CHAPTER 8

Physics of the Threshold: The Search for a Mediator

8.1 What Kind of Physical Object Could Mediate Succession?

These requirements are severe. The mediator must correspond to a physically realizable causal threshold, not merely an energetic event. It must isolate a high-curvature region in a way that makes the prior exterior description incomplete for the interior, and it must do so without supplying a hidden channel through which detailed state information is assumed to seed another universe.

From Chapter 7, three non-negotiable functions follow directly. The mediator must:

i. *Enforce causal isolation* – provide a localized one-way boundary beyond which causal influence cannot return to the prior exterior domain.
ii. *Exclude contingent historical detail from the prior exterior description* – make that detail causally inaccessible to the exterior without requiring a claim of fundamental information destruction.
iii. *Respect architectural admissibility* – remain compatible with the foundational conditions that any physically intelligible regime must independently satisfy.

Each requirement is severe; together, they leave almost no room for alternatives. They immediately exclude large classes of physical systems that might otherwise seem plausible candidates.

The mediator must be a physically realizable structure with a localized gravitationally generated domain of one-way causal accessibility relative to the prior exterior. That domain must isolate the high-curvature transition from outward causal influence during mediation. It must make contingent interior history inaccessible to that exterior description without asserting fundamental information destruction, while remaining compatible with the foundational admissibility conditions.

These are the demands. They follow from the cumulative logic of the preceding chapters. The mediator of cosmic succession is not any object, however dense or energetic. It must provide causal isolation, remove contingent historical detail from the prior exterior's accessible description, and remain compatible with architectural admissibility. The remainder of this chapter examines what physical structures can satisfy these demands—and why only one presently known relativistic structure appears to do so.

8.2 Why Candidate Astrophysical Objects Fail

At first glance, many compact or energetic astrophysical objects might appear capable of mediating succession. Stars exhaust their fuel. Dense remnants store enormous energy. Violent processes dissipate information. Yet closer examination reveals that these systems fail one or more of the essential criteria.

White dwarfs are endpoints of stellar evolution stabilized by electron degeneracy pressure. While extremely dense, they remain fully embedded in the causal structure of the surrounding spacetime. They continue to radiate and interact with their environment, remaining causally open. Signals, radiation, and matter propagate outward without obstruction. There is no invariant one-way causal boundary and therefore no local causal isolation of the required kind. Whatever history accumulates within a white dwarf remains accessible in principle, though not necessarily recoverable. White dwarfs cannot serve as mediators of succession.

Neutron stars push this logic further. Their densities approach nuclear scales, and their internal states are governed by exotic forms of matter. Nevertheless, they lack the geometric feature required for local causal isolation in the selected channel: their radius remains larger than their Schwarzschild radius $R_s = 2GM/c^2$, where M is the gravitational mass of the star used in this Schwarzschild comparison. No event horizon forms. Despite extreme gravity, neutron stars do not sever causal accessibility. Their surfaces emit radiation, participate in interactions, and retain detailed information about their internal composition. They compress matter, but they do not place their interior history behind an invariant one-way causal boundary of the required kind.

Quasars and active galactic nuclei are among the most luminous and violent phenomena in the universe. They dissipate energy on colossal scales and radically restructure their environments. However, dissipation alone is insufficient. These systems amplify historical complexity rather than filtering it. They broadcast information rather than absorbing it, and they rely on extended causal interaction with their surroundings. They are engines of history, not its terminators.

One might object that sufficiently long timescales or sufficiently strong dissipation could, in principle, wash out historical detail. But statistical scrambling is not the same as causal exclusion. As long as causal accessibility remains open, dispersed or scrambled information may remain in principle connected to the regime's exterior causal description. The mediator requirement is stronger: contingent interior detail must become inaccessible to the prior exterior as a consequence of the causal geometry itself.

The failure of these candidates is not accidental; it is a direct consequence of their causal openness. Any object lacking an invariant boundary of causal accessibility fails the first requirement. Any object that merely dissipates without isolating fails the second. The third requirement is compatibility with the foundational architecture. Preservation of local microstructure alone does not imply transmission of a state across closure and is not, by itself, a failure of that requirement.

The mediator requirement is a localized gravitationally generated domain whose evolving boundary satisfies the one-way condition during mediation; trapping alone is insufficient during the high-curvature transition. Known gravitational collapse provides the presently identified relativistic candidate; whether a complete successor is realized remains open.

8.2.1 Why a Horizon Is Not One Feature Among Others

The structural property isolated here is local causal isolation of the transition relative to the prior exterior. It may be characterized through trapped or marginally trapped regions and their dynamical causal boundaries; a permanent global event horizon is not required.

