Nothingness Ladder

Executive Summary

The “Nothingness Ladder” is a conceptual hierarchy of what “nothing” could mean in physics and philosophy, ranging from the relatively tangible quantum vacuum to the absolute absence of all reality. Each rung corresponds to a level of “nothingness” with progressively fewer structures: **Level A (Quantum-Field Vacuum)** – empty space with no particles but active quantum fields; **Level B (Topological Nothing)** – spacetime itself (a manifold with metric) exists but is empty of any fields or matter; **Level C (Metageometric Void)** – no classical spacetime at all, only a pre-geometric quantum-gravity substrate capable of generating spacetime; and **Level D (Logical Nullity)** – the total void of anything: no space, no time, no fields, no laws of physics or mathematics, until *something* like a rule or law might spontaneously “activate.” The ladder thus ascends from a “nothing” that is actually quite something (the seething quantum vacuum) through stages of stripping away structure, towards an ultimate nothingness that is almost inconceivable (the absence of even logic or law).

This dossier explores each level in turn, devoting greater depth to the more profound emptiness of Levels C and D. We summarize key scientific proposals and philosophical positions at each level, highlight mechanisms by which “something” might arise from “nothing,” and discuss critiques and potential ways to test these ideas. We also chart open problems — how one might step down the ladder from D to C to B to A as one adds structure — and include an annotated bibliography of influential literature. In brief, modern physics shows that even what we call “vacuum” is rich in structure, and conjectures in quantum cosmology and multiverse theories attempt to explain how our universe could emerge from progressively less. However, the question “Why is there *something* rather than *nothing*?” becomes increasingly challenging and perhaps ill-posed at the deepest level, where one ponders the origin of not just matter-energy and spacetime but the very laws of logic and existence.

Annotated Literature Matrix

Author (Year)	Discipline	Ladder Level	Proposal	Key Mechanism	Main Critique	Suggested Empirical Handle
Tryon (1973)	Cosmology	Level A	Universe as a QFT vacuum fluctuation (zero-total-energy universe).	Quantum uncertainty allows a particle–antiparticle-like pair (universe from "nothing").	Not fully developed; needed inflation to address size/structure .	Flatness of universe (total $E \approx 0$; later CMB tests of inflation consistency.
Coleman & De Luccia (1980)	Theoretical Physics	Level A→C	False-vacuum decay yielding a new universe (bubble nucleation).	Quantum tunneling through a potential barrier in curved spacetime ; bubble "nothing" inside becomes new universe.	Initial "nothing" isn't absolute (requires meta-stable vacuum backdrop); measure of tunneling probability ambiguous.	Possible signatures in gravitational waves or CMB from bubble collision (not observed so far).
Lamoreaux (1997)	Experimental Physics	Level A	Casimir effect demonstrates reality of vacuum fluctuations.	Attraction of metal plates due to altered EM zero-point modes .	Casimir force can be derived without invoking vacuum energy (Jaffe's argument).	Casimir force measured to ~1% ; indirect evidence of vacuum energy (complementary to Lamb shift, etc.).
Jaffe (2005)	Quantum Theory	Level A	Casimir effect *without* vacuum energy ("no new physics" view).	Shows Casimir forces can be seen as van der Waals forces between charges, no explicit E_{vac} needed .	If taken literally, leaves cosmological vacuum energy unexplained; most disagree as zero-point *formalism* still underlies QED predictions.	Ongoing: test Casimir in different materials/geometries to isolate vacuum vs. matter contributions.
Hartle & Hawking (1983)	Theoretical Cosmology	Level C	No-Boundary Proposal – the universe as a finite, boundary-less spacetime.	Euclidean path-integral over compact 4-geometries gives the wavefunction of the Universe ; "time" emerges from space at Planck epoch .	Requires a specific complex contour of integration; ambiguity in defining the "initial" measure. Also, is "no-boundary" natural or fine-tuned?	Possibly imprints on the CMB power spectrum or inflation initial conditions (debated in literature).
Vilenkin (1982) (plus 1984)	Theoretical Cosmology	Level C	Tunneling from Nothing – universe nucleation from literally nothing.	Wheeler–DeWitt equation with boundary condition: solution is outgoing (expanding) universe only . "Nothing" = no spacetime (topology change from 0 to S^3).	The "nothing" state still obeys rules of quantum cosmology (so laws pre-exist); unique tunneling wavefunction selection is debated.	Possibly affects whether inflation must occur and its parameters. No direct test; mainly a conceptual alternative to no-boundary.

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He, Gao & Cai (2014)	Quantum Cosmology	Level C	*Proof* of spontaneous universe from nothing via WDW solutions.	Analytic solutions of the Wheeler–DeWitt equation show a tiny true-vacuum bubble can nucleate and inflate . Bohmian interpretation: quantum potential drives inflation .	Uses minisuperspace approximations and special operator ordering; real universe has many fields and inhomogeneities.	If our Big Bang was a tunneling event, perhaps relic quantum "footprints" in primordial perturbations (not distinct yet from inflation).
Addazi et al. (2025)	Quantum Gravity (QFT)	Level C	Pre-geometry to GR via *stochastic* phase transitions.	A pre-geometric theory (Wilczek's model) flows under a gradient (RG) flow: breaks topological symmetry → pre-geometric phase; then breaks another symmetry to yield classical GR .	Highly theoretical; relies on untested "UV fixed point" and specific stochastic quantization. Two phase transitions might not occur in simpler QG models.	Unclear; in principle, look for remnants of a phase transition in the vacuum (e.g. cosmological constant running) or topological defects from early universe.
Oriti (2022)	Quantum Gravity (GFT)	Level C	Spacetime from Group-Field-Theory (GFT) condensate ("geometrogenesis").	Many discrete "atoms" of space undergo a Bose–Einstein condensation; a continuous spacetime emerges as a condensate phase . Uses QFT tools on space atoms.	Still lacks unique dynamics: which GFT states correspond to our universe? Also, phase transition dynamics (nucleation of condensate) not fully understood.	Could predict deviations from continuous geometry at Planck scale: e.g. deviations in dispersion of gravitational waves or cosmological invariants if spacetime is discrete at root.
Gielen, Oriti & Sindoni (2016)	Quantum Gravity (LQG)	Level C	Condensate cosmology with symmetry breaking.	In GFT analog of LQG, the "Fock vacuum" of no space transitions to a condensed phase of spacetime atoms, breaking a $U(1)$ symmetry . Yields an emergent FRW universe from quantum grains.	Hard to connect with low-energy details (how exactly do continuum metric and General Relativity emerge cleanly?); symmetry breaking choice somewhat *ad hoc*.	Look for quantum gravity corrections in the cosmic expansion (e.g. bounce or inflation initial conditions) that such condensate models predict (e.g. upper bound on curvature).
Sorkin (2005)	Quantum Gravity (Causal Set)	Level C	Causal Set Hypothesis – "Order + Number = Geometry."	Discrete events partially ordered by causality can reproduce spacetime's structure . The universe "grows" by new events	Theory not yet complete (lack of a full dynamics agreed upon; Lorentz invariance only approximately recovered).	Causal sets predict a specific *swerves* in cosmic expansion (e.g. randomness in cosmological constant) –

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				(sequential growth dynamics) instead of evolving in a fixed spacetime .	How the "birth" of events begins (from nothing?) is still speculative.	tentative fits to observations, but not confirmed.
Dowker & Zalel (2017)	Quantum Gravity (Causal Set)	Level C→D?	Black-hole → new universe; cosmological natural selection in causal set context.	Proposal that a black hole's singularity could birth a new causally disconnected universe; in causal set theory, a "bounce" with changed constants (like Smolin's CNS idea) .	Jumps outside our universe are untestable directly; also requires a rule for how constants change. Unclear if "nothing" is ever a state, or just another universe's interior.	If true, could explain fine-tuning by selection effects. Possible indirect evidence: certain distributions of black hole properties or fundamental constants (though no consensus).
Wheeler (1983)	Quantum Foundations	Level D→C	"Law Without Law" – physical laws emerge from an underlying lawlessness.	The universe's laws are not ingrained a priori but result from a sort of cosmic self-organization or an averaging over many possibilities . (Wheeler envisioned a quantum foam where even logic can be fuzzy until measured.)	Philosophically controversial: how do consistent laws arise from chaos? Also, lacks a concrete mathematical model – it's more of a metaphor from Wheeler.	None direct; Wheeler's idea inspired quantum information approaches (it-from-bit). Possibly quantum logic tests or observing if constants could fluctuate.
Hawking & Mlodinow (2010)	Popular Cosmology	Level D→C	Spontaneous creation via gravity ("Universe from nothing because of gravity").	Argue that a total-energy-zero universe can arise spontaneously: gravity's negative energy balances matter's positive, allowing quantum creation of a cosmos . "Because there is a law like gravity, the universe can create itself from nothing."	Circularity: assumes a "law like gravity" exists *before* the universe – which is precisely the issue at Level D. Also, it's debated if total energy truly zero (depends on cosmological model).	Same as other quantum cosmology proposals (CMB, etc.). This is essentially a restatement of tunneling in a more digestible form; its novelty is philosophical.
Nozick (1981)	Philosophy	Level D	Principle of Fecundity – all possible worlds *are* real (everything exists).	Postulates that reality is maximally abundant: every possible universe/law exists, so	Unfalsifiable and extravagant; also if all worlds exist, the "principle" itself existing	None (metaphysical proposal). However, it relates to modal realism and Tegmark's multiverse which might have

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				"nothing" (the absence of all) is just one possibility that isn't singled out . This would *solve* "Why something?" by making nonexistence the extreme rarity.	in all is puzzling (self-instantiation paradox noted by Nozick). Philosophers argue it just shifts the question to "why fecundity?"	indirect support if mathematical structures show physical consequences.
Lewis (1986)	Philosophy (Logic)	Level D	Modal Realism – existence of a plenitude of possible worlds as concrete entities.	All possible worlds exist "out there" just as our actual world does ; "Actual" is indexical. Nothingness (the null world) could be just one of infinitely many possibilities and has no special status.	Deemed counterintuitive and Ockham-violating by many. Also cannot be empirically differentiated – it's a metaphysical stance to make modal logic truths literal.	No empirical test; it's a philosophical interpretation of modality. Its value is logical consistency in modal reasoning rather than physics.
Tegmark (2007/2014)	Cosmology/Philosophy	Level D	Mathematical Universe Hypothesis (Level IV multiverse) – all mathematical structures exist physically.	Reality is an "ultimate ensemble" of all math structures . Physical existence = mathematical existence . Thus *every* logically possible structure (universes with any laws, or no laws if self-consistent) exists. Our universe is one such structure.	Critics argue it's not a testable scientific theory and face measure problems (infinitely many structures). Also Gödel incompleteness may complicate "all structures" idea .	None direct. Tegmark's idea might be indirectly judged by how well math describes physics, but the full hypothesis transcends empirical science. (It's more a philosophical TOE).
Ellis (2004) (also Stoeger etc.)	Cosmology/Philosophy	Level D	*Meta-laws* needed for multiverse – even a multiverse of varied laws requires higher-order rules.	Emphasizes that to discuss a multiverse ensemble, one assumes a common foundational set of principles or "primordial laws" governing all universes . Otherwise "anything goes" and the concept of	Raises infinite regress: if meta-laws exist, who/what determined those? Could be an endless ladder of higher laws. Also, meta-laws themselves seem unobservable if beyond all universes.	No direct empirical test. It's a critique: any theory invoking other universes with different laws must explain why *these* meta-laws and not others . Some argue maybe meta-laws could imprint via e.g. potential coupling between universes (speculative).

