Section 11. Computation and Causality: What is the Universe Computing?

This section addresses a fundamental interpretive question: if the universe is a lossless entropic information network, then in what sense can it be understood as "computing"? QIA proposes that computation is not an external abstract operation applied to physics, but a natural description of controlled transformations of routing structure under constraints. Causality, in turn, is treated as an emergent ordering of constraint updates perceived at the classical interface.

11.1 Quantum gate as a controlled re-routing transformation

In quantum information theory, a quantum gate is modeled as a unitary operator acting on qubits. In QIA, the same concept is expressed in network language: a gate is a controlled re-routing transformation. It is an operation that reshapes the routing landscape such that wave-pattern encoding flows into a new configuration while preserving global information conservation. A gate therefore corresponds to a constraint-controlled modification of the routing operator $\boldsymbol{\mathcal{R}}$, producing a predictable transformation of codewords.

$$Quantum\ gate \approx controlled\ routing\ transformation:\ \Psi \rightarrow \boldsymbol{\mathcal{R}}\_gate(\Psi)$$

11.2 Circuit model vs measurement-based model (MBQC) in QIA language

QIA provides a unified interpretation of the two major computation paradigms: the circuit model and measurement-based quantum computation (MBQC). In the circuit model, gates are explicitly applied sequentially, corresponding to a series of controlled re-routing transformations. In MBQC, by contrast, a large entangled resource state is prepared first, and computation is performed primarily through measurement constraints applied at selected nodes. In QIA terms, the circuit model emphasizes explicit routing transforms, while MBQC emphasizes constraint-driven routing selection on a pre-established correlation topology. Both are therefore special cases of routing management in a lossless entropic network.

11.3 Complexity as entropic routing cost

Computational complexity is typically defined in terms of resource usage: time steps, gate counts, or circuit depth. QIA introduces a physical reinterpretation: complexity corresponds to entropic routing cost. A process is complex when maintaining or achieving a desired routing transformation requires high entropic expenditure or extensive routing reconfiguration across the network. Thus, complexity is not merely a counting measure; it is a thermodynamic-compatibility measure. This suggests a direct link between complexity growth and entropy production in the classical interface.

$$Complexity \;\approx\; entropic\ routing\ cost \sim \boldsymbol{\mathcal{A}}\ (routing\ action)$$

11.4 Apparent causality as perceived ordering of constraint updates

In QIA, causality is treated as an emergent interface phenomenon rather than a primitive rule of the universe. If routing updates are fundamental, then what observers interpret as cause and effect is the perceived ordering of constraint injections and subsequent stabilization steps. An event appears as a cause when it is associated with a constraint update that reshapes compatibility conditions. The corresponding effect is the stabilization of routing into a new attractor. Therefore, causality is a macroscopic narrative of routing transitions under entropic ordering.

$$Cause - effect\ appearance:\ constraint\ injection \;\rightarrow\; routing\ update \;\rightarrow\; stabilization$$

11.5 Retrocausality illusion when routing constraints are global

Certain quantum experiments appear to suggest retrocausality, as if future measurement choices influence past states. QIA explains this effect without reversing physical time. When routing constraints are global—meaning that the compatibility structure of the distributed code depends on boundary conditions at multiple nodes—the final global routing configuration can only be described consistently after all constraints are specified. If an observer insists on describing intermediate states using incomplete boundary data, the later constraint injections can appear to "rewrite the past." In QIA this is a retrocausality illusion: it reflects global routing consistency requirements, not backward propagation of classical information.