A trapped or marginally trapped surface alone does not determine the causal character, orientation, or persistence of its evolving boundary. Those properties must establish one-way accessibility throughout the required mediation interval (Ashtekar and Krishnan 2004).

A trapped region is quasi-local, whereas an event horizon is a global boundary defined only with the completed future spacetime. The mediator needs one-way causal accessibility during the transition, not a claim of permanent inaccessibility in every possible completion. Section 9.11 keeps this local requirement separate from closure of a complete regime.

This observation closes the space of physically consistent candidates more decisively than a catalogue ever could. The mediator of succession is not defined by density, violence, or longevity, but by the existence of an invariant causal boundary encoded in spacetime geometry itself. Such a boundary supplies the local causal-isolation ingredient required by mediation; it does not by itself establish global regime closure.

The question is therefore whether known relativistic physics supplies a localized horizon or trapped-region structure capable of isolating the high-curvature transition from the prior exterior. Gravitational collapse provides that local mediator ingredient. Its existence alone does not establish matching, global completion, or the realization of a complete successor cosmological regime.

Not every horizon satisfies the requirements identified here. Cosmological horizons, de Sitter horizons, and observer-dependent horizons such as Rindler horizons delimit domains of accessibility, but they do not arise from the gravitational isolation of a localized physical system. The present argument concerns horizons associated with physically bounded structures capable of acting as mediators of succession. The distinction is essential: mediation requires not merely a limitation of access, but a localized one-way causal threshold generated by the dynamics of the regime itself.

8.3 Black Holes as Causal Thresholds

Gravitational collapse provides the only presently known relativistic mediator candidate because it can combine trapped-region formation, localized causal isolation, and access to high curvature. This identification does not establish a permanent event horizon or a complete successor regime.

A trapped or marginally trapped region is characterized by the behavior of null congruences locally or quasi-locally. Its dynamical boundary can isolate a high-curvature domain from outward influence on the prior exterior during mediation. By contrast, an event horizon is the boundary of the causal past of future null infinity in a completed spacetime (Hawking and Ellis 1973); its existence and permanence depend on the global completion.

The framework requires the former causal-isolation property during mediation. It does not require the boundary to be a permanent global event horizon; Appendix I leaves the matching and global completion open.

A trapped region supplies a candidate route to high curvature; the required causal isolation additionally depends on the causal character, orientation, and evolution of its boundary. Neither that region nor a possible event horizon is itself the structural closure of an entire cosmological regime.

Local causal isolation can arise from gravitational collapse under suitable conditions on the matter distribution, spacetime, and dynamics. Singularity and incompleteness results such as those discussed by Penrose (1969) do not by themselves establish horizon formation in every admissible gravitational history. The relevant requirement is an internal physical route to mediation where the necessary conditions are met, rather than a universal production law.

During the required mediation interval, the relevant boundary is one-way relative to the prior exterior: inward influence may enter, while the high-curvature transition cannot send outward causal influence across it. Its later global status is a question for the completed spacetime, not an assumption of the mediator argument.

A regular trapping boundary is not itself a curvature singularity. Classical spacetime may extend smoothly across it; the classical description becomes inadequate deeper in the high-curvature domain. Whether a global event horizon exists in the completed geometry is separate from this local statement.

Black-hole collapse is thus the only presently known relativistic route that combines a localized trapped domain with evolution toward high curvature. It is a mediator candidate; causal isolation alone does not guarantee complete-regime succession.

Any further causal domain should not be pictured as a smaller spacetime geometrically contained inside the preceding universe. The black-hole geometry supplies a local trapped region and a route toward high curvature within the original spacetime. If a distinct cosmological regime is realized through the nonsingular continuation adopted later, that regime possesses its own internally defined spacetime rather than occupying a location in a common external container.

8.4 Black Holes as Relativistic Mediator Candidates

Local causal isolation alone is not sufficient. The mediator must also remove the detailed interior history from the causal accessibility of the prior exterior. This is an operational statement about causal domains, not a claim of fundamental information destruction.

Black holes satisfy this requirement in a manner that is both precise and physically unavoidable. The laws of black hole thermodynamics assign to black holes an entropy proportional to the area of their event horizons (Bekenstein 1973; Hawking 1975). This entropy is not metaphorical. It is interpreted as counting the number of microscopic configurations consistent with the macroscopic black hole parameters. Unlike ordinary thermodynamic systems, whose entropy scales with volume, black hole entropy scales with

surface area. This indicates an extreme form of informational coarse-graining. An astronomical number of distinct microscopic configurations—the contingent states identified in Chapter 7—become indistinguishable from the outside, mapping onto a single macroscopic description defined by a handful of parameters.