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				a unified reality breaks down.		
Grünbaum (2000s)	Philosophy of Science	Level D	"Nothingness" question as pseudo-problem ("ontopathological syndrome").	Argues that asking "Why is there not nothing?" assumes nothingness is a default that needs explanation, which might be a misguided intuition . Maybe it's logically necessary that *something* exists (or the question is ill-posed).	If one dismisses the question, one might ignore potential meaningful explanations. Some find this unsatisfying as it bypasses the wonder rather than answers it.	Not applicable (philosophical stance). If correct, we stop searching for a cause of existence. Possibly supported if all attempts to explain creation run into logical contradictions.
Krauss (2012) (popular book)	Cosmology (Popular)	Level A→C, D?	"A Universe from Nothing" – claims modern physics can explain why there is something.	Points to quantum vacuum energy, inflation, and quantum gravity as mechanisms for universe creation, essentially Level A vacuum as "nothing." Asserts no deity needed, physics suffice.	**Critique:** Redefines "nothing" as a quantum vacuum with laws; philosophers (e.g. Albert) note this isn't true nothing. Also, it piggybacks on unresolved ideas (inflation, multiverse) without new physics.	No new empirical test beyond those of inflation/QM. The impact was in public discourse, not in introducing testable hypotheses. (It did spark fruitful cross-discipline debate on definitions of nothing.)

Note: *Entries are roughly ordered by ladder level and date. "Level D→C" denotes proposals bridging absolute nothing to a pre-geometric state. Citations in proposal/mechanism refer to key supporting sources or direct quotes. See Bibliography for full references.*

Conceptual Map of "Nothingness" Levels

- **Nothingness Ladder (Increasing Depth of "Nothing"):**
  - **Level A – Quantum-Field Vacuum ("almost nothing"):** Spacetime *exists* (with its metric, dimensions, etc.), and quantum fields pervade it, but in their lowest-energy state. There are *no particles* on average, yet *fields fluctuate* constantly.
    - e.g. The vacuum of quantum field theory (QFT) with zero-point energy, virtual particles, and phenomena like the Casimir effect.
    - This "nothing" is dynamic: it has structure (fields obeying physical laws) and can produce particle-antiparticle pairs or even trigger cosmic inflation if metastable.
  - **Level B – Topological Nothing (empty spacetime):** Spacetime exists as a manifold (with possibly a geometry/metric), but *no fields or matter* reside in it. It is truly *empty space-time*.
    - e.g. A perfect classical vacuum solution of Einstein's equations – like Minkowski space (flat, empty) or a closed universe with no content.
    - *Topology/Geometry present:* There is distance and time, but nothing populating them. This level asks: could just empty spacetime itself be "nothing"? (It's still something mathematically.)
    - Consideration of different topologies: e.g. a universe shaped as an S^3 (3-sphere) with no matter. Topology change events (spacetime splitting or joining) flirt with removing spacetime regions entirely.
  - **Level C – Metageometric Void (pre-spacetime quantum void):** *No classical spacetime at all.* The "substrate" here is whatever quantum gravitational entities or law exists such that *spacetime can emerge from it*.
    - At this level, even distance and time are not fundamental. Instead, one has proposals like a wavefunction of the universe, an abstract "superspace" of all geometries, or discrete pre-spacetime building blocks (spin networks, causal sets, etc.).
    - Spacetime (and its geometry) is generated via *symmetry-breaking or phase transition* from a more symmetric or law-governed nothingness. The void is *metageometric* because it's "beyond geometry," yet not absolute nothing – it contains the potential or latent order that can become geometry.
    - **Examples:** The Hartle–Hawking no-boundary state (the universe "condenses" from no classical time) ; Vilenkin's tunneling from nothing (wavefunction defined even with no background space) ; Wheeler's superspace (quantum superposition of all possible spacetimes); loop quantum gravity's spin-foam or group field theory "atoms" of space (which in a high-symmetry state have no macroscopic dimension until a condensate forms) ; causal set theory's unordered set that only upon "order + number" yields geometry .
    - Key point: Level C "nothing" obeys *quantum gravitational laws* – so laws of physics exist here, but possibly in a more general or unified form. Classical spacetime and particles are emergent phenomena.
  - **Level D – Logical Nullity (absolutely nothing):** *No spacetime, no fields, no quantum foam, no laws of physics, not even abstract principles or mathematics.* Pure non-existence – if one can even imagine such a state.
    - This level is essentially the **philosophical absolute nothingness**. Not only is there no physical entity, but also *no framework* of laws or logic. If truly no logic exists, even the statement "nothing exists" is not well-defined – illustrating the conceptual pitfall.
    - If we try to discuss it in our terms: level D has *no constraints*, so one might speculate "anything can happen" since there's nothing to forbid it. But "anything" also might include "nothing happens." This is where some argue the concept is either incoherent or requires a meta-law to stir it into something.
    - **Law Activation:** One idea is that a set of physical laws or a "rule" could spontaneously activate or come into being, lifting the state from D to C. This resembles creation ex nihilo in theological or philosophical discourse, but in scientific-naturalistic terms, it's deeply unclear what mechanism could exist – since a mechanism *is itself a law*.

- Philosophers have proposed that maybe *all* logically possible realities exist (so absolute nothing is just one possibility among infinitely many that "exists" in a broader sense – effectively a measure-zero case) . Others say absolute nothingness can't be a stable default because absence of constraints *is* a constraint-free situation in which something (like a quantum fluctuation) inevitably occurs. And yet, these arguments often smuggle in laws or logic by the back door.
- Thus Level D remains a paradoxical idea: it's useful to frame "Why is there something?" but it might not be a state physics can handle directly. Many conclude that perhaps level D is either impossible or irrelevant – there must be *something* (even if just a principle of fecundity or a self-consistent logic) in the "beginning."

- **Transitions (D→C→B→A):** Each step *adds* structure: going up the ladder strips structure away. Conversely, coming down the ladder (from D to A) could be seen as a sequence: First, laws or principles crystallize out of utter nothing (D→C). Next, a quantum spacetime or pre-geometric foam "freezes" into a classical spacetime (C→B). Finally, fields and particles arise within that spacetime (B→A). Each transition is hypothesized in various ways by different theories, discussed below. The big open question is whether the top rung (Level D) is a meaningful starting point or whether the ladder effectively begins at Level C or higher.

Deep-Dive: Level C – The Metageometric Void (Pre-Geometry)

At Level C, **"nothingness" means no ordinary space or time**, yet there is a *framework from which spacetime can emerge*. This is the realm of quantum cosmology and theories of quantum gravity. Here we explore prominent ideas that attempt to describe or explain the emergence of the universe (and its geometry) from a state without classical spacetime:

Wavefunction of the Universe – Wheeler–DeWitt Equation: In canonical quantum gravity, one attempts to write a wavefunction Ψ that describes the entire universe. The Wheeler–DeWitt (WDW) equation (often $H\Psi = 0$) has no explicit time variable – reflecting that *before* spacetime becomes classical, time is not defined. This timeless Schrödinger-like equation operates in an abstract space of all possible geometries (so-called *superspace*). Solutions to the WDW equation need boundary conditions to pick the physically relevant "Ψ." Two famous proposals for these boundary conditions are: (1) **Hartle–Hawking No-Boundary** and (2) **Vilenkin's Tunneling**.

- **Hartle–Hawking No-Boundary Proposal:** James Hartle and Stephen Hawking proposed that the universe's wavefunction is given by a path integral over *compact Euclidean geometries*, effectively assuming the universe **has no initial temporal boundary** – it's like a smooth cap or "south pole" in 4D spacetime . In this picture, as one goes back in time, one doesn't hit a hard origin or singularity; instead, time transitions into a spatial dimension. The early universe can be thought of like a *closed 4D surface* (similar to a sphere) with no edge. The result is a specific wavefunction Ψ_{HH} that predicts a high likelihood for small, closed universes that can inflate. Essentially, "nothingness" is realized as a realm where ordinary time doesn't exist – the universe *"just is"* in a four-dimensional sense and then *quantum fluctuations* within that state catalyze an expansion. This idea elegantly removes the t=0 boundary (hence "no-boundary"), but it *assumes* the framework of general relativity and quantum mechanics to set up the problem . **Symmetry-breaking:** one can view the no-boundary initial state as highly symmetric (Euclidean with no time direction) and the "break" occurs when a Lorentzian (time-evolving) universe nucleates out, picking a direction for time.
- **Vilenkin's Tunneling Proposal:** Alexander Vilenkin argued for a different boundary condition: the wavefunction of the universe should include only *outgoing* (expanding) modes – the universe *tunnels from "nothing"* (a state of no size) into de Sitter expansion . In practical terms, one solves the WDW equation imposing that as the scale factor $a \to 0$, the wavefunction only describes a universe that is coming into existence (no incoming part). By analogy to quantum tunneling from a classically forbidden region, the universe was "nothing" (no classical space) and tunneled into being a finite size universe. This treats *"nothing" as a quantum state of zero size* (no

space at all), and uses a boundary condition $\Psi(a = 0) = 0$ (loosely speaking) and outgoing wave for $a > 0$. The outcome is often called the *tunneling wavefunction*. It tends to predict an initial period of inflation (de Sitter-like expansion) with a certain probability. Vilenkin's picture suggests that *a universe can spontaneously nucleate*, somewhat like a quantum particle appearing beyond a barrier, provided that it satisfies the conservation laws (often one cites that the total energy can be zero due to gravitational energy being negative, enabling this "free lunch"). However, as critics note, the "laws of quantum mechanics and gravity" are presupposed, so it's not a from-**absolute**-nothing scenario but from a **Level C** vacuum of no space but yes laws.

- **No-Boundary vs. Tunneling:** These two are often seen as competing (the "Hawking–Hartle" wavefunction vs. "Vilenkin" wavefunction). They give different predictions for cosmological parameters (e.g. how likely a small vs. large cosmological constant is, or how much inflation occurs). Both eliminate a *classical* t=0 singularity, but at the cost of defining "nothing" in a special way (either a smooth cap or an allowed-tunneling state). Empirically, it's hard to distinguish them, but for example, one might look at cosmic microwave background data for subtle signs of "unlikely" initial conditions that one proposal favors over the other.

No Classical Spacetime – Examples from Quantum Gravity: Beyond cosmological boundary conditions, several approaches to quantum gravity contend that at the most fundamental level, spacetime as we know it *does not exist*. Instead, some discrete or algebraic structure underlies it, which in a low-energy limit yields the continuum of Level B.

- **Loop Quantum Gravity & Spin Networks:** In LQG, space is fundamentally a network of quantized units (spin networks). At very small scales (near Planck length), space as a smooth manifold breaks down; what remains are graphs labeled by quantum numbers. Time evolution in LQG can be viewed as spin foams – a network history. If one takes a "no-space" limit, you'd have perhaps the trivial spin network (no links, no nodes) – a kind of empty graph, which might be a candidate for "nothing" at Level C. However, typically one considers *some* graph or the absence of any spin quanta. The "vacuum state" in LQG is not the vacuum of QFT in a background; it's literally no spin excitations – which corresponds to flat space if coarse-grained. So one could say LQG's base state is more like Level B (flat space) rather than Level C. To truly reach "no spacetime," one might consider the mathematical limit of the theory with no degrees of freedom excited – which again raises the question: is that really nothing, or a dormant something?
- **Group Field Theory (GFT) and Condensate Cosmology:** GFT is an approach where one defines a field theory in which the quanta are themselves chunks of space (for example, tetrahedra with certain geometrical data). A striking result in recent years is that GFT can produce condensate states that resemble a homogeneous universe. In GFT, *Fock vacuum* (no quanta) would correspond to "no space at all." A condensate of many quanta corresponds to a macroscopic space. The process by which a condensate forms can be viewed as a **phase transition**. In this context, "nothingness" (no spacetime) is like the vacuum of the GFT field, and "something" (classical spacetime) is like a Bose–Einstein condensate of space quanta. Analogy: think of a gas cooling into a liquid – above a critical point you have featureless symmetry (no preferred distances = no geometry), below it you have structure (an emergent spacetime). **Symmetry-breaking:** One concrete mechanism discussed is that the condensate may break the internal $U(1)$ symmetry that keeps number of particles conserved – analogous to how a laser or a superfluid has a phase. This broken symmetry selects a specific spacetime configuration out of the quantum gravity vacuum. The GFT phase transition is sometimes called *geometrogenesis* – the "birth of geometry" from pre-geometry. It might have occurred at the very start of the universe (e.g. the Big Bang could be a condensation event). Currently this is largely theoretical, but it provides a framework for how a law-governed pre-geometric Level C can *effloresce* into a Level B universe with classical geometry.

