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Emulsion-based microfluidics for high-throughput biology

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A challenge for many biological experiments is that they require huge numbers of reactions to be performed. For example, in a typical screen, millions of microbes must be assayed; in a directed evolution experiment, hundreds of millions of cells must be sorted; to sequence the human genome, billions of biochemical reactions must be performed. In these cases, the reactions themselves are fairly simple, but the vast numbers that must be performed make the experiments challenging and very expensive. We have developed an emulsion-based microfluidic system that can perform billions of reactions quickly and inexpensively. The system follows modular design principles, making it generally applicable to biological experiments. To illustrate this, we will describe two proof-of-concept demonstrations. We will describe the use of this system to evolve a natural enzyme to have higher catalytic activity; this required screening hundreds of millions of mutants, which took a few hours and used only 100 microliters of reagent. To perform the same screen using a robot would have taken 2 years and cost over 1 million dollars-in pipette tips alone. We will also describe how we are using this approach for genomic DNA sequencing; with this system we can perform billions of sequencing reactions in a few hours using less than 1 milliliter of total reagent. The speed and universality of this approach enables a range of new high-throughput biological studies.