As matter and radiation cross a black-hole horizon, their detailed microphysical state becomes inaccessible to the classical exterior description. The exterior can continue to be characterized by a small set of macroscopic parameters, but those parameters are properties of the black-hole solution within the original regime; they are not a compressed state transmitted to a successor.

Black-hole thermodynamics therefore provides a physically precise form of coarse-grained irreversibility for the exterior causal domain. The Bekenstein–Hawking entropy quantifies horizon capacity; it need not be interpreted as a ledger in which a preceding regime pays a debt to a further regime.

The classical no-hair theorems sharpen the exterior coarse-graining statement. Under stationary conditions, an equilibrium black hole is characterized externally by a small set of macroscopic parameters such as mass, electric charge, and angular momentum (Israel 1967; Carter 1971; Robinson 1975). Detailed information about the composition and history of the collapsing matter is not recoverable from that stationary exterior description. These parameters remain properties of the black-hole solution within the original regime; they are not architectural data transmitted across closure and are not assumed to determine the state of any subsequent regime.

Ordinary dissipation can scramble or disperse information while leaving the system causally open. A horizon introduces a stronger, geometric restriction: the interior is excluded from causal influence on the classical exterior. That is the relevant distinction here. The framework does not require the stronger assertion that the horizon fundamentally erases quantum information.

To the best of current knowledge, black holes are the only known relativistic structures that combine a localized causal horizon, irreversible gravitational collapse, and access to a regime in which classical geometry eventually becomes insufficient. This is a uniqueness claim within the presently known relativistic inventory, not a metaphysical theorem excluding every possible mediator in a future theory.

The present argument does not imply that every gravitational collapse generates a subsequent domain. It establishes only that, within known physics, gravitationally collapsed regions constitute the only presently known structures capable of mediating physically admissible transitions under the constraints derived so far.

8.4.1 On Horizons, Trapped Regions, and Local Causal Isolation

At this stage, it is worth pausing to dispel a common but subtle misunderstanding. The causal horizon that plays a central role in the argument above is often described informally as the result of an “overwhelming gravitational force.” While suggestive, this picture is misleading.

A horizon is not a barrier created by an arbitrarily strong force. If it were, escape would merely be a question of sufficient energy, propulsion, or exotic interaction. Yet this is precisely what fails. For a global event horizon in the relevant completed spacetime, even photons, traveling at the universal speed limit c, cannot escape once the horizon is crossed. This alone signals that the phenomenon at stake is not dynamical but structural.

A trapped or marginally trapped surface does not, by itself, establish causal isolation from the prior exterior. For the mediation channel considered here, the required property is that no future-directed causal curve from the protected high-curvature transition domain reaches the specified prior exterior during the mediation interval, within the causal description used by the construction. The relevant domains and interval must be physically specified.

Where a smooth Lorentzian description applies, the construction must justify the boundary's causal character, orientation, and separating role throughout that interval. A suitable spacelike or null future outer trapping boundary can provide the local one-way crossing property under the relevant hypotheses; a timelike marginally trapped tube is locally traversable in both directions. Local crossing restrictions must also be accompanied by control of possible routes around the boundary or its ends. The classical hypotheses supporting those restrictions must be checked wherever effective high-curvature dynamics is invoked.

This is an interval-dependent requirement relative to the prior exterior, not an assumption of a permanent global event horizon. It permits inward causal influence and establishes neither fundamental information destruction nor the isolation of a complete successor regime. The latter still requires the matching and global-completion construction discussed in §9.11 and Appendix I.

Crucially, this boundary does not exist independently. It is not an added structure, nor a universal surface imposed from outside. It is a feature of the causal geometry generated by the gravitating configuration. In the uncharged, nonrotating, spherically symmetric Schwarzschild idealization, the areal radius $R_s = 2GM/c^2$ is the exact horizon threshold: inside it every future-directed causal curve has decreasing areal radius. This is a property of the causal geometry, not of the magnitude of the local curvature, which at the horizon of a sufficiently massive black hole can be arbitrarily small. In general, dynamical or nonspherical collapse, however, R_s is not a universal local horizon-formation criterion; horizon formation must instead be characterized through the appropriate event-horizon or trapped-surface structure, whose location can require global or quasi-local analysis (Ashtekar and Krishnan 2004; Curiel 2019). Configurations whose boundary provides one-way causal isolation relative to the prior exterior during mediation satisfy this requirement.

This distinction clarifies why even the most well-known astrophysical objects short of black holes fail the local causal-isolation requirement. Neutron stars, for example, possess enormous mass and exhibit gravitational fields of extraordinary strength. Yet their radius remains larger than their Schwarzschild radius. Spacetime around them is severely curved, but not to the point where outward-directed trajectories vanish. Light can still escape. Causal accessibility, though strained, remains intact. As long as they remain neutron stars rather than collapsing into black holes, their surfaces remain outside the relevant horizon.

