The Grammar of Science

Nancy Cartwright's Nomological Machines and the Closure Framework: Why Scientific Laws Are Local and the World Is Dappled

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> *It takes a nomological machine to get a law of nature. A fixed arrangement of components with stable capacities in the right environment will, with repeated operation, give rise to the regular behavior we represent in our laws.*
> Nancy Cartwright, The Dappled World, 1999

> *Every finite closure generates remainder. The remainder is not noise. It is the proof that the grammar is finite.*
> CF Dietz, Consciousness, Closure, and the Cosmos, 2026

Abstract

Nancy Cartwright has spent four decades arguing that the laws of physics do not describe a unified, seamlessly governed world. They describe the behavior of nomological machines: locally maintained arrangements of components with stable capacities that produce regular behavior within their operating conditions and fail to do so outside them. Her dappled world is a world of patches: domains where specific laws hold because specific machines are running, surrounded by everything the machines do not govern. This paper argues that Cartwright's nomological machines are closure regimes, that her dappled world is the world of irreducible remainder, and that her capacities are what closure regimes deploy in maintaining their organizational identity. The convergence is philosophically precise: both frameworks deny that the world is governed by universal, context-independent laws, both affirm that the regularities science discovers are locally maintained rather than globally given, and both trace this locality to the constitutive structure of organized systems rather than to the limitations of human inquiry. The closure framework provides Cartwright's account with what it currently lacks: an explanation of why organized systems must generate locally bounded regularities at all, derived from what it means to be a finite organized system in an inexhaustible world. Cartwright provides the closure framework with what it needs in philosophy of science: the most careful and empirically grounded account available of how scientific laws actually work and why fundamentalism, the view that all regularities derive from a single set of universal laws, fails both as a description of science and as a metaphysics of nature.

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1. Why Planets Move in Ellipses

All planets move in ellipses. This is one of the most celebrated regularities in the history of science. Kepler derived it from observation. Newton explained it from gravitational theory. It appears in textbooks as a paradigm case of a scientific law: universal, precise, derived from fundamental principles.

Nancy Cartwright wants to know when it holds. The answer is: when the planetary system is running properly as a nomological machine. The planets move in ellipses when the sun dominates gravitational influence, when no large external bodies perturb the system significantly, when the planets are much less massive than the sun, and when nothing else in the vicinity disrupts the stable arrangement of gravitational forces that produces elliptical orbits. Remove any of these conditions and the planets do not move in ellipses. Pass a large enough body through the solar system and planetary orbits deform. Place the system near enough to another star and the gravitational competition changes everything. The law holds ceteris paribus: all other things being equal. And all other things are equal only when the machine is running.

This observation, which seems obvious once made, has radical consequences for how we understand scientific laws and the world they describe. If laws hold only when the right conditions are maintained, then laws are not descriptions of how the world universally is. They are descriptions of how things behave when specific arrangements are in place. The arrangements are the machines. The machines produce the regularities. Without the machines, there are no regularities of the relevant kind.

Cartwright calls this the dappled world: a world that is not seamlessly governed by a single set of universal laws but patched together from domains where specific machines are running and producing local regularities, surrounded by everything the machines do not govern. The world of science is not a unified whole describable by a complete theory. It is a collection of overlapping patches, each maintained by its own arrangement of capacities, each producing regularities that hold within the patch and fail outside it.

That description of the world, arrived at from philosophy of science through careful attention to how scientific laws actually work, is precisely what the closure framework describes from philosophy of mind. A closure regime maintains a local domain of constituted facts. The facts hold within the closure and generate remainder at the boundary: the content that falls outside the closure's scope. The world is dappled not because scientists have not yet found the unified theory but because it is the nature of any organized system to maintain a local domain of order surrounded by what it cannot order. Cartwright found the dappled world in the practice of science. The closure framework derives it from the structure of organization itself.

2. Cartwright's Four Claims

Cartwright's philosophy of science has four interconnected components developed across How the Laws of Physics Lie, The Dappled World, and her subsequent work on causation and evidence-based policy.

2.1 Laws Lie: Scientific Laws Do Not Describe How the World Universally Is

Cartwright's first and most provocative claim is that the laws of physics, in their standard theoretical formulation, lie. Not in the sense that they are false but in the sense that they describe how things behave only under idealized conditions that rarely if ever obtain in the actual world. Newton's law of gravity describes the force between two point masses in a universe containing nothing else. Coulomb's law describes the force between two point charges in a vacuum. Maxwell's equations describe electromagnetic fields in the absence of material media. These descriptions are accurate for the idealized situations they characterize. They are systematically inaccurate for the actual situations where multiple forces act simultaneously, where media are present, where boundaries complicate the field equations.