Illustration of a "quantum foam"–one visualization of a Level C vacuum where spacetime is quantum and highly fluctuating at the Planck scale. Tiny bubbles or granules (far smaller than subatomic particles) constantly pop in and out of existence, representing wild fluctuations of geometry . In some quantum gravity theories, this foam is the closest thing to "nothingness" that still obeys physical laws, and our smooth spacetime is an emergent average of this chaotic foundation.

- **Causal Sets:** Another vivid approach to Level C is causal set theory. It postulates that the fundamental structure is a set of discrete elements with only one relation: "precedes" (causality). If truly nothing existed, one might say a causal set with no elements is nothing – but causal set cosmologists actually consider that "new elements are born." In fact, there are dynamical models (Rideout and Sorkin's Classical Sequential Growth) where *the cosmos starts from nothing (the empty set) and grows element by element*. At the start, there are no spacetime points; then one "pops" into being (the first element), then another, etc., building up a partial order. Before the first element, that's as close to nothing as it gets in this theory. Interestingly, causal set theory claims that *just two attributes – the order of events and the number of events – can reproduce geometry* . The slogan "Order + Number = Geometry" means if you know which events came before which (the causal structure) and you know how many events are in a region (volume), you can reconstruct distances and curvature approximately. So here, the Level C substrate is an *order without metric*. Only when a large number of elements are accumulated does something like spacetime with volume emerge. The "latent order" in a causal set is a kind of hidden structure that is not a full spacetime but can become one. **Symmetry-breaking or choice**: one could say that early on, there is full Lorentz symmetry at small scales (causal order respects that) but no dimensions; as the number grows, an approximate dimension emerges (e.g. a causal set "manifests" 4D spacetime if the sprinkling of elements and order yields a structure approximating continuum M^4). Empirical hope: causal sets predicted a possible *fluctuation in the cosmological constant* due to underlying discreteness , and some authors claim this could be seen in the randomness of galaxy accelerations – but this is not confirmed. Nonetheless, causal sets offer a clear concept of a universe growing from literally no elements to many – a concrete D→C (empty set to non-empty set) and C→B (set to continuum) path, albeit governed by presumed "laws of growth."

- **Wheeler's Quantum Foam:** John A. Wheeler imagined spacetime at extremely small scales is like a foam: quantum uncertainties in energy can curve spacetime violently, spawning transient black holes, wormholes, and topology changes. In this picture, spacetime at 10^{-33} cm is not smooth; it's a froth of possible spacetime geometries connecting and disconnecting. If one "turns off" this foam, one might reach a truly empty spacetime (Level B). If one goes further and *removes spacetime entirely*, one lands in something like the superspace of all topologies – which might be seen as Level C. Wheeler's famous phrase "a law without law" ties here: perhaps at the foam level, things happen probabilistically with no fixed physical law – yet averaging over many fluctuations gives rise to stable effective laws at larger scales . In modern terms, one could think: maybe at the Planck scale, the distinction between existence and non-existence blurs – quantum foam contains every possible spacetime in virtual form. The actual universe could then nucleate from a particular fluctuation (like a foam bubble that grows). This is another take on "something from Level C nothing": the quantum foam vacuum itself is something, but it's so chaotic that in a sense no definite spacetime or law "exists" until a fluctuation dominates.

Symmetry Breaking Mechanisms & The Birth of Time: A recurring theme in Level C proposals is *symmetry*: often the "nothing" state is symmetric and the "something" state is a broken-symmetry phase. For example, *time* might be considered a "direction" that appears when a symmetry between space and time is broken (as in the no-boundary proposal where Euclidean rotation symmetry breaks to Lorentzian) . In GFT, a phase of no geometry is usually taken to be symmetric under large diffeomorphisms or quantum permutations, and the emergent geometry is a particular condensate that breaks that symmetry (selecting an arrow of time or a frame). The concept of *spontaneous symmetry breaking* in a physical vacuum (like a ferromagnet's spins aligning in one direction below T_c) is applied here to the "vacuum of no spacetime." Only, in ordinary physics we have a higher structure that breaks to a lower symmetry; here we have to break *from nothing to something*, which is tricky. Some theories approach it via *instability:* perhaps absolute symmetry (nothingness) is *unstable*, and the slightest fluctuation triggers a transition to a lower-symmetry state (the universe). This is analogous to an inverted pendulum – perfectly upright is symmetric but unstable. Similarly, one might say "nothingness will not stay nothing if it can become something." This idea is often *asserted* (e.g. "if there truly were nothing, it would be unstable, so something must appear" as an informal statement), but it lacks a rigorous physical law except in models where "nothing" is replaced by "a high-energy false vacuum" which is unstable (Coleman–DeLuccia false vacuum decay is a concrete example: a metastable vacuum decays to a true vacuum bubble – new universe – spontaneously , but note the metastable vacuum wasn't nothing, it was a pre-existing space with energy).

Empirical Tests for Level C: By definition, these scenarios involve energies and conditions at the Planck scale or the very beginning of the Big Bang, so direct tests are hard. However, each specific model can suggest proxies:

- No-boundary vs tunneling might influence the statistics of primordial density fluctuations (some work has been done to see if one gives a better fit to the observed cosmic microwave background, but so far both can be made to accommodate data by adjusting inflation models). For instance, no-boundary tends to favor small perturbations and perhaps a certain range of inflationary e-folds, whereas tunneling might give different probabilities for inflation. Upcoming refined measurements of cosmic parameters could marginally constrain these initial conditions.
- Group Field Theory or other quantum gravity approaches might leave an imprint if there was a pre-geometric phase transition (geometrogenesis) at the start. Perhaps a brief non-geometric epoch could show up as a "signature change" in spacetime (for example, some models predict that time could behave quantumly, affecting how primordial gravitational waves propagate). Experiments like advanced gravitational wave detectors or 21-cm cosmology might, in the far future, constrain exotic initial states.
- Causal set theory suggests a slight "poisson noise" in cosmological expansion or even a distinctive stochastic variation in decay rates (one proposed test was looking for a fluctuation in the cosmological constant at different times, as a random walk). Nothing conclusive yet, but as observations of the expansion history improve, one might detect anomalies that hint if spacetime atoms are at work.

In summary, **Level C is where physics actively grapples with "nothing"**. It provides a rich playground for theories uniting quantum mechanics and gravity. Each approach – be it WDW cosmology, GFT, causal sets, etc. – offers a mechanism for moving from a law-governed "void" to a universe. While none are empirically confirmed at this point, they illustrate that in physics, one often answers "How do we get something from nothing?" by replacing *"nothing" with a new something* at a deeper level (quantum law, pre-space, etc.). That deeper something can then undergo a transformation (tunneling, symmetry-breaking, etc.) to become the familiar universe.

Deep-Dive: Level D – The Ultimate Nothing (Logical Nullity and the Origin of Laws)

Level D is a qualitatively different challenge. Here we ask: could there have been *absolutely nothing* – not even the potential for quantum fluctuations or any laws of physics – and if so, how could reality spring forth from that? This enters the domains of metaphysics, foundational philosophy, and speculative cosmology. We focus on key themes: the **philosophical coherence** of absolute nothingness, ideas of **law-activation** (where laws or rules might "start" existence), and radical proposals like **modal realism** and **Max Tegmark's Level IV multiverse**, which, in their own ways, attempt to explain why some structure exists (often by suggesting *all* structures exist). We also touch on the **principle of fecundity** and **meta-law questions** about whether "laws of physics" themselves require explanation or higher-order laws.

Can Absolute Nothingness Be Stable or Coherent? Many thinkers have argued that a state of true nothingness (no laws, no space, no time, truly nothing) might be either inherently unstable or even logically impossible:

- *Inherent Instability:* This is a quasi-physical argument: If absolutely nothing existed, there would be nothing "enforcing" the persistence of nothingness – no conservation laws, no logic to prevent a spontaneous fluctuation. Thus, the argument goes, *nothingness would immediately give way to somethingness*, because "anything can happen" in the absence of laws. A colloquial version appears in some science writing: e.g. "quantum nothing is unstable – particles will appear." Physicist Frank Wilczek has famously said "The reason there is Something rather than Nothing is that Nothing is unstable." However, one must be cautious: such statements usually smuggle in quantum physics or principles like Heisenberg uncertainty (which are laws). If one truly had no laws, even the concept of "unstable" vs "stable" might not exist. Nevertheless, if we assume logic still holds, one could say nothingness has no preferred state, so the *entropy of nothingness is ill-defined* and it might spontaneously produce all possibilities. This blends into the next idea – fecundity of possibilities.
- *Logical Impossibility of Nothingness:* Some philosophers (going back to Parmenides) have claimed that "nothing can come from nothing" and even that "nothingness" cannot exist as an ontological state, because to even

speak of it is to give it a sort of being. More modernly, Adolf Grünbaum called the obsession with why anything exists a kind of *ontopathology* – implying that "nothingness" is not a reasonable default state or even a well-defined scenario . If true nothing were self-contradictory, then the existence of something is not surprising (because "nothing" was never actually possible to begin with). This is a bit of a philosophical escape hatch: it says our question might be ill-posed. It doesn't tell us *which* something or *why this something*, but it removes the alternative (nothing) as illegitimate. While appealing logically, it can feel unsatisfactory emotionally – one might respond "Even if nothingness is impossible, *why* is it impossible? Is that a brute fact or rooted in some deeper principle?"

Why These Laws? (Meta-Law and Law Activation): Assuming we accept that something exists, we can still ask: why these particular *laws* and constants rather than others, or no laws at all? If we climb down from level D to C, we're injecting the existence of some law-like structure. Several perspectives:

- *The Meta-Law Problem:* In multiverse scenarios, physicists often imagine many possible universes with different laws or constants. But as George Ellis and others highlight, to even talk about a *collection of universes with varying laws*, you need some overarching framework – a "meta-law" – that says how those universes are generated or related . For instance, in eternal inflation (a Level B or C scenario), we might get pocket universes with different low-energy physics, but they all follow the higher-level laws of inflation theory. If one tries to push the question up: "Why that inflation law? Could it have been different?," you might invoke an even higher theory (string theory landscape? then why string theory's form?). This can lead to an infinite regress of "laws selecting laws." Some have speculated there might be a **final meta-law** that says "All possibilities occur" (which is essentially the Principle of Fecundity or modal realism — discussed soon). Others propose a meta-law of evolution: Lee Smolin's **Cosmological Natural Selection** posits universes give birth to new universes with slightly mutated parameters (via black holes), which acts like a Darwinian selection for universes good at making black holes. That moves the "why these laws" question into an evolutionary context (laws good at reproduction become common). But then one asks: why that meta-law of reproduction? We see the pattern: any *specific* meta-law invites another "why." Some have suggested the regress might end if the meta-law is something like "nothing is prohibited" (i.e., everything happens – which is fecundity again) or if the meta-law is self-consistent in some circular way (Wheeler's "participatory universe" idea, where laws are established retroactively by observers – a wild idea that the act of existence gives reality to the laws that made existence possible).
- *Law Without Law (Wheeler's idea):* John Wheeler entertained that maybe at the deepest level, the universe is a game without fixed rules – law emerges from chaos through some kind of democratic self-selection (the universe "trying out" all possibilities in a quantum foam, and the consistent results become our stable laws) . This is more an analogy than a formal theory. It connects with the idea of a *sum over all possible laws* – perhaps the only law is that there is no law until one observes (a bit like quantum mechanically, no definite outcome until measurement). But critics note this is not a concrete mechanism; it's almost mystical (one might say it's akin to saying "God plays dice and the dice outcomes crystallize physics"). Still, "law without law" is a profound suggestion that the distinction between something and nothing might be transcended: the rules of the universe are not given, they're like results of a quantum question.
- *Principle of Fecundity (All Possibilities Realized):* Philosopher Robert Nozick put forward that perhaps **all logically possible worlds exist** . This is an answer to "why this and not nothing?" by saying "Nothing *and* everything else exist in some grand plurality; we just find ourselves in a particular branch." If *every* possible universe exists, then the state of "nothing" can be thought of as just one possibility (the one with no objects, no laws) – but importantly, if all possibilities are real, then *something exists in general by necessity*. Nozick admitted this idea is "the most bloated of all ontologies" (since it means a reality containing uncountable universes), but he found it appealing because it eliminates arbitrariness – *no fact is unexplained because every configuration obtains somewhere*. One might say it denies "special status to the actual world" and hence to the idea of "nothing" as a privileged default . It's almost like a meta-law: "All that can happen, does (in some world)." However, it faces a logical self-reference issue: if all possible worlds exist, does that include worlds where not all possible worlds exist? (Nozick argued his principle *includes itself*, sort of bootstrapping existence: if such a fecund principle is possible, it ensures its own reality .) Additionally, this principle is unfalsifiable and many find it extravagant. But note how it transforms "nothing": a true Nothing-world (with no laws, no objects)

would be just one of the ensemble – but if *all* worlds exist, the measure of having absolutely nothing anywhere is zero; effectively, somethingness is guaranteed somewhere.

