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Macroscopic states, operations, and correlations

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To understand the emergence of macroscopic irreversibility from microscopic reversible dynamics, the idea of coarse-graining plays a fundamental role. In this work, we focus on the concept of macroscopic states, i.e. coarse representations of microscopic details, defined as states that can be inferred solely from the outcomes of macroscopic measurements. Building on the theories of quantum statistical sufficiency and quantum Bayesian retrodiction, we characterize macroscopic states through several equivalent formulations, ranging from algebraic to explicitly constructive. We introduce a hierarchy of macroscopicity-non-decreasing operations and develop a resource theory of microscopicity that unifies and generalizes existing resource theories of coherence, athermality, nonuniformity, and asymmetry. Finally, we introduce the concept of inferential reference frames and reinterpret macroscopic entropy as a measure of inferential asymmetry, i.e., irretrodictability. This perspective clarifies how specific quantum features are either preserved or lost depending on the observer's reference frame. Applying this framework, we examine locally microscopic correlation and establish the necessary and sufficient conditions for it to vanish in terms of information recoverability.

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