The standard response is that the laws are correct in principle and the complications are merely practical: in principle we could add all the corrections and arrive at an accurate description of the actual situation. Cartwright contests this. The corrections are not corrections to a fundamentally accurate description. They are the acknowledgment that the fundamental description is not about actual situations at all. It is about idealized situations that the world approximates when the right conditions are maintained. The law does not hold universally. It holds when the right machine is running.

2.2 Nomological Machines: Regularities Require Arrangements

Cartwright's central concept is the nomological machine: a fixed arrangement of components with stable capacities that in the right stable environment will, with repeated operation, give rise to the regular behavior recorded in scientific laws. The planetary system is a nomological machine: the arrangement of sun and planets with their gravitational capacities, shielded enough from external perturbation, produces the elliptical orbits that Kepler's law records. A laboratory experiment is a nomological machine: the arrangement of apparatus, substances, and measuring instruments, shielded from irrelevant influences, produces the regular relationship between inputs and outputs that the experimental law records.

Machines are what make laws hold. Without the machine, there is no law. The same gravitational capacity that produces elliptical orbits in the planetary machine produces hyperbolic trajectories for comets, irregular precession for systems near other massive bodies, and chaotic behavior for closely packed gravitational systems. The capacity is stable. The law is not. The law is what the capacity produces when arranged with other capacities in the right stable machine.

This means that scientific laws are fundamentally about machines rather than about the world as a whole. To discover a law is to discover that a particular machine produces a particular regularity. To apply a law is to identify a situation as an instance of the machine the law describes. To explain a phenomenon using a law is to show how the machine that produces the law is operating in the situation being explained. Science is the study of machines and the regularities they produce, not the discovery of universal truths about an unrestricted world.

2.3 Capacities: What Things Can Do Matters More Than What Things Do

The fundamental building blocks of Cartwright's world are not regularities but capacities: the stable powers that components of nomological machines have to produce specific effects when exercised in the right conditions. The gravitational capacity of the sun is what it can do: attract massive bodies with a force proportional to their masses and inversely proportional to the square of the distance. The sun has this capacity regardless of whether it is currently exercising it. The capacity is the real feature of the world. The regularity is what the capacity produces when assembled into a machine with the right conditions for its exercise.

Capacities are more fundamental than regularities because they persist when the machine is not running and explain what the machine will do when it does run. The gravitational capacity of a body exists whether or not there are other massive bodies nearby. When there are, the capacity is exercised and produces the gravitational effects the law predicts. When there are not, the capacity is latent but real. The law is conditional on the machine. The capacity is not.

This priority of capacities over regularities distinguishes Cartwright's position from Humean empiricism, which treats regularities as the fundamental facts and capacities as convenient summaries of regularities. For Cartwright the order of explanation is inverted: capacities are the fundamental facts and regularities are what capacities produce when arranged in machines. The world is primarily a world of things with powers to do things, not a world of patterns of events.

2.4 The Dappled World: Reality Is a Patchwork, Not a Unity

Cartwright's fourth claim follows from the first three. If laws hold only when machines are running, and machines are locally maintained arrangements of components, then the domains where laws hold are local: the patches where the relevant machines are operating. Outside those patches, the same components exercise their capacities in different arrangements, producing different regularities or no stable regularities at all. The world is not governed by a single unified set of laws. It is a patchwork of domains, each maintained by its own machines, each producing its own local regularities.

Cartwright calls this the dappled world and opposes it to fundamentalism: the view that all regularities ultimately derive from a single fundamental theory whose laws govern everything everywhere without exception. Fundamentalism is the default assumption of much physics and philosophy of physics. Cartwright argues that it is both empirically unsupported and philosophically motivated by an aspiration to unity that the world does not actually possess. The dappled world is not a failure of science. It is what the world actually is: a rich collection of overlapping domains, each with its own organized structures, each producing its own regularities, with no single theory that governs them all.

3. What Cartwright Needs

Cartwright's account of nomological machines and the dappled world is among the most carefully argued positions in contemporary philosophy of science. It is supported by detailed analysis of how scientific laws actually work in physics, economics, and medicine. It has been

tested against objections from fundamentalists, from reductionists, and from philosophers who defend the unity of science. It has survived those tests in substance while provoking productive debate.