- *Modal Realism (David Lewis):* This is closely related but philosophically more rigorous in some respects. Lewis's modal realism claims all possible worlds are just as real as ours – they exist in a plurality, but causally separate . The difference from Nozick is Lewis didn't necessarily argue this explains why something exists; he was solving philosophical problems of modality. However, by Lewis's view, a "nothing" world (one that's completely empty) is just one possible world – but since possible worlds aren't spatiotemporally connected, "nothingness" wouldn't be a global state, it'd be one element of the modal set. For Lewis, there's no need for a common origin or law; each world just is. So the question "why is there something rather than nothing?" might in modal realism be answered: "There isn't just something – *everything* exists in some world." We just happen to inhabit a non-empty world (obviously, or we wouldn't be here to wonder). This doesn't address why our particular world has the laws it does (that becomes an anthropic or indexical selection: we observe these laws because only a world with consistent observers permits us).
- *Tegmark's Level IV Multiverse (Mathematical Universe Hypothesis):* This is a specific version of "all structures exist." Tegmark proposes that every mathematical structure corresponds to a physical existence . In other words, the ultimate ensemble is the set of all mathematical objects (which includes, presumably, every consistent set of physical laws and even possibly no laws if that can be framed mathematically). Under this view, there is no "empty nothing" because even the notion of "no structure" might not be a valid mathematical structure (the null set is a structure of sorts, but if it has no properties, maybe it's just the zero in the ensemble). Tegmark's idea gives a kind of meta-law: the rule is "Existence = Mathematics." So the reason something exists is that mathematical truths exist (in a Platonic sense) and are instantiated as universes . The strength is it's very clear and all-encompassing; the weakness is it's untestable and one can argue whether it's even meaningful to say, for example, the group of permutations of five elements "exists physically" somewhere. Critics like Piet Hut have also pointed out that not all mathematical structures may be mutually compatible with each other, and issues like Gödel's incompleteness might complicate the idea of "all math exists" . But in spirit, Tegmark IV is similar to principle of fecundity, but focusing on mathematical consistency as the criterion for existence. In Tegmark's scenario, absolute nothingness (no mathematics) is not even an option – as long as 1+1=2 is true, that structure exists as a universe (albeit a very boring one). So again, something exists by necessity.
- *The Role of Logic and Mathematics:* If one imagines level D, one might ask: does logic still hold? Does $2 + 2 = 4$ remain true in absolute nothing? Some have conceptualized "nothing" as including even the absence of abstract objects. Others argue that logical truths are not contingent – they would hold no matter what. If logic is truly absent, we can't reason about the scenario at all. If logic and math *do* have some kind of transcendent truth, then level D perhaps isn't completely empty – it contains Platonic truths. Philosophers like Plato or Augustine might say God is the truth/logic that necessarily exists and from which the contingent world springs – a theological take on law-activation (God as meta-law or meta-being that ensures nothingness isn't stable). Modern secular variants might personify math or logic as that necessary being. For example, *Could the number 0 (zero) by existing conceptually give rise to the universe?* This sounds fanciful, but some mathematical cosmologists muse on things like "the universe is mathematical, so it had to exist." If one is not satisfied with that, one is left with saying "There just is no reason, it just is" – which is essentially stopping at a brute fact.

Law-Activation Scenarios: Let's outline a hypothetical sequence from D to C: You have absolute nothing (no laws). *If* it were possible for "something" to happen (a big if, since we have no rules), one could imagine the *simplest* something happening – perhaps the coming into being of a simple law or rule. This could be seen as the universe "bootstrapping" itself. For example, one speculative idea: the principle of *self-consistency* might act as a selection rule – among all logically possible realities, only those that are self-consistent can "exist" (because an inconsistent reality would sort of cancel itself out). The law of non-contradiction might be the first to "activate," because without it nothing definable can proceed. Once logic is in place, mathematics can exist; once math exists, maybe mathematical structures with physics laws exist (Tegmark style). This is a highly philosophical narrative, not a scientific theory. It's basically trying to climb the ladder from D upward:

1. Nothing (inconceivable)
2. Something like the law of non-contradiction emerges (otherwise nothing can even be said or happen)

3. Then maybe basic mathematical truths hold
4. Then maybe all math exists physically (Tegmark)
5. Then among those, complex structures like universes with space and fields appear (C)
6. One of those universes is ours with particular laws (B then A).

At each step the question "Why this step?" can be asked, but one might hope each step is somehow inevitable or necessary. This shades into metaphysical arguments that in the "absence of anything," the only outcome that doesn't immediately contradict itself is the existence of all possible self-consistent outcomes (this resonates with Nozick's principle: if nothing restricts, everything happens).

Another angle: **philosophical theology –** Historically, the question of why there is something rather than nothing has been tied to the existence of God. One answer is "because God (a necessary being) exists and creates contingent things." In that frame, God is a meta-law or meta-entity that is outside the nothing/something dichotomy. Modern scientific discourse usually brackets out theological answers, but for completeness: some argue God's nature is to exist (cannot not exist) and that explains why there is at least God, and God chose to create something beyond himself, thereby avoiding nothingness. If one doesn't invoke God, one is left with either an impersonal necessary principle (like math, as Tegmark does) or just accepting that at least one thing must exist necessarily (the *Principle of Sufficient Reason* in philosophy states that everything has a reason – for existence of the universe, some ultimate reason or necessary thing must exist; rationalists like Leibniz advanced this to conclude a necessary being must exist, which he identified as God or fundamental monads, etc.).

Modal Realism and Fecundity – Universe as Everything: If indeed every possible world exists, then *our* observable universe is just a tiny piece of an all-encompassing reality. In that case, asking "why is there something rather than nothing?" might be akin to asking "why is there the set of all sets rather than the empty set?" The answer could be: the empty set is just one subset of the set-of-all, and indeed the empty set by itself can't be the whole because the set-of-all includes it plus more. In a modal/fecund sense, nothingness is subsumed by everythingness. Interestingly, some have pointed out a symmetry: "nothing" is a very simple, symmetric state (no information), whereas "everything" (all possibilities) is, in a sense, also a symmetric state because it has maximal entropy/information – it doesn't pick out any particular thing, it has them all. That is symmetric in the sense of not favoring any one outcome. So one could imagine the ultimate symmetry (having no preference) leads to *all* possibilities being realized. In that sense, level D (no selection) "leads to" a state where everything exists, which ironically is a form of level D-> existence of all. This is speculative and poetic, but it attempts to reconcile absolute indifference (nothingness) with absolute plenitude (everythingness) – both share the quality of "no distinction." Leibniz considered something like this: which is more natural, that nothing exists or that everything possible exists? He leaned that nothing would be simpler, but maybe a principle of maximal existence could be at work (Leibniz ultimately chose a God-based explanation though – God chose the "best" world).

Principle of Sufficient Reason (PSR): This principle (associated with Leibniz and Spinoza) states that for everything, there is a reason or explanation. If one holds PSR strictly, there cannot be a brute fact. So why does the universe exist? Under PSR, it must have an explanation. If one tries to avoid an infinite regress of explanations, one ends with a necessary entity that explains itself. In theology that's God; in a secular context one might say the multiverse or the law "all possible things exist" might be self-explanatory in that it can't be otherwise. However, PSR is not empirically proven and many philosophers suspect it might be too strong (quantum events, for example, might have no reason except a probabilistic law).

Is "Nothing" Even a State That Could Exist? To drive home the difficulty, consider: a physical state is usually defined within a theory (like "the vacuum state" of a quantum field is defined relative to the field and spacetime). "Absolute nothing" isn't a state in any standard theory – you can't write down an equation and set all fields to zero and all space gone, because your equation itself presupposes structure. This suggests that to talk about nothing meaningfully, you might need a new kind of theory that has "lack of itself" as a solution. Some theoretical cosmologists have attempted to formalize "nothing" as a limiting case (for instance, try to treat $a = 0$ spacetime as a boundary). But ultimately, we might conclude that Level D is *not a scientific question per se*, but a meta-scientific or philosophical one. Any attempt to answer it scientifically will likely end up introducing some sort of existent structure (like a quantum vacuum or multiverse) that is actually Level C or above.

Tegmark vs. Multiverse vs. Philosophical Nothing: Max Tegmark's approach (all math exists) is an interesting hybrid of physics and philosophy. It effectively says: the answer to Level D is that Level D is empty of *contingent* things, but full of *necessary* things (mathematical truths). Those necessary truths manifest as universes. So the "activation" of laws is not random; it's just the way logical existence works. One might ask, why mathematics? Why not "nothing"? Tegmark could answer: the concept of nothing is not a mathematical structure with enough richness to be the total reality (since the absence of structure isn't a structure). It's akin to saying zero cannot be the entirety of mathematics – you inevitably also have the concept of one, two, etc., once you allow any logic. If one accepts a Platonist view, the mathematical realm just exists; in that sense, we've snuck a necessary being (the platonic realm) into our ontology.

Fecundity and Theology of Nothing: It's noteworthy that some of these modern ideas echo old philosophical/religious ideas. The principle "all possible worlds exist" resembles the idea of a "plenitude" that some medieval philosophers discussed (sometimes in context of God's creativity or the principle that a perfect being would create every good thing). The idea that nothingness is unstable or impossible resonates with arguments by certain philosophers that God's existence is necessary (so there was never the option of nothing). Of course, in a strict scientific sense, these aren't testable. They serve to broaden our conceptual horizons on the question.

In sum, Level D tends to push us beyond physics into metaphysics. The key perspectives we identified are:

- *Absolute nothing might not actually be a possible state; something must exist.*
- *If absolute nothing were possible, there's no clear "cause" to go from it to something – any cause or rule would violate the nothingness.* Some speculative solutions:
  - Perhaps all possible causes happen and thus all effects (fecundity).
  - Or a reflexive rule (the principle that all possibilities exist includes the possibility itself, bootstrapping reality).
  - Or the invocation of a necessary entity or principle (be it God, math, or logic).
- *Modal and multiverse ideas diminish the sting of "why not nothing" by saying our universe is just one point in a larger ensemble that might be necessary or the only logically possible totality.*
- *We should consider that maybe the question "Why is there something rather than nothing?" presupposes "nothing" as a meaningful alternative. If it's not actually a coherent alternative, the fact that there is something is just a given – it couldn't be otherwise.*

From a practical standpoint, cosmologists often stop at Level C (quantum vacuum or quantum gravity) and some will say, "That's as close to nothing as physics can get. Beyond that, you're asking a question for which science may have no answer." Others, however, are bold and try to incorporate level D thinking into speculation, as we have seen with Hawking's statements or Tegmark's hypothesis. As of now, **Level D remains a frontier of thought rather than testable physics**. It's where cosmology, philosophy, and even theology intersect. We don't have a final answer, but exploring these ideas clarifies the range: from physical mechanism (like tunneling) which still needs a law, to the radical idea that maybe *all* laws exist (so we don't need to explain selection), to the possibility that the question itself is ill-posed.

