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Rewriting the Rules for Diagnostics: Implications of Probability and Measure Theory for SARS-CoV-2 Testing

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Estimating prevalence, i.e. the fraction of a population that has been previously infected by a disease such as SARS-CoV-2, is among the most important tasks in epidemiology. When estimating prevalence, it is often assumed that diagnostic classification of samples is necessary. However, this assumption is false. In this talk, I demonstrate that a perspective rooted in metrology is necessary to formulate the mathematical framework describing a diagnostic test. In particular, I show how conditional probability models of diagnostic measurement outcomes for positive and negative samples yield: (i) an unbiased and converging estimate of prevalence without classifying samples; and (ii) an minimum-error classification strategy. I will show how traditional prevalence estimates fail to converge and that a minimum uncertainty prevalence estimation strategy can be constructed in terms of the *bathtub principle.* Throughout the talk, I will use examples from real-world SARS-CoV-2 antibody tests to illustrate main ideas and validate the analysis.