There is a gap, however, that Cartwright's framework does not fully close. She explains that laws require machines and that machines are locally maintained arrangements. She explains that the world is dappled because machines are local. But she does not derive the locality of machines from a more fundamental account of what any organized arrangement of components must be. Her argument is primarily inductive and empirical: she shows that the laws we actually have require machines, that the machines we actually find are local, and that the world we actually inhabit is therefore dappled. This is powerful evidence. It does not answer the question of why organized arrangements must be local in the first place.

The closure framework closes this gap. Any organized system draws distinctions, establishes identity criteria, and maintains lawful relationships among its elements. These constitutive activities produce a local domain of order: the facts the system's identity criteria can constitute, the relationships the system's lawful structure can maintain. Outside that domain lies remainder: the content the system's identity criteria cannot capture, the interactions the system's lawful structure cannot govern. The locality of nomological machines is not a contingent feature of the specific machines science has found. It is a structural necessity: any organized system generates a local domain of order and remainder at its boundary. The dappled world is what any world containing organized systems must look like.

4. Two Concepts That Ground the Dappled World

The closure framework is introduced here at the minimum level needed to ground Cartwright's account. Two concepts.

4.1 Closure Regime: What a Nomological Machine Is Philosophically

A closure regime is a system that stabilizes some content by drawing distinctions, establishing identity criteria, and maintaining lawful relationships among its elements. It constitutes facts within its scope and generates remainder at its boundary: the content its identity criteria cannot capture.

Cartwright's nomological machine is a closure regime in this precise sense. The machine is a fixed arrangement of components with stable capacities: these are the identity criteria and lawful relationships of the closure. The machine produces regular behavior when operating in the right environment: this is the closure constituting facts within its scope. The machine fails to produce the regular behavior outside its operating conditions: this is the closure encountering remainder at its boundary. The law that the machine produces is a grammar-relative fact in the language of the closure framework: a fact that holds within the closure's scope and fails outside it, exactly as ceteris paribus laws hold within the machine's operating conditions and fail outside them.

Remainder is the key concept that Cartwright's framework implies but does not formalize. When the machine breaks down, when the ceteris paribus conditions fail, when the law does not

hold: this is remainder. The content of the world that the machine's identity criteria cannot constitute, the interactions that fall outside the machine's lawful structure, the perturbations that disrupt the machine's regular operation: all of this is remainder at the boundary of the closure regime. Cartwright describes the experience of remainder, the systematic failure of laws outside their machines, without naming it structurally. The closure framework names what Cartwright has been pointing at throughout her career.

4.2 The Dappled World Is the World of Irreducible Remainder

The world is dappled because organized systems generate remainder. Every closure regime maintains a local domain of order surrounded by content it cannot order. The overlap of many closure regimes, each with its own local domain and its own remainder, produces the complex, heterogeneous, partially ordered world that Cartwright describes. No single closure regime encompasses the whole world. No single grammar covers everything. The world is always larger than any organized description of it, and that excess is irreducible: it cannot be eliminated by finding a better theory or a more comprehensive machine.

This is the closure framework's structural derivation of Cartwright's empirical finding. Cartwright argues from the practice of science: we find that laws require machines, machines are local, therefore the world is dappled. The closure framework argues from the structure of organization: any organized system generates a local domain of order and remainder, therefore any world containing organized systems is dappled. Both arguments are correct. The structural argument shows why the empirical finding must hold wherever organized systems exist, not merely in the specific domains of science that Cartwright has studied.

5. Four Claims, One Structure

The vocabulary correspondence between Cartwright's philosophy of science and the closure framework is direct and precise. What Cartwright calls a nomological machine, the closure framework calls a closure regime. What Cartwright calls the law that a machine produces, the framework calls a grammar-relative fact: a fact that holds within the closure's scope and fails outside it. What Cartwright calls the ceteris paribus condition, the framework calls the closure's boundary conditions: the conditions that must hold for the closure to maintain its organizational identity and constitute the facts it is organized to constitute. What Cartwright calls the dappled world, the framework calls the world of irreducible remainder: the world as it is when every closure's local domain is surrounded by what it cannot order. And what Cartwright calls a capacity, the stable power a component has to produce specific effects, the framework calls the constitutive feature of a component within a closure regime: the contribution it makes to the closure's organizational identity and lawful structure.

5.1 Laws Lie Because Closures Are Finite

Cartwright's claim that laws lie follows as a structural consequence of the closure framework. The law of gravitation does not describe how the world universally is. It describes how things behave within the closure regime of the gravitational machine: the locally maintained arrangement of massive bodies where gravitational capacities dominate and other influences are

negligible. Outside that closure, gravity still operates as a capacity. But the law, the regular association between gravitational force and mass and distance, holds only when the closure's boundary conditions are satisfied.