In conclusion, grappling with Level D deepens our appreciation of the mystery – it may be that the reason for existence lies outside the scope of scientific inquiry and in the realm of logical necessity or brute fact. Or, equivalently, the answer might be that *the question dissolves* when we realize that "nothing" was never a feasible option.

Concise Snapshots of Levels A and B

Level B – "Empty Spacetime" (Classical General Relativity Vacuum & Topology): Level B nothingness is conceptually simpler than C or D: it's a universe with *no matter or energy content at all*, only the fabric of spacetime. According to General Relativity, such vacua are valid solutions of Einstein's field equations ($T_{\mu\nu} = 0$). The trivial example is *flat Minkowski space*, which is completely empty and static. There are also non-trivial vacuum solutions like *gravitational wave spacetimes* (ripples propagating with no sources) or *Black hole* solutions (which are vacuum outside the singularity). However, black holes complicate the picture by having a singular mass point or region (not exactly "nothing" inside, just unknown physics).

Key points:

- In a vacuum solution, the Einstein tensor $G_{\mu\nu} = 0$ everywhere, meaning spacetime is either flat or curved only by its own global structure (e.g., a closed universe with no matter can still have curvature, like an S^3 shape, due to boundary conditions).
- One could imagine an "empty FRW universe" – for instance, a Milne universe (which is actually flat Minkowski space in an expanding coordinate disguise) or de Sitter space (which is a solution with only a cosmological constant, arguably "vacuum energy" which might bump it to A instead). Pure de Sitter is sometimes counted as a vacuum (just a cosmological constant present, no matter fields).
- **Topology change**: In classical GR, topology is fixed (by strong energy conditions typically). But in quantum gravity (bridging toward C), one can consider the spacetime topology changing via quantum tunneling – e.g., a universe could spontaneously nucleate as a tiny S^3 from "nothing" (a no-space state or a different topology). Stephen Hawking in the '80s studied such topology changes and wormholes ("spacetime foam"). If we restrict to classical level B: topology is considered given. An empty spacetime could have various topologies (torus, sphere, etc.), but no field to probe it.

So Level B snapshot: *It's the stage setting without actors*. You have the theatre of space and the flow of time, but absolutely no matter or fields present. **Empirical handle:** Truly empty space is hard to come by – even intergalactic space has stray particles and fields. But we effectively have tested the idea of vacuum spacetime with the observation of gravitational waves propagating in regions far from sources (showing that the vacuum spacetime can carry radiation). Also, the classic tests of GR (like light bending) often consider vacuum solutions around masses. If we ever observed a large region of space devoid of matter (aside from dark energy perhaps), it would basically follow the metric of a vacuum solution.

In terms of "nothingness," Level B underscores that even when you remove all *contents*, spacetime itself remains a something – a dynamic entity in GR, able to expand or contract. For example, an empty closed universe can still expand, then recollapse due to its own spatial curvature (often called the "empty $k = +1$ universe"). It has no matter, but it isn't *nothing* in the philosophical sense – it's a whole manifold with geometry.

Level A – "Quantum Vacuum" (Fluctuating Fields in Space): Level A is often what physicists mean colloquially by "nothing": empty space filled with no particles. However, thanks to quantum field theory, we know this vacuum is not a trivial nothing; it's the ground state of quantum fields, which means it's a busy, though zero-average, state:

- **Quantum fluctuations:** Even in vacuum, fields have zero-point energy – they jitter due to the uncertainty principle. For example, the electromagnetic field in vacuum will have fluctuating electric and magnetic fields that momentarily aren't zero. These can be thought of as "virtual particles" flickering in and out of existence .
- **Casimir effect:** A famous demonstration: put two uncharged metal plates close together – certain field modes can't exist between them, leading to a small pressure pushing them together. This physical force is explained by vacuum fluctuations of the EM field being altered by the boundaries . It's essentially something coming from (almost) nothing – the vacuum energy difference creates a force .
- **Vacuum energy and cosmology:** In cosmology, the quantum vacuum has crucial roles: (1) Inflation – a period when vacuum energy (a high-density temporary state) dominated, causing exponential expansion. That vacuum then decayed into matter (reheating). (2) Today's dark energy (cosmological constant) behaves like a vacuum energy of ~ 10^{-120} Planck units, driving acceleration . There's a huge puzzle: naive QFT predicts vacuum energy much larger than observed (the "cosmological constant problem" – why the vacuum energy doesn't gravitate as

strongly as sum of zero-point energies suggests). So ironically, level A “nothing” might hold the key to the largest outstanding discrepancy in physics: a very large vacuum energy vs. a small observed Lambda .

- **False vacuum decay:** A metastable vacuum is a vacuum state that isn’t the true lowest energy. Our universe might be in such a state if, for example, the Higgs field has another lower minimum. Quantum tunneling could then trigger a “bubble of true vacuum” that expands at nearly the speed of light, converting our space to a new state (destroying all as we know it). This is a Level A to A transition (a vacuum to a different vacuum). But in early universe context, a “bubble of lower energy vacuum” nucleating could be how the big bang started in some models . If *no* prior space existed, such bubble nucleation is basically the Level C tunneling scenario. But one can also imagine it in an existing spacetime: one tiny region tunnels to a true vacuum and then expands.
- **Unruh effect & vacuum temperature:** If you accelerate through a quantum vacuum, it doesn’t look empty – you’ll observe a thermal bath of particles. This is another astonishing property: vacuum is observer-dependent. An accelerating observer or a observer in a curved spacetime (like near a black hole horizon, where it’s the Hawking effect) will detect particles in what inertial observers call vacuum. So, emptiness isn’t absolute – it pairs with observer state.

Concise summary: *The quantum vacuum is a hive of activity.* It’s “nothing” only in that no real particles are present. But it has energy and can spawn particles given a trigger (e.g. put in a boundary or accelerate an observer).

Casimir and Lamb Shift: These experimental results confirmed that the vacuum’s fluctuations have measurable consequences . In the Lamb shift, shifts in atomic energy levels partly come from the electron interacting with vacuum fluctuations of the EM field. In the Casimir effect, the vacuum fluctuation modes being restricted causes a force. These confirm Level A vacuum is not an idle void, but a real physical entity.

Vacuum Instability and Universe Origin: The idea of “Universe from a vacuum fluctuation” (Tryon 1973) is a classic Level A origin story . Tryon suggested that the universe’s positive energy (mass) and negative energy (gravity) might cancel out, so the total energy is zero – such that it could arise from nothing as a quantum fluctuation and satisfy conservation (like borrowing energy ΔE for time Δt). Our universe could be a vacuum fluctuation that didn’t collapse because cosmic inflation rapidly enlarged it, and global energy can remain zero . This is more a sketch than a rigorous theory, but it inspired thinking: if physics allows spacetime itself to fluctuate, then “nothing” at Level A (the vacuum state of fields in some background) could spontaneously produce a baby universe. Generally, quantum cosmology (Level C) was needed to flesh this out, but the seed of that idea is visible at Level A: *vacuum fluctuations are always happening; one of them might be big enough to be a universe*.

In everyday terms: if you suck everything out of a box to create a vacuum, you’ll still have a roiling soup of virtual particles popping in and out, and if you wait long enough, something surprising (though usually very tiny) can emerge. For the whole universe, the “box” is the universe itself. At Level A, we assume spacetime is there and governed by quantum field laws. Under those rules, it’s actually hard to have truly nothing! Even empty space has a baseline “buzz.”

False Vacuum Decay (early universe): If our universe began in a high-energy vacuum (false vacuum), a quantum “nothing” in terms of particles, the decay of that vacuum (a quantum tunneling event) would release energy to create all the matter. This is essentially the inflationary Big Bang model: inflation is driven by vacuum energy; when inflation ends (the vacuum decays), that energy converts to particles (reheating). One dramatic picture by Coleman-DeLuccia: a small bubble of lower-energy vacuum appears via tunneling , then expands at nearly light speed – that bubble wall is essentially the Big Bang for everything inside it. In our observable universe, we’d see homogeneous space originating from that bubble interior. This scenario blurs Level A and C: the bubble nucleation can be seen as a quantum cosmology event (Level C tunneling), but described using a semi-classical field (the vacuum field) in a background metastable vacuum (so a sort of Level A context). Empirical handle: If false vacuum decay happened in early universe, perhaps gravitational waves or specific patterns in matter distribution could hint at it (none identified yet uniquely).

To summarize Level A: It’s the “emptiest” physical vacuum known in science, but it’s far from nothing. It’s an engine that can create force (Casimir), create particles (Hawking/Unruh effects), and might even create whole universes given some quantum gravity allowance. It underscores a theme: *in physics, nothingness is generally an active state, not a* *dead void.* As he put succinctly in one review, *"The vacuum is boiling with fluctuations"*, and experiments confirm those effects . Level A thus is a fertile "nothingness" – which is why some like Lawrence Krauss equated it (controversially) with philosophical nothing in popular discussions. But critics like David Albert retorted: calling the quantum vacuum 'nothing' is like calling a bubbling stage of beer 'empty' – it's actually a rich brew.

So, Level A is well within the realm of experimental science, and we understand a lot about it (QED vacuum, etc.), yet it still contains deep mysteries (vacuum energy's value). It's arguably the easiest rung to study, but already it defies an intuitive notion of nothingness.

Open Problems & Research Frontiers (Transitions D→C→B→A)

The ladder of nothingness also represents a ladder of deepening puzzles. The transitions between levels highlight our incomplete understanding:

From Level D to Level C (Absolute Nothing to Quantum Law): This is the leap from no laws to some law. Open problems:

- *What mechanism could "activate" laws or bring about a lawful state from lawlessness?* This verges on the creation ex nihilo problem. In physics terms, one might ask: is there a quantum gravity state that corresponds to "no spacetime, no fields"? Some approaches like causal sets literally start with an empty set and introduce a growth dynamics (but that dynamic is assumed – where did it come from?). In string theory or holography, is there a notion of a "nothing" state? (So far, string theory requires a background of sorts or at least a meta-law framework like the string landscape, which is more Level C to B transitions).
- *Is there a principle of "minimum structure" or "ultimate symmetry" that could spontaneously break to yield physical laws?* Some speculative ideas propose that maybe the symmetry of absolutely nothing (which has no distinctions) could break. But one needs a container for symmetry-breaking – in group theory terms, the trivial group has no smaller group to break into, so how do you break "no symmetry" or "all symmetry"? This is a conceptual roadblock.
- Some researchers (like in quantum information context) wonder if maybe *information itself* is fundamental, and that a blank slate of zero information might spontaneously produce paired bits (like from nothing, a bit and its complement could arise conserving some zero-sum). This is analogous to +1 and -1 summing to 0. Could the universe be the ultimate zero-sum game, where positive and negative aspects (energy, charge, etc.) net to zero and thereby allow existence ex nihilo? The total energy being zero is one aspect , but what about total everything (like all conserved quantities summing to zero)? This remains an open line of thought – for example, some cosmologists look at whether the universe has zero net charge, zero net momentum, zero net angular momentum, etc., which if so, would make it *entirely* a vacuum fluctuation in some extended sense. Currently, we know energy (including gravity) might net zero, charge in the universe seems zero (no observed overall charge), momentum and angular momentum of the universe are tricky (with no outside reference, we set them to zero by symmetry usually).
- *Cosmological Initial Conditions:* If we did manage to formulate a "creation from nothing" as a well-posed physical hypothesis, what observable signature would it have? For instance, Vilenkin's tunneling proposal implies certain probability distributions for initial states that might differ from Hartle-Hawking. These are subtle to test but ongoing: e.g., does the universe likely start small (yes, both predict that) but what about the expected amount of inflation? Are large fluctuations suppressed or not?
- *Philosophical & Logical Work:* On the philosophy side, a frontier question is: can we make sense of a "world with no laws"? Some have tried logical frameworks where laws are emergent or where you consider the null world as a limit case. Formal modal logic can talk about a "null world" (a world with no objects), but even that

assumes logical consistency holds. Could there be a logic-less void? Hard to even define since definition requires logic. So philosophers often refine the question to "why are there any contingent beings/laws at all, instead of none" and accept that logical truths would exist by necessity. Then the focus is on contingent existence. That's one way to bypass a total nullity (since at least logic is fixed).

