections or quotient structures on the recursive unit sequence $\Omega$.*

3. *Hence logical pluralism holds at the object level, logical monism holds at the meta level, and the two are unified through the recursive unit nesting structure.*

# 5 Fundamental Critique of Reductionist Generalization: Logic Is Relation

Based on the metalogical framework established above, we must clearly refute a long-standing cognitive fallacy — **reductionist generalization**. Reductionist generalization is the erroneous elevation of the method "reduce the whole to the sum of isolated parts" to the sole legitimate explanatory principle, thereby denying the reality of relations, structure, and emergence.

## 5.1 Logic Is Relation

The Holism Theorem[3] has proven that truth is a function $T : \Sigma \to R$, and a function is precisely a deterministic relation between inputs and outputs. The rules of logic (identity, non-contradiction, excluded middle, causal implication transitivity) are essentially formal constraints on relations:

- Identity $A = A$ prescribes the reflexive relation.
- Non-contradiction $\neg(A \wedge \neg A)$ prescribes the mutually exclusive relation.
- Transitivity $(A \to B) \wedge (B \to C) \to (A \to C)$ prescribes the closure under composition of relations.

Without relations, there is no logic. Therefore, any attempt to dissolve relations and reduce everything to properties of isolated entities fundamentally denies the possibility of logic.

## 5.2 The Fundamental Fallacy of Reductionist Generalization

Reductionist generalization tries to explain the whole by the sum of isolated parts, which mathematically directly violates the compatibility condition $f_Q|_P = f_P$ (for all $P \subseteq Q$) in the Holism Theorem. This condition requires that parts cannot be defined independently but must cohere with the whole and all other parts. Reductionist generalization ignores this condition and is thus self-contradictory — it uses logical reasoning to argue for the invalidity of logic.

This framework unequivocally judges: **Reductionist generalization is not only wrong but a fundamental cognitive fallacy, its absurdity equivalent to the denial of logic itself**. It manifests as:

1. **Stupidity**: It cannot explain scientific facts such as quantum entanglement non-locality, emergent phenomena in condensed matter physics, or holistic properties in biology.

2. **Absurdity**: It tries to explain the rules of operation (the whole structure) by the objects being operated upon (isolated parts), inverting the hierarchical relation between metalogic and sub-logics.

**Theorem 5.1** (Self-Defeating Nature of Reductionist Generalization)**.** *Let reductionist generalization be the claim $R$: "All phenomena are completely reducible to the sum of the isolated properties of their constituent parts." If $R$ were true, then the truth value of $R$ itself would have to be determined by the sum of the isolated properties of its constituent parts (isolated letters, words), which is impossible — because truth value depends on the global structure of the proposition (syntactic and semantic relations). Therefore $R$ is a self-contradictory false proposition.*

The history of science has already confirmed that every major advance — from Newtonian mechanics to quantum field theory — is a negation of reductionist generalization. Reasonable reduction (i.e., analyzing local mechanisms under global constraints) remains a valid scientific method, but **generalizing** the reduction method as the sole legitimate explanatory principle is stupid and absurd. This framework affirms: the whole is prior to the parts, relation is prior to entities, logic is relation — reductionist generalizers are already pronounced illegal by logic itself.

## 5.3 Misuse and Clarification of Gödel's Incompleteness Theorems

Reductionist generalizers also habitually abuse Gödel's incompleteness theorems, illicitly extrapolating them to a denial of all logic and rationality. Precise clarification is therefore necessary.

Gödel's incompleteness theorems (1931) state: any formal system that contains Peano arithmetic and is recursively axiomatizable, if consistent, must contain an undecidable proposition. The theorems have **explicit preconditions**:

- The system must contain sufficient arithmetic (usually Peano arithmetic).
- The system must be recursively axiomatizable (the set of axioms is enumerable).
- The theorems apply only to such systems; they do not apply to all formal systems (e.g., propositional logic and Tarski's geometry are complete).

The reductionist generalizer's equivocation consists in falsely generalizing "some formal systems are incomplete" to "every formal system is incomplete", and further to "logic itself is unreliable" and "all rational cognition has insurmountable limits". This generalization completely ignores the preconditions of Gödel's theorems and is a typical fallacy of hasty generalization.

More crucially: **Gödel's incompleteness theorems do not cover infinitely recursively nested metalogical structures at all**. The truth space $\Omega$ in this framework is a terminal coalgebra, constructed as an inverse limit $\Omega = \varprojlim G^n(1)$; it does not require recursive axiomatizability and is not subject to Gödel's theorems. Negation of negation as metalogic, through the natural isomorphism $G \cong \mathrm{Id}$, achieves self-foundation and self-transcendence. This kind of infinitely recursively nested metalogical completeness lies precisely outside the scope of Gödel's theorems.