A black hole marks a qualitative change in causal accessibility. In the spherical, uncharged, nonrotating Schwarzschild idealization, compression within the corresponding critical areal radius yields the familiar horizon condition. Dynamical, rotating, charged, or nonspherical collapse instead requires the appropriate trapped-region and global or quasi-local criteria. Where such a one-way domain forms, the local isolation relevant to mediation is a matter of causal kind, not merely stronger gravity.

Seen this way, black holes are selected within the presently known relativistic inventory not because they are exotic or exceptionally dense, but because they combine a localized one-way causal horizon with gravitational evolution toward high curvature. Objects that remain causally open do not satisfy this mediator profile. The conclusion is comparative and provisional: it does not exclude a functionally equivalent mediator in future physics.

8.4.2 Geometric Irreversibility versus Thermodynamic Irreversibility

The irreversibility associated with black holes must be distinguished at two levels: thermodynamic and geometric. Both are essential, but they follow from different structures.

Thermodynamic irreversibility, as developed in Chapter 3, is tied to persistent records and to the history-dependent accessibility of later configurations. Black-hole thermodynamics supplies a particularly strong form of coarse-graining for the exterior description: the Bekenstein–Hawking entropy assigns a horizon capacity proportional to area, while the detailed state of infalling matter is no longer recoverable from the stationary exterior macroscopic parameters. This is a statement about accessibility and coarse-graining, not about a monotonic depletion of a microscopic state inventory.

A distinct restriction is encoded in the causal geometry of a classical black-hole spacetime. Across a future event horizon, matter and signals can pass from the exterior into the black-hole region, but future-directed causal curves cannot carry signals from that region back to the exterior. The asymmetry therefore restricts outward communication; it does not prevent the exterior from influencing the interior. This restriction follows from the causal structure of the specified spacetime rather than from statistical coarse-graining.

The distinction is between scrambling within an accessible system and the absence of an outward causal channel. Thermodynamic processes may disperse information among microscopic degrees of freedom, whereas the event horizon excludes direct causal recovery from the black-hole region by exterior observers. This geometric statement does not establish fundamental destruction of quantum information or determine the outcome of a quantum-gravitational continuation.

The horizon is therefore a locus where causal asymmetry becomes geometrically exact for the exterior description. Thermodynamic coarse-graining and geometric one-way accessibility reinforce one another, but neither implies that a detailed state is transferred beyond closure.

Taken together, these properties explain why black holes are natural mediators within the present framework. They provide causal isolation and a route to high curvature while eliminating any need to postulate a detailed transmitted state. Whether a nonsingular quantum-gravitational continuation exists is a separate question.

8.5 From Threshold to Transition: The Open Question

The open question is whether the mediator profile identified above can be completed by a physically adequate nonsingular high-curvature continuation. Classical general relativity describes horizon formation and the interior evolution toward the singular regime, but it does not provide the physics that replaces that singular endpoint. A quantum-gravitational description is therefore required before black-hole mediation can be connected to the bounce realization used in the remainder of this book.

The macroscopic black-hole parameters characterize the mediator within its own spacetime. They are not boundary data that the framework assumes to be copied into a new universe. The transition problem is instead whether a quantum-gravitational description can replace the classical singular regime by a nonsingular high-density continuation compatible with the same foundational admissibility conditions.

The exterior black-hole mass parameter M_{ext} and the total energy $E_{\mathrm{b}} = \rho_{\mathrm{crit}}\, V_{\mathrm{b}}$ assigned to the effective bounce domain are conceptually distinct quantities. Here ρ_{crit} is the critical bounce energy density and V_{b} is the proper volume of the effective bounce domain (§9.1 and §9.4). Classical spherical collapse supplies a well-defined exterior mass parameter, but the present framework does not derive its relation to the energy of the quantum-corrected bounce domain. In particular, the equality $E_{\mathrm{ext}} = M_{\mathrm{ext}}\, \mathrm{c}^2 = E_{\mathrm{b}}$ is not assumed. Establishing such a relation requires a consistent dynamical matching between the collapsing exterior geometry and the effective high-curvature interior; Appendix I states this open matching problem explicitly.

Answering that question requires physics beyond classical general relativity. Candidate approaches to quantum gravity provide examples of nonsingular interiors and bounce-like continuations, but the present framework imports only the structural features explicitly stated in Chapter 9; it does not infer a microscopic transport map from one causal regime to another.

This chapter therefore establishes a restricted result: if black-hole-mediated succession is physically realized, black holes are the only presently known relativistic structures satisfying the mediator requirements developed here. The next chapter introduces the effective quantum-gravitational input used to describe the high-curvature transition and derives the quantitative bridge that follows it.