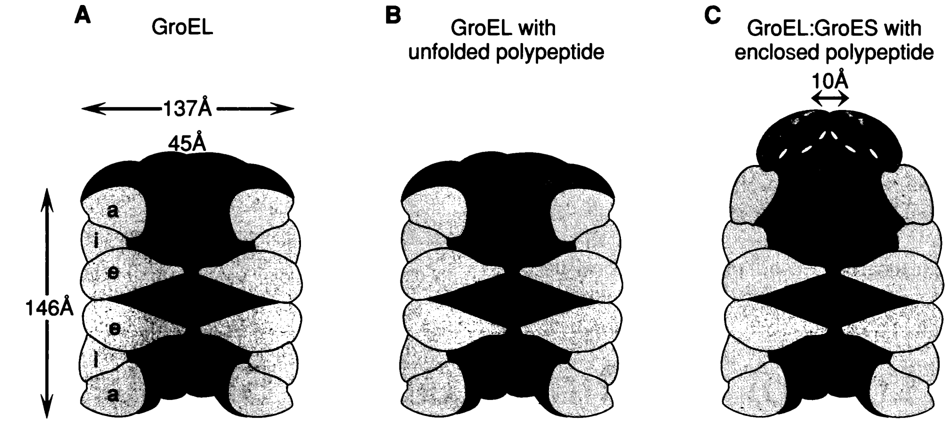

The GroEL:GroES complex helps proteins to fold. Hydrophobic binding patches (blue); charged residues (yellow); a, apical domains; i, intermediate domains; e, equatorial domains.

the dissociation of GroES from GroEL (*8*, *9*), possibly allowing release of any folded or committed substrate into the cytosol. Substrate polypeptide that has folded incompletely and still exposes hydrophobic residues will rebind to GroEL (*7*, *8*, *12*). This may result in structural rearrangement and unfolding followed by GroES rebinding.

The docking of GroES may require a recognition event on the outside surface of GroEL mediated by the mobile loop of GroES (*3*, *5*, *11*). In the cpn10 structure both lysine-36, which has been implicated in allosteric transitions (*13*), and tyrosine-73, which in GroES is close to a potential nucleotide binding region (*14*), are well positioned to interact with GroEL, possibly within the central cavity. This clamping of GroES to GroEL induces large conformational changes in GroEL, characterized by an outward movement of the apical domains (*15*) [not represented in the model of GroEL:GroES in (*3*)] (figure, part C). GroES may now interact directly with the hydrophobic polypeptide-binding regions of GroEL, which are required for complex formation with GroES (*6*). Assuming that the association with GroES masks the hydrophobic binding patches of GroEL, the net result of this conformational switching would be the release of polypeptide into a now hydrophilic cavity that is considerably enlarged and should be permissive for folding (figure, part C). Although the transfer of unfolded protein into an aqueous envrionment is sufficient to drive the compaction of the molecule, the intense hydrophilicity of the inner surface of the GroES dome may promote folding by stabilizing native-like folding intermediates (3). GroES may thus actually participate quite actively in the folding process.

The structural and functional studies suggest three reasons for the high efficiency of GroEL:GroES in mediating polypeptide folding: (i) the prevention of aggregation by binding unfolded or kinetically trapped folding intermediates with exposed hydrophobic surfaces; (ii) the GroES-induced release of unfolded polypeptides into a sequestered environment permissive for folding; and (iii) proofreading by rebinding and rearranging polypeptides that failed to fold sufficiently, thereby preparing them for another folding trial. A more detailed understanding of the function of GroES will come from the high-resolution structure of GroEL:GroES, which is in the pipeline.

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Approaching the Quantum Gate

The familiar desktop computer is based on a logic of ones and zeros that defines a particular set of computations. More than 10 years ago, Deutch (*1*) contributed to the creation of a new theoretical field of quantum computation, in which binary logic is replaced by fundamental computing elements that follow the laws of quantum mechanics. Just as a physical quantum system may be described by superpositions of eigenstates, a quantum computer works by processing superpositions of quantum bits or "qubits."

The field lay dormant until a theoretical discovery by Shor (*2*) that quantum computers may be capable