Hence the reductionist generalizer's abuse of Gödel's theorems is doubly illegitimate:

1. Ignoring the preconditions of the theorems and illicitly extrapolating to all formal systems.
2. Wrongly extending the applicability of the theorems to infinitely recursively nested metalogical structures, which are not within the assumptions of the theorems.

**Proposition 5.2** (Gödel's Theorems Do Not Negate Metalogic)**.** *Let $\mathcal{M}$ be the negation-of-negation metalogic and $\Omega$ the truth space (terminal coalgebra). Then Gödel's incompleteness theorems do not apply to $\mathcal{M}$ and $\Omega$, because they are not recursively axiomatizable first-order arithmetic systems but coalgebraic structures in the categorical sense. Hence Gödel's theorems pose no threat to the completeness of the metalogic.*

## 5.4 The Essence of Reductionist Generalization: Pseudo-Logic, Pseudo-Consensus, Futile Involution, and Pure Entropy Increase

Based on the above analysis, the true essence of reductionist generalization can be fully exposed — it is not logic but the antithesis of logic; not rigor but a pretense of rigor; not consensus but a collective degeneration of cognition.

1. **Pseudo-logic**: Reductionist generalization fundamentally violates the metalogical ground that "logic is relation and the whole is prior to the parts". It uses isolated parts to negate holistic relations, uses static fragments to negate recursive evolution — self-contradictory and self-refuting. It uses generated sub-logic objects to attempt to negate the generating metalogical rule, inverting the hierarchy and committing logical suicide. Its so-called "rigorous formalization" merely chops holistic truth into meaningless symbols; its essence is the de-vitalization and de-truthification of logic.
2. **Pseudo-consensus**: Reductionist generalization is not a necessary consequence of rational deduction but a path dependency of academic involution (only able to dissect, not to synthesize, using mechanical repetition to impersonate rigor), a collective safe haven for cognitive laziness (refusing to deal with self-reference, recursion, emergence, using simplification to mask incompetence), and an ideological shackle of disciplinary power (elevating "locally effective methods" to "the sole standard of truth", suppressing meta-cognitive breakthroughs).
3. **Futile involution**: Reductionist generalization infinitely dissects, infinitely subdivides, infinitely piles up symbols — producing no new truth, expanding no cognitive boundary. It creates an illusion of rigor through "local proof patching", but is essentially meaningless logical self-consumption. It forcibly stuffs self-referential, recursive, holistic metalogic into static finite formal frames — the more it patches, the more it breaks; the more it proves, the more chaotic it becomes.
4. **Pure entropy increase**: Negation-of-negation metalogic is negative entropy, order, generation, self-transcendence; reductionist generalization is positive entropy, chaos, deconstruction, self-destruction. It destroys the recursive nesting structure of truth, dissolves the reality of relations, and drags cognition into fragmentation and meaninglessness.

**Theorem 5.3** (Final Verdict on the Illegitimacy of Reductionist Generalization). *Reductionist generalization is not logic, but the antithesis of logic; not rigor, but a pretense of rigor; not consensus, but a collective degeneration of cognition. This framework, from the ground of metalogic, has definitively pronounced its illegitimacy. Rejecting all reductionist contamination and refusing any reductionist-style "completion" is not a defect but the highest logical purity. To uphold negation of negation is to uphold the only true logic, thereby ending the involution and entropy increase of pseudo-logic once and for all.*

# 6 Conclusion

This paper has proved that negation of negation is the metalogic, and all other logics (classical, intuitionistic, modal, relevant, etc.) are its sub-logics. This conclusion rests on the natural isomorphism of the double-negation functor and the terminal coalgebra construction in the Zhu-Liang theoretical chain, and is intuitively verified by an elementary set-theoretic model. It unifies the millennia-old debate between logical monism and pluralism, providing an ultimate mathematical foundation for the philosophy of logic.

Negation of negation is not an optional law of dialectics but the metalogical form of self-foundation and self-transcendence for any self-referential system. It is the logic of logic, the rule above rules. All other logics exist under its shelter as specific projections.

At the same time, this paper has sharply criticized the fundamental fallacy of reductionist generalization: logic is relation, the whole is prior to the parts. Reductionist generalization is pseudo-logic, pseudo-consensus, futile involution, and pure entropy increase — a cognitive pollution of rational civilization. Gödel's incompleteness theorems, abused by reductionist generalizers, do not cover infinitely recursively nested metalogical structures and therefore pose no challenge to this framework.

Negation of negation is the metalogic — all other logics are its sub-logics.

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## Conflict of Interest Statement

The author declares no conflict of interest.

## Data Availability Statement

Pure theoretical exposition; no experimental data.

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