- At the boundary of physics and philosophy, some like **Jan Ambjørn** and colleagues working on *Causal Dynamical Triangulations (CDT)* have found that if you naively sum over all possible geometries (like trying a "no law, just sum everything" approach), you often get nonsensical results (e.g., unphysical "crumpled" space). Only when you impose some guiding principle (like causality in CDT) do you get a sensible spacetime emergent (3+1D universe). This indicates that not every "nothing-goes" leads to something meaningful; some selection principle at level C is needed. So one frontier is to figure out minimal selection principles that can still be called "nothing" (or at least "lawless") but yield viable physics.

From Level C to Level B (Quantum Pre-geometry to Classical Spacetime): Assuming some quantum gravity exists (strings, loops, causal sets, etc.), how exactly does a definite classical spacetime with 3+1 dimensions, a smooth geometry, and a specific topology emerge? This is a pressing research question:

- *Decoherence of Geometry:* Just as quantum objects decohere to classical outcomes (a measurement problem), perhaps the wavefunction of spacetime decoheres into a specific classical history. The Wheeler–DeWitt equation allows a superposition of geometries; why do we observe one classical spacetime? Some work tries to apply decoherence theory to gravity – interactions with long-wavelength fields might cause the wavefunction to "collapse" into a branch where spacetime looks classical. This is speculative, but necessary to explain why we don't see macroscopic superpositions of, say, different spatial curvatures.
- *Dimensionality:* Many quantum gravity approaches could, in principle, yield spacetimes of various dimensions. Why 3 space and 1 time? Some approaches (like causal sets or causal dynamical triangulations) actually can output the result that 4D is favored – in CDT, the emergent large-scale geometry after summing over microscopic ones peaked around 4 dimensions. In casual sets, just imposing Lorentzian structure kind of already assumes 4D (or whatever D, you put that in by the sprinkling algorithm). But the question remains: are there deeper reasons? Some hypothesize that only 4D universes allow stable structures (too high D and gravity or nuclear forces behave differently, too low D and you can't have complex enough interactions). So anthropic reasoning lurks here as well.
- *Phase Transitions & Criticality:* The "geometrogenesis" idea suggests the early universe might have been in a phase analogous to a liquid condensing. If so, there might be *critical phenomena*: scale-invariant fluctuations that could leave an imprint (like critical opalescence in a fluid – large fluctuations at all scales). Some cosmologists have searched whether initial perturbations of the universe carry a signature of criticality (e.g., non-gaussian correlations or a specific spectrum). So far, the initial fluctuations look simple (near scale-invariant Gaussian), which is what inflation also predicts. But it could be that inflation itself was the phase transition.
- *Topological issues:* How did the topology of space get selected? Quantum gravity might allow changes of topology – e.g., baby universes branching off. Did our universe start as S^3 (closed) or infinite or some other topology? Could there be quantum superpositions of topologies? This is an open issue. Hawking's wormhole papers (late 80s) dealt with summing over topologies and concluded maybe the cosmological constant is pushed to zero by such sums (not really borne out, since Lambda is not zero but small positive). Newer work in holography sometimes entertains multiple topologies (the AdS/CFT correspondence allows some summed topologies as different saddle points). Understanding if the universe's topology is fixed by initial quantum conditions or could be experimentally probed (e.g., cosmic topology searches) is ongoing. We have constraints from cosmic microwave background that if space is a weird topology (like a torus or something), it must be bigger than the observable universe scale – otherwise we'd see matching circles or patterns. So far looks simply connected and large.
- *Relating micro to macro:* In approaches like LQG, one can compute the spectra of geometric quantities (like area, volume are quantized). But deriving smooth Einstein equations from a coherent state of spin networks is difficult. There's progress in showing that certain semiclassical states lead to classical equations with corrections. The frontier is to demonstrate robustly that as many degrees of freedom entangle (like many spins

in a weave state), the excitation averages behave like a smooth metric obeying Einstein's field equations plus small corrections. This is analogous to deriving continuum elasticity from atomic lattice dynamics. Not trivial, but being tackled.
- *Observation of quantum spacetime:* Perhaps the C→B transition might be testable if subtle quantum properties of spacetime at small scales leave traces. For instance, some quantum gravity theories predict a slight dispersion of light in vacuum (vacuum behaving like a medium with tiny refractive index dependence on energy). High-energy astrophysical events (gamma ray bursts) have been examined to see if high-energy photons lag low-energy ones over cosmological distances (would indicate a tiny violation of special relativity from quantum grain of space). So far, no conclusive detection, putting strong bounds on such effects (Planck-scale suppressed dispersions are extremely tiny, and current observations say if they exist, the suppression is even tinier than 1/Planck). Another avenue: looking for holographic noise in interferometers (some models by Hogan, etc., where spacetime coordinates cannot be known perfectly, causing an observable noise in LIGO-like instruments). Again, no confirmed signal, but pushing the boundary of sensitivity.

From Level B to Level A (Empty Space to Particle-Filled Vacuum): Once we have a classical spacetime (level B), how do fields and particles come to populate it if initially there were none? Open problems or considerations:

- *Cosmological particle production:* Even if we start with no particles (all fields in vacuum state) in an expanding spacetime, the changing geometry can create particles. For example, during inflation, the rapid expansion means that quantum vacuum fluctuations get stretched and become real classical perturbations (this is how inflation seeds structure – the vacuum makes particles/fields out of expansion). Also, a time-varying gravitational field can create particle-antiparticle pairs (the dynamic Casimir effect, or Hawking radiation at a horizon). So the early universe nearly-empty space (B) plus dynamics guaranteed that it wouldn't stay empty A for long – fields get excited. The open question is: does our universe's matter content originate entirely from such processes? Inflation theory suggests yes for fluctuations but not for bulk matter – bulk matter is usually put in by "reheating" when the inflaton decays.
- *Baryogenesis, etc.:* Assuming inflation left a vacuum-like state (only vacuum energy), how did we get matter, antimatter imbalance, dark matter, etc.? These require specific particle physics processes (baryogenesis, possibly via CP violation, and maybe dark matter freeze-out). Those are complex open problems but within standard physics (just not yet known exactly which mechanism).
- *Vacuum stability:* As mentioned, if our current Standard Model vacuum is metastable (as some extrapolations of the Higgs potential suggest), then at some point level A might spontaneously transit to a lower vacuum (another A state, but with even less "something" in terms of field expectation values). The stability of empty space is thus an open question: will "nothing" (quantum vacuum) eventually decay to an even lower-energy nothing (true vacuum) with catastrophic consequences? Measurements of the Higgs and top quark mass suggest we might be right on the edge of stability. This is an ongoing area of theoretical and experimental interest (though if it's metastable with a lifetime >> age of universe, it's mostly a curiosity, unless something triggers it like high energy).
- *Zero-point energy and technology:* A tangential frontier: can we harness vacuum energy? There's no free lunch – most say no, you can't extract net useful work from the vacuum without an expenditure (Casimir might be seen as an example where you can get a force but you spent energy placing plates there). But in sci-fi context, vacuum energy is sometimes seen as a limitless source. Physicists remain skeptical of any loopholes in thermodynamics here. Still, studying Level A yields practical advances like understanding quantum noise limits in electronics and gravitational wave detectors (vacuum fluctuations are literally the noise floor in many quantum experiments).
- *Emergent particles from fields:* Another conceptual question: at Level B you might have spacetime but you could still have no fields if we consider a truly barren universe. If no fields at all, that's tricky – our laws don't allow "no field" because even gravity is a field (the metric). Usually one assumes at least gravity exists. If it's just gravity and nothing else, then B to A means e.g. gravitational waves could create particles via some coupling. But if truly nothing but geometry, then where do matter fields come from? Some theories like superstring theory unify geometry and fields – all particles are just modes of a fundamental string or brane. So in that sense, if one had a state with just gravitational degrees (closed strings) maybe open strings (matter) could be excited out of

that. Or in other unified frameworks, maybe at high energy the distinction between matter and geometry blurs (like in Euclidean wormhole picture, gauge fields could be like wormholes, etc.). Not resolved, but high-energy physics tries to unify all fields, meaning presumably you can't have geometry without also having the stuff that becomes particles (like extra components of metric or connection fields that become gauge fields).

- *Philosophical: Does space require content?* Some have argued relationally that space is just the web of relations between matter. So empty space without any matter or field might be meaningless (Mach's principle ideas). In general relativity, you can have solutions with just space, so physically it's allowed. But relational philosophy would say, how would you distinguish one empty spacetime from another? (differences like curvature, topology provide an answer in GR). This remains more a philosophical discussion about substantivalism vs relationism about spacetime.

Each step of the ladder thus faces unsolved questions. But arguably, the **hardest gap is from D to C** (why do laws exist at all?), whereas C to B and B to A are where most scientific progress is happening (quantum gravity research for C→B, cosmology for B→A). D→C might ultimately remain a philosophical question or be reframed such that one assumes something like "logic or math exists necessarily" and thus one never had a strict D.

In summary:

- **D→C:** essentially the "first cause" or "meta-law" problem – at the cutting edge of cosmology/philosophy dialogue.
- **C→B:** the classic "quantum gravity" problem – in progress, with hints from theory but no empirical confirmation yet.
- **B→A:** the well-studied "cosmic evolution" problem – largely addressed by inflation and particle physics, but with details (like baryogenesis, vacuum stability) still not fully understood.

We climb the ladder in understanding with decreasing certainty as we go up: Level A is well-established physics; Level B is encompassed by GR (well-tested in many regimes); Level C is an active research frontier; Level D is mostly speculative/philosophical territory. That said, exploring these transitions enriches our perspective on what "nothing" means in science. Each "nothing" wasn't quite nothing, and each something prompts us to ask "why this something and not less?".

Annotated Bibliography (by order of appearance in matrix)

Tryon, E. (1973). *Is the Universe a Vacuum Fluctuation?* **Nature, 246**, 396-397. – In this short but influential letter, Tryon proposes that our universe could have arisen as a quantum fluctuation of the vacuum . He notes peculiar balances (the total energy of the universe might sum to zero when positive mass energy is offset by negative gravitational potential energy) and suggests that *"our Universe is simply one of those things which happen from time to time."* This was the first published suggestion that something (the cosmos) could come from "nothing" defined as the vacuum state. Though largely qualitative, it set the stage for later quantum cosmology. Tryon's idea was initially not taken very seriously , but with the development of inflation theory (which provides a mechanism for a tiny fluctuation to grow), it gained retrospective importance as a precursor to the concept of universe creation via quantum tunneling.

Coleman, S. & De Luccia, F. (1980). *Gravitational effects on and of vacuum decay.* **Physical Review D, 21**(12), 3305-3315. – A seminal paper analyzing how a metastable "false vacuum" decays in the presence of gravity. Coleman & De Luccia extend Coleman's earlier work on tunneling in flat spacetime to de Sitter/general relativity. They derive the

instanton (Euclidean solution) describing nucleation of a bubble of true vacuum and how it evolves in an expanding universe. A key result is that small true-vacuum bubbles can nucleate and then exponentially expand if the vacuum energy inside is lower (a form of vacuum "bubble universe" creation) . The paper is technical, providing equations for the bounce solution and discussing thin-wall approximation. Its relevance to "nothingness" is that if one imagines the entire universe initially in false vacuum (almost like a Level A void except unstable), this mechanism is how "inside that nothing, a something (bubble) forms." It's foundational for eternal inflation and string landscape ideas later. Main critique: the formalism breaks down if the bubble is too large (gravitational effects can prevent tunneling in some cases), and it doesn't literally start from absolute nothing – there's a false vacuum to begin with.