The law lies not because it is false within its machine but because it presents as universal what is in fact local. The closure framework explains why this is inevitable. Any law is a grammar-relative fact: it holds within the scope of the closure that constitutes it and fails at the closure's boundary. A universal law would require a closure that generates no remainder: an infinite closure that covers everything. There are no infinite closures. Therefore every law is local, every law holds ceteris paribus, and every law that presents as universal is, in Cartwright's precise sense, lying about its scope.

5.2 Nomological Machines Are Closure Regimes

Cartwright defines a nomological machine as a fixed arrangement of components with stable capacities in the right stable environment. The closure framework defines a closure regime as a system that stabilizes some content through identity criteria and lawful relationships among its elements. These are the same definition in different vocabularies.

The arrangement of components is the closure's constitutive structure. The stable capacities are the lawful relationships that the closure maintains among its elements. The right stable environment is the closure's boundary conditions: the conditions that must hold for the closure to maintain its organizational identity. The repeated regular operation is the closure constituting facts within its scope: producing the same outputs for the same inputs because the same organizational structure is maintaining the same identity criteria. And the law the machine produces is the grammar-relative fact that the closure constitutes: the regularity that holds within the closure and fails outside it.

This equivalence extends to Cartwright's distinction between naturally occurring machines and engineered ones. The planetary system is a naturally occurring closure regime: a gravitational organization that maintains its structure through the dynamics of massive bodies rather than through deliberate construction. A laboratory experiment is an engineered closure regime: a deliberately constructed arrangement designed to isolate specific capacities and produce specific regularities. Both are closure regimes. The difference is in how the closure's boundary conditions came to be maintained, not in the structural character of the closure itself.

5.3 Capacities Are Closure Contributions

Cartwright's capacities, the stable powers that components of machines have to produce specific effects, are what components contribute to closure regimes. A component within a closure regime participates in the closure's organizational identity: its lawful relationships with other components are part of what maintains the closure's constitutive structure. The component's capacity is its contribution to that structure: what it does within the closure's organizational context that makes the closure what it is.

The priority of capacities over regularities in Cartwright's framework corresponds to the priority of closure identity over grammar-relative facts in the CC-C framework. The closure's

organizational identity, its constitutive structure and identity criteria, is more fundamental than the specific facts it constitutes. The facts follow from the identity. Similarly, a component's capacity is more fundamental than the regularities it participates in producing. The regularities follow from the capacity when the capacity is exercised in the right organizational context.

This connection helps explain one of the most important features of Cartwright's capacities: their open-endedness. A capacity can be exercised in many different organizational contexts, producing different effects in different machines. Gravity produces elliptical orbits in the planetary machine, hyperbolic trajectories for comets, and chaotic dynamics in closely packed systems. The capacity is the same. The organizational context determines which effects are produced. This is precisely the behavior of a component that contributes to different closure regimes with different organizational structures: its contribution varies with the closure it is in, even though the component itself remains what it is.

5.4 The Dappled World Is the World of Structural Necessity

Cartwright's dappled world, the world of overlapping patches rather than unified governance, is not a contingent feature of the specific world science has found. It is a structural necessity in any world containing organized systems. The closure framework derives this from first principles.

Any organized system generates a local domain of order surrounded by remainder. Multiple organized systems generate multiple overlapping local domains, each with its own boundary conditions and its own remainder. The intersection of these domains is where multiple closures simultaneously maintain their organizational identity: where multiple machines are simultaneously running. The complement of all domains, the pure remainder that no current closure regime models, is the unorganized background against which all organized structures exist. The world is dappled because organized systems are finite and the world is inexhaustible. This is not a finding about our world in particular. It is a consequence of what any finite organized system must be.

Cartwright's fundamentalism is not merely empirically unsupported. It is structurally impossible. A theory that governs everything without remainder would require an infinite closure: an organized system with no boundary, no identity criteria that exclude anything, no content that falls outside its scope. There are no infinite closures. The aspiration to a theory of everything is not a scientific goal that might eventually be achieved. It is a structural impossibility that the dappled world permanently and necessarily precludes.

6. What Each Framework Provides the Other

The convergence between Cartwright's philosophy of science and the closure framework is precise and mutually supporting. Each provides what the other lacks.

