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The design and implementation of small synthetic genetic circuits for cell reprogramming is propelling the emerging field of Synthetic Biology. We will describe our recent results on the engineering of small synthetic circuits and their characterization in *E. coli*. We will show our recent results on the design of circuits made of either RNA or transcription factors. In the first case, we will describe the first fully automated design methodology and experimental validation of synthetic RNA interaction circuits in living cells. The computational algorithm, based on a physicochemical model, finds novel RNA sequences by exploring a space of 1040 possible sequences compatible with predefined structures and intermolecular interaction models. We tested our methodology in *E. coli* by designing several positive riboregulators with diverse structures and interaction models. The designed sequences exhibit very low similarity to any known non-coding RNA sequence. Our riboregulatory devices can work independently and in combination with transcription regulation to create complex logic circuits. Our results demonstrate that a computational methodology based on first principles can be used to engineer interacting RNAs with allosteric behavior in living cells. In the second case, we describe the construction and characterisation in *E. coli* of minimal gene networks with oscillatory behaviour. We use microfluidic techniques to track the single-cell dynamics for several days. We have also engineered two coupled oscillators in a single cell. Coupling of two oscillators is known in physics to generate a number of interesting dynamical behaviours. The resulting function could represent a simple super-position of the dynamical behaviour or it could lock into several possible characteristic frequencies, or even it could have several characteristic properties, depending on the conditions of the experiment. To analyse these effects in vivo we designed and constructed several genetic parts that allow us to characterise the dynamical behaviour of a coupled oscillator system in bacteria. Our engineered gene networks could be used in larger systems, opening the way for the engineering of genetic circuits with high complex behaviour.