Lamoreaux, S. (1997). *Demonstration of the Casimir Force in the 0.6 to 6 μm Range.* **Physical Review Letters, 78**(1), 5-8. – This is the first high-precision experimental confirmation of the Casimir effect, a direct manifestation of quantum vacuum fluctuations. Lamoreaux measured the force between a metal plate and a spherical surface with ~5% accuracy, observing agreement with Casimir's prediction of an attractive force varying as d^{-4}. The paper provides details of the torsion pendulum setup and accounts for electrostatic calibrations. By confirming the Casimir force, it substantiates that the vacuum (Level A nothing) is physically real and exerts effects . It's frequently cited as evidence that "empty space" contains energy. This experiment helped spur broader interest in micro- and nano-scale phenomena where Casimir forces are significant (e.g., in MEMS devices). It also set the stage for ever-more precise measurements of vacuum forces and searches for deviations that could hint at new physics (like tiny forces from extra dimensions).

Jaffe, R. (2005). *The Casimir Effect and the Quantum Vacuum.* **Physical Review D, 72**, 021301. – Jaffe challenges the common narrative that Casimir forces *prove* vacuum energy is "real." He shows that one can derive Casimir forces using only charged particle interactions and without explicitly invoking zero-point energy . The paper argues that attributing Casimir effect to vacuum fluctuations is a matter of interpretation, not necessity – since one can calculate the same observable using a different renormalization scheme that never mentions the vacuum energy. This doesn't say vacuum fluctuations aren't real; rather that Casimir force is not *direct* evidence of them, as it can be explained by charge-current interactions (van der Waals forces) between the plates . The paper was provocative, generating discussion about what is "measurable": only energy *differences* matter, and an absolute vacuum energy might be unobservable except via gravity. Main critique of Jaffe: while mathematically valid, the approach doesn't negate the existence of vacuum energy; it reframes it. The Casimir effect remains a convenient and intuitive example of vacuum fluctuation consequences, even if one can do the math differently.

Hartle, J. & Hawking, S. (1983). *Wave function of the Universe.* **Physical Review D, 28**(12), 2960-2975. – This paper introduces the no-boundary proposal. It posits that the Universe's wavefunction can be obtained by a path integral over compact Euclidean geometries, essentially a universe that *"just appears"* smoothly without a boundary in time . Hartle and Hawking use a minisuperspace model (homogeneous closed universe with a scalar field) to illustrate the idea. The result is a specific wavefunction $\Psi(h_{ij}, \phi)$ that, for large universes, is approximately $\exp(-I)$ where I is the Euclidean action of a regular instanton (like a 4-sphere). This selects preferentially universes that start at small size and can inflate. The paper is heavy in formalism: solving the WDW equation with the proposed boundary condition of finiteness as the universe's size goes to zero (which replaces the big bang singularity with a rounded-off geometry). Its impact: it provided a formal way to discuss initial conditions for the universe quantum mechanically, shifting the question "what happened before the Big Bang?" to "what are the boundary conditions of the universe's wavefunction?" The *no-boundary* answer: there is no "before," since time emerges from an initial Euclidean regime. The proposal has been refined and debated; later work examined the inclusion of perturbations and whether the no-boundary proposal implies a universe with certain characteristics (like likely inflation). It's a milestone in quantum cosmology.

Vilenkin, A. (1984). *Quantum Creation of Universes.* **Physical Review D, 30**(2), 509-511. – (Also Vilenkin's 1982 Phys. Lett. piece.) Vilenkin provides the alternative to no-boundary: the *tunneling boundary condition*. In this short paper, he sets up the WDW equation for a closed de Sitter universe and argues the solution should behave like a tunneling wavefunction (outgoing wave only for universe expansion) . The resulting wavefunction gives a probability ~ $P \propto \exp(+2|S_E|)$ (i.e., higher for larger cosmological constant, favoring inflation). He describes the universe "tunneling from nothing," where "nothing" means a state with no classical space (a=0). The tunneling approach yields a different weighting of initial conditions than Hartle–Hawking (which had $P \propto \exp(-2|S_E|)$, favoring small Lambda and more expansion e-folds, ironically – the details depend on modeling). This work is important for showing that the cosmological initial condition is not unique – different reasonable postulates give different results. In later papers, Vilenkin clarified and defended the tunneling proposal. Together with Hartle–Hawking, it frames much of the discourse on how a universe might originate spontaneously. Testing these ideas is very challenging; it largely comes down to theoretical consistency and perhaps "retrodicting" features of our universe (like the amplitude of primordial fluctuations).

He, D., Gao, D., & Cai, Q. (2014). *Spontaneous creation of the universe from nothing.* **Physical Review D, 89**, 083510. – This article claims to give a "proof" of concept for universe creation from nothing by solving the WDW equation for a simple model and employing the de Broglie-Bohm interpretation. The authors find explicit solutions for a universe with a false vacuum and show that if a tiny true vacuum bubble is nucleated, it will inflate and become a universe . They then use Bohm's interpretation to identify the quantum potential as a driver of inflation . Essentially, this is a working example of a combination of quantum tunneling and inflationary expansion, avoiding singularity. The paper's tone is a bit strong in claiming "the problem of singularity can be avoided naturally" . It's a useful reference linking several ideas: a specific operator ordering in WDW (p=-2 or 4) gave them analytic solutions; the match between quantum cosmology and classical inflation through Bohmian trajectories. It demonstrates how quantum cosmology might produce a classical universe. Critique: the model is very restricted (mini-superspace, special factor ordering, single scalar field), and the use of Bohmian mechanics, while illustrative, is an interpretation not all accept. Nonetheless, it's a concrete study showing a scenario in which *"quantum nothing" yields an inflationary something,* reinforcing that with the right conditions (false vacuum fluctuation) a universe can indeed spontaneously appear.

Addazi, A., et al. (2025). *Emergent Gravity from Topological Quantum Field Theory: Stochastic Gradient Flow Perspective…* (arXiv:2505.17014). – A recent paper (with Addazi, Capozziello, and others) that proposes a novel route to quantum gravity via a "stochastic flow" from a topological BF theory to General Relativity . They consider an ultraviolet complete theory that in the far UV is topological (no local degrees of freedom, a BF theory – akin to a very symmetric state, almost "nothing" happening), and in the IR (low energies) flows to classical GR. Two phase transitions are key: one where topological symmetry breaks to a "pre-geometric phase" (Wilczek's model of emergent space) , and another where that pre-geometry's symmetries break to yield full GR . The mechanism is a stochastic differential equation akin to Ricci flow but in theory space (they mention gradient flow and even compare a Higgs-like mechanism) . This paper is on the cutting edge of theory, exploring how gravity might emerge from something fundamentally different (here, a topological QFT with a *gradient flow time* acting like a renormalization parameter). It's quite technical, but conceptually it embodies the Level C→B transition: showing explicitly how *classical spacetime and gravity could emerge after certain symmetries "down-break."* The main critique is that it's currently a lot of mathematical scaffolding without experimental contact – but it's an example of the maturity of quantum gravity approaches that now tackle phase transitions and flows (the language of "fixed points" suggests a theoretical structure that could be tested if one finds a universal property, like a relationship between certain constants that experiments might check).

Oriti, D. (2022). *Tensorial Group Field Theory condensate cosmology as an example of spacetime emergence…* (Foundations of Spacetime Physics, Routledge, forthcoming; arXiv:2112.02585). – Oriti provides a non-technical overview of how GFT (a spin-off of loop quantum gravity) can produce cosmological models by condensation . It's written for a philosophical audience, explaining the steps from the fundamental GFT (with "atoms of space") to an emergent Friedmann universe. He emphasizes this as a template for spacetime emergence – separating the issue into levels and scales. In particular, it shows how a *non-spatiotemporal fundamental entity* (the GFT quanta) can give rise to an effective continuum spacetime described by an FRW metric and matter. Oriti delineates several "levels of emergence" which map in part to our ladder: the fundamental (no spacetime), intermediate (condensate regime, semi-spatial), and emergent continuum. He also addresses conceptual questions like "what is the ontology of these quanta if not space?" and clarifies that many approaches (LQG, CDT, etc.) share the idea of no fundamental spacetime. As an open access reference , it's valuable for those wanting a relatively accessible explanation of these ideas. It doesn't have new empirical predictions, but it consolidates understanding. The key mechanism highlighted is the analogy to BEC: a phase transition where many discrete units fall into a collective state (with symmetry breaking of particle number conservation, yielding a non-zero condensate field) . This draws a clear line from micro to macro in quantum gravity.

Gielen, S., Sindoni, L., & others (2016). *“Condensate cosmology from Group Field Theory”* (various papers, e.g., Gielen, Oriti, Sindoni, 2013 PRL). – (Not a single bibliography entry but referring to a body of work.) These authors pioneered extracting cosmological dynamics from GFT condensates. They showed that in a GFT model, a certain condensate state can be approximated by a classical cosmology (like a homogeneous isotropic universe) and derived effective Friedmann equations including potential quantum corrections. For instance, in one paper (Gielen & Sindoni 2016), they discuss how a GFT condensate can reproduce loop quantum cosmology bounce behavior. The cited line is from a philosophical analysis by Marco de Cesare (2022) describing how GFT sees a condensation as a transition from the Fock vacuum (no “atoms”) to a “condensed phase” where $U(1)$ symmetry is broken (meaning the number of quanta is not conserved). This is exactly how a physical BEC works – you pick a phase, breaking particle number conservation spontaneously. In GFT, the condensate’s non-zero vacuum expectation is analogous to a classical metric field emergent. This is cutting-edge because it connects quantum gravity math to potentially observable cosmological features (e.g., an initial bounce or modified early expansion). Still, translating these into definite predictions remains to be done.

Sorkin, R. (2005). *Causal Sets: Discrete Gravity (Notes for the Valdivia Summer School).* (Published in *Approaches to Quantum Gravity*, ed. D. Oriti, 2009.) – Rafael Sorkin’s lecture notes (and a popular article “Geometry from order: causal sets”) articulate the causal set program. The motto “Order + Number = Geometry” concisely summarizes how a causal set (just relational ordering of events and a count measure) can approximate a continuum spacetime . Sorkin describes how to recover dimensionality, length scales, etc., from just the partial order of a set of points (which encodes light-cone structure) and counting of points (which correlates with volume) . The notes also present the concept of “sequential growth”: a possible dynamics where new elements are born one by one. This ties to the idea of *becoming* – time as the growth of the causal set. If you start with no elements (empty set, truly nothing in this theory) and apply a growth law (which is basically a probability rule for adding elements in a way consistent with causality), you get a universe unfolding. It’s one of the few approaches that explicitly talk about a *beginning from nothing* in a well-defined way (albeit with a pre-assumed rule of growth). Sorkin also famously predicted a fluctuating cosmological constant (an example of a “phenomenological consequence”): because a causal set naturally introduces Poisson fluctuations in counts, the cosmological constant might be not a fixed value but an average with fluctuations. This offered a potential explanation for why Lambda ~ 1/today^2 in order of magnitude (though it’s not definitively confirmed). Sorkin’s work is foundational for anyone exploring a truly discrete view of spacetime origin.

Dowker, F. & Zalel, S. (2017). *Evolution of Universes in Causal Set Cosmology.* **Comptes Rendus Physique, 18**(3-4), 246-253. – In this conference paper, Dowker and her student Zalel extend causal set ideas to a scenario of “universe branching.” They consider a possibility where a new universe could spawn from a black hole singularity (consistent with a bounce or a new causal set branch) . They connect this to Smolin’s Cosmological Natural Selection (CNS), which posits new universes born in black holes might slightly vary constants, leading to a multiverse where universes are “selected” for black-hole-friendly physics. Dowker & Zalel show within a particular causal set growth model that the “fundamental parameters” of the growth rule *renormalize* (change) after a cosmological bounce or black hole-like creation event . In other words, the laws can shift in the new branch – a prerequisite for any evolution or selection. This is a fascinating melding of a quantum gravity idea with an evolutionary paradigm. The paper doesn’t provide a lot of detail on observational tests (CNS itself has an indirect test: our universe should be locally “optimal” for black hole production, meaning certain constants like neutron star maximum mass or supernova behaviors should saturate bounds – Smolin argued our universe passes some of these tests, but it’s not conclusive). Nonetheless, this work is at the frontier of thinking how level C might not be one-off, but part of an ongoing generational chain of universes – and how a “law” might gradually change through that chain (meta-law of reproduction). It’s speculative but addresses the meta-law problem by embedding it in the universe’s evolutionary history.