For Cartwright's framework, the closure account provides the structural derivation of why machines must be local and the world must be dappled. Cartwright argues empirically and inductively: from the specific laws and machines of physics, chemistry, economics, and medicine to the general conclusion that the world is dappled. The closure framework derives the same

conclusion from structural first principles: from what it means to be a finite organized system in a world that exceeds any finite system's organizing capacity. The structural derivation shows that Cartwright's empirical finding is not a contingent feature of the specific domains she has studied but a structural necessity that holds wherever organized systems exist. This gives her anti-fundamentalism a philosophical foundation that transcends the empirical evidence for it.

For the closure framework, Cartwright's work provides the philosophy of science that shows how the framework's structural claims play out in the actual practice of scientific inquiry. The closure framework says that knowledge is constituted within grammars that are local and generate remainder. Cartwright shows in detail how this works for the specific grammars of physics, economics, and medicine: how their laws require machines, how their machines have boundaries, how their boundaries determine where the laws hold and where they fail. The Grammar of Knowing established the epistemological claim. The Grammar of Healing demonstrated it for medicine. Cartwright demonstrates it for physics and social science with forty years of careful philosophical analysis. The suite gains its most rigorous philosophy of science paper through Cartwright's work.

The connection to the Grammar of Healing deserves specific mention. The Grammar of Healing argued that the RCT grammar, the randomized controlled trial as the machine that produces knowledge of drug efficacy, generates remainder at its center: it cannot model the causal mechanism that makes placebos work because it draws its central distinction at exactly the boundary where cognitive and biological closure interact. Cartwright's analysis of nomological machines provides the exact philosophical vocabulary for this claim. The RCT is a nomological machine. Like all nomological machines, it produces regularities within its operating conditions and generates remainder outside them. The placebo mechanism is exactly what falls outside the RCT machine's organizational scope. Cartwright and the Grammar of Healing are describing the same structural truth about scientific knowledge from different angles.

7. The Grammar of Science

Planets move in ellipses when the planetary machine is running. They do not move in ellipses absolutely, universally, regardless of conditions. They move in ellipses ceteris paribus: when the other things that would disrupt the machine are absent and the arrangement that produces elliptical orbits is stably maintained.

Nancy Cartwright has spent four decades following the implications of that observation. Through nomological machines and capacities, through the dappled world and its patches, through evidence-based policy and the limitations of causal inference across contexts, she has built the most careful and empirically grounded account in philosophy of science of why scientific laws are local and the world resists unified governance. She has shown that fundamentalism is not merely unproven but wrong: the laws do not describe how the world universally is, they describe how things behave when the right machines are running, and the right machines are always and only locally maintained.

The closure framework derives the same conclusion from a different direction. Any finite organized system maintains a local domain of order surrounded by remainder. The regularities the system produces hold within its domain. They fail at its boundary. The world is dappled because

organized systems are finite and the world exceeds any finite system's organizing capacity. The grammar of science is not the grammar of the world. It is the grammar that science has managed to constitute so far, surrounded by the remainder it has not yet reached and cannot in principle eliminate.

Cartwright found the dappled world in the laboratories of physics and in the field studies of economics and medicine. The closure framework finds it in the structural necessity of any finite organized system in an inexhaustible world. Both findings are correct, and what they are correct about is the same thing: the world is organized in patches, each patch is locally maintained, and the space between the patches is not ignorance waiting to be filled but remainder that is structurally produced by the very act of organizing anything at all. The grammar of science is the grammar of finite systems building local order in a world that exceeds it. Cartwright named the world that results. The closure framework names the structure that makes it necessary.

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Author's Note

This paper is the seventh in a series engaging thinkers whose work converges with the closure framework developed in Consciousness, Closure, and the Cosmos. Nancy Cartwright is Emeritus Professor of Philosophy at the University of California, San Diego, and Professor of Philosophy at the University of Durham. Her work spans philosophy of physics, philosophy of economics, causation theory, and evidence-based policy. She has been a central figure in philosophy of science for four decades, and her opposition to fundamentalism has shaped how philosophers think about scientific laws, models, and mechanisms. The author regards Cartwright's nomological machine as among the most important concepts in twentieth-century philosophy of science, and this paper argues that the closure framework provides its structural philosophical grounding. The connection to the Grammar of Healing through the RCT analysis is particularly significant: it shows that the same structural insight about local scientific regularities and their remainder reaches from physics to medicine along the same analytical path. The author welcomes engagement from Cartwright directly and from philosophers of science, scientists, and policy analysts who find the connection between local regularities and structured remainder either clarifying or contestable.