Section 16. Limitations and Open Problems

Any proposed foundational framework must be explicit about its limitations. QIA aims to replace interpretive postulates with a concrete routing-based mechanism; however, several components require further formal development to reach the level of a fully closed theory. This section enumerates the main open problems, focusing on definitional sharpness, mathematical derivations, and scaling consistency across physical regimes.

16.1 Observer-independent definition of information

A primary challenge is to define information in a way that is fully observer-independent yet still operationally meaningful. QIA treats information as wave-pattern encoding, but the formal definition must be sharpened so that it does not implicitly depend on an observer's chosen basis, measurement context, or coarse-graining scheme. A rigorous definition must specify which aspects of phase, amplitude, and correlation count as "information" intrinsically, and how this intrinsic content can be quantified as a functional of the global state Ψ or density structure ρ. Without such sharpness, the concept risks becoming a rephrasing of standard quantum formalism rather than a genuinely explanatory primitive.

16.2 Derivation of the Born rule from routing equilibrium

While QIA proposes that Born-rule statistics emerge from routing equilibrium weights across attractors, the derivation must be made mathematically tight. Specifically, one must define the routing measure over attractor channels and prove that under general conditions it yields probabilities equivalent to $|\langle i|\Psi\rangle|^2$. This requires specifying the routing cost functional, the stability criterion, and the measure that converts attractor weights into observable outcome frequencies. Achieving this derivation would significantly strengthen QIA by turning its core thesis into a quantitative theorem rather than a qualitative mechanism proposal.

16.3 Connection to field theory and gravity

QIA is currently framed at the level of network information architecture and measurement dynamics. A major open problem is to connect this architecture explicitly to quantum field theory and gravity. In CUWF, gravity is interpreted through entropic wave-field interactions and boundary dynamics. Therefore, QIA should ultimately show how routing structure maps onto field-theoretic degrees of freedom, and how gravitational or spacetime curvature phenomena appear as emergent consequences of entropic routing constraints. This likely requires cross-referencing the CUWF gravity framework and expressing routing operators in field functional language $\Psi[U]$.

16.4 Unambiguous definition of network nodes (coarse-graining rule)

Because QIA describes the universe as an entropic network, the definition of nodes is crucial. At present, nodes are described as regions defined by entropic boundaries. However, a full theory must provide an unambiguous coarse-graining rule: how to partition the underlying wave substrate into nodes and links such that predictions are stable and non-arbitrary. This includes defining the rule for when two regions count as distinct nodes, how coupling operators are assigned, and how boundary degrees of freedom are treated. Without such a rule, node definitions may become ad hoc and theory-dependent.

16.5 Scaling problem: micro ⟶ meso ⟶ macro

Finally, QIA must address scaling consistency. The framework introduces mechanisms at the microscopic level (wave-pattern encoding and routing dynamics), but must demonstrate how these mechanisms scale through mesoscopic regimes into macroscopic classical behavior. This scaling problem includes specifying how routing overload produces robust pointer states at larger scales, how entropic bottlenecks grow with system size, and how effective classical laws emerge without losing the underlying information-conserving architecture. A complete scaling theory would allow QIA to generate quantitative crossover predictions rather than qualitative narratives.