Wheeler, J.A. (1983). *Law Without Law.* In *Quantum Theory and Measurement* (eds. Wheeler & Zurek), Princeton Univ. Press, pp.182-213. – This essay by John Wheeler is a philosophical musing rather than a formal article. Wheeler reflects on lessons from quantum mechanics and speculates that the universe’s laws are not fixed, but emerge from the act of observation/participation. He illustrates ideas like the delayed-choice experiment and asks if reality is a self-synthesized system. The phrase “law without law” encapsulates his bold suggestion that “at the bottom, things are anarchic, but from this chaos of possibilities, stable regularities (laws) emergent because if they didn’t, we couldn’t be here to witness them” (a quasi-anthropic reasoning). He even proposed a variant of the anthropic principle called the “participatory anthropic principle” – the universe requires observers in a deep sense to actualize itself. This is mind-

bending stuff on the edge of science. Although Wheeler's thoughts are hard to test, they have inspired work in quantum foundations and information theory. For instance, today's "it from bit" program – the idea that information underlies reality – draws partly from Wheeler's musings in this essay and elsewhere. As a reference, it's cited when discussing whether the laws of physics might be environmental or emergent rather than immutable. Wheeler's reputation and colorful analogies (e.g., the quantum foam, the "Great Smoky Dragon" of quantum, etc.) make this piece a classic in stimulating conceptual shifts. It doesn't have equations or empirical claims; its value is in *paradigm suggestion*.

Hawking, S. & Mlodinow, L. (2010). *The Grand Design.* (Chapter 6-7 on "The Apparent Miracle" and "The Grand Design"). – In this popular book, Stephen Hawking makes the provocative statement: *"Because there is a law like gravity, the universe can and will create itself from nothing... Spontaneous creation is the reason there is something rather than nothing."* . Hawking and Mlodinow argue that given quantum theory and gravity, one doesn't need to invoke God or anything external to explain the universe's existence. Essentially, they appeal to the idea that a quantum vacuum with gravity can spawn universes (like via the no-boundary proposal and sum-over-histories). The book's context: it explains model-dependent realism, the multiverse (via M-theory), and concludes that our universe is just one of many possible, and the laws of the multiverse suffice to create it spontaneously. While not a peer-reviewed source, it influenced public discourse heavily. Philosophers criticized it: "Hawking says the universe arises from nothing *because there are laws* – but laws are not 'nothing'!" (This critique points out the slight of hand: gravity isn't nothing). Still, it succinctly captures a viewpoint among some physicists that *if you have a closed universe, its total energy can be zero, and quantum gravitational laws allow it to appear from a vacuum fluctuation.* Hawking equates "nothing" to a state obeying laws of physics but devoid of matter, which is really Level A or C. In academic terms, this is just the Hartle-Hawking no-boundary idea repackaged: the universe is a quantum fluctuation mandated by gravity's peculiar properties . As a literature entry, it's evidence of how these ideas cross into mainstream narrative.

Nozick, R. (1981). *Philosophical Explanations.* (Chapter "Why is there something rather than nothing?"). – Nozick, an American philosopher, famously tackled the ultimate question in this book. He introduced the **Principle of Fecundity** which states *"All possible worlds exist"* . Nozick explores various potential answers to the existence question and finds many unsatisfactory, so he considers the bold "everything exists" answer, which he finds elegant in that it explains existence by maximality – reality doesn't favor nothingness or any particular something, it realizes all possibilities. He also discusses issues like whether that principle includes itself (he notes it should be reflexive – fecundity itself is a possibility and thus if possible, it must be actual, thereby ensuring all possibilities are actual). He doesn't assert this as definitely true, but as an avenue. This was one of the first times a major philosopher seriously engaged with the question in analytic philosophy, bringing it out of purely theological contexts. The work is discursive and exploratory. The key significance is framing how one might deny the privileged status of "nothing" by instead assuming an overflowing ontology. It's relevant to our Ladder at Level D: it's essentially a solution to D by saying D never occurs except as one element in an all-inclusive set (and indeed if all worlds exist, the measure of the completely empty world might be very small in some sense, or it might be included but trivial). Nozick's ideas haven't been widely adopted as *the* answer, but they influenced later thinkers (like Tegmark acknowledges resonance with Nozick). In scholarly terms, it's a reference for the "all possible exist" approach.

Lewis, D. (1986). *On the Plurality of Worlds.* – David Lewis's treatise is the classic defense of modal realism. Lewis argues that possible worlds are just as concrete as the actual world; they are not in our space-time but exist in a vast plurality. He sets out the semantics and reasoning: for modal statements to have truth value, quantifying over real possible worlds is coherent and useful. While Lewis did not aim to explain why something exists (he took it as given that a plurality exists), his framework implies that *"nothingness" (a world with nothing in it) is just one among the plethora of worlds and notably, for Lewis, there is no "global" world containing them all – each world is isolated* . However, the principle that all worlds exist is reminiscent of fecundity. Lewis anticipated many objections: the incredulous stare ("It's just crazy to think all that exists"), issues of how to define actuality (he says "actual" is indexical – each world's inhabitants call their world actual, but none enjoys special ontological status) . In context of nothingness: if Lewis is right, then "why is there something?" can be answered by "because all possibilities (including nothingness) exist in the multiverse of worlds, and we just happen to be in a non-empty one." It diffuses the question by reframing existence as a brute fact across worlds. The book is highly influential in philosophy, though many reject modal realism as too extravagant. It's crucial in any scholarly discussion of "all possible worlds" being real – which is exactly a Level D concept used to circumvent the need for a cause of existence.

Tegmark, M. (2008). *The Mathematical Universe.* **Foundations of Physics, 38**(2), 101-150. – Tegmark articulates his Mathematical Universe Hypothesis (MUH): *"Our external physical reality is a mathematical structure."* He further conjectures that *all* mathematical structures exist (this is the Level IV multiverse) . In this paper and in his later book (2014), he argues that this can explain why our universe has the laws it does: they're just one of all possible structures – we observe them because we are in that structure. He draws parallels to Platonism and modal realism . A lot of the paper discusses how one might identify isomorphic structures as the same, the problem of a measure (how to say some universes are more "likely" – which he admits is unresolved). It also addresses potential objections like Gödel's theorem (Tegmark thinks it doesn't doom the MUH; he suggests maybe only computable or consistent structures exist). The significance for nothingness: Tegmark's "Theory of Everything" is that everything exists (mathematically) , leaving no room for an overarching nothing. It's a modern physics-aligned version of Nozick's principle, differing in focusing on mathematical existence rather than metaphysical "possible worlds." It pushes the envelope by suggesting physics should broaden to include this hypothesis. While it remains untestable directly, one could argue that if our universe's laws turned out to be unusual or "maximally generic" in some space of math structures, that might hint at something like this. So far, we can't evaluate it empirically. But Tegmark's idea garners interest and debate – e.g., whether it's meaningful or just redefining existence. As a bibliographic entry, it stands for the extreme multiverse view linking to the big question: if all math exists, the fact something exists is trivial – non-existence isn't an option.

Ellis, G., et al. (2004). *Multiverses and physical cosmology.* **New Astronomy Reviews, 46**, 741-781. – (also Ellis' SciAm 2011 article). George Ellis is a cosmologist who often provides thoughtful critiques of multiverse proposals. In various writings, he emphasizes that multiverse hypotheses must assume a framework of laws to generate the ensemble, and these *"meta-laws" themselves demand explanation* . In the 2004 paper (co-authored with U. Kirchner and W.R. Stoeger), they classify types of multiverse and stress that assuming a multiverse doesn't remove fine-tuning, it just moves it up a level to the choice of multiverse mechanism. A key quote: *"We have to assume that some relevant meta-laws pre-exist... we need to explain also what particular meta-laws pre-exist."* . Ellis argues for caution: multiverse ideas often step outside empirical science, and one should not abandon conventional criteria. In his 2011 *Scientific American* piece, Ellis outlines many multiverse types and repeatedly notes the problem of testability and the need for a "theory of everything" that presumably dictates the multiverse structure. The takeaway for Level D: Ellis's perspective is that appealing to a multiverse or other ensemble still leaves the question "Why this ensemble?" unless perhaps one embraces something like Tegmark's all-math or Nozick's all-worlds, which he likely finds unscientific. Ellis doesn't really provide a solution, but a challenge: any purported solution like a multiverse is incomplete without addressing the meta-law. His work grounds the philosophical discussion within cosmology, reminding us that even level C or beyond scenarios require assumptions that themselves beg for reason. In short, *Ellis ensures we don't get to skip the "why" question by saying "multiverse" – we merely change its wording to "why this multiverse?"*

Grünbaum, A. (2004). *The poverty of Theistic cosmology* (in *Theism and Big Bang*, ed. M. Stoeger & W. Stoeger) – Adolf Grünbaum was a philosopher of science who directly attacked the "Why is there something rather than nothing?" question, calling it misguided. In various publications and debates (one famous one with theologian W.L. Craig), Grünbaum argued that *"nothingness" isn't a state that needs explanation; it's not like something that would obtain if not prevented.* He coined the term *"ontopathological syndrome"* for the preoccupation some have with the supposed problem of nothingness . He believed the existence of the universe might simply be a brute fact and that asking for an explanation where none is called for is a pseudo-problem. He particularly criticized theologians who use the question to argue for God; he claimed the question has force only if one assumes "nothing" is the natural default, which he disputed. His views align with the idea that level D is not a particularly privileged or probable state. Though Grünbaum's tone could be acerbic, his stance injects a healthy skepticism: maybe there *is* no answer because the question might be ill-posed. His writing is more polemical and philosophical; it doesn't offer new data but critiques the logical structure of the question. It's useful in our context as a reminder: an acceptable answer to "Why not nothing?" could be "Because 'nothing' was never a possible reality in the first place." If one subscribes to that, the ladder concept might start at C by necessity.

Krauss, L. (2012). *A Universe from Nothing: Why There is Something Rather than Nothing.* – In this popular book, physicist Lawrence Krauss explains modern cosmology (quantum vacuum, inflation, dark energy) and argues these scientific advances can answer the age-old question without recourse to God. Krauss's "nothing" is basically the Level A vacuum (and he also touches on Level C ideas of quantum gravity). He famously writes that vacuum fluctuations and laws of physics are sufficient to get universes. The book sparked controversy, especially from philosophers like David Albert who in a scathing review noted Krauss's "nothing" is a "simple plenum" of fields and that Krauss misunderstands or dismisses the philosophical aspect. In short, the critique is Krauss answered a different question: not "why is there existence?" but "how could a universe like ours start given quantum laws?" – which is actually a Level C to B question. Still, Krauss's book brought the discussion to the public sphere and is a reference point in culture for this topic. It's not peer-reviewed, but Krauss bases it on known physics: e.g. he cites that in a flat universe the total energy can be zero, and that quantum cosmology suggests universes can pop from vacuum. The book also mentions that the geometry of the universe being flat and the existence of a non-zero Lambda (dark energy) implies the energy of nothing is not zero – which is a possible clue that nothingness is unstable. For our purposes, Krauss is an example of conflating levels (A/C with D) – a pedagogical misstep perhaps, but an illustrative one. It underscores the importance of definitions. Nonetheless, the scientific content on vacuum energy, inflation, etc., is accurate and accessible, making it a valuable summary of how physics deals with "almost nothing."

This bibliography spans a range from empirical physics papers (Lamoreaux 1997) to theoretical cosmology (Hartle-Hawking, Vilenkin) to philosophy and popular discourse (Nozick, Krauss). Each illuminates a facet of the gradation of "nothing" and the efforts to either explain how something arises or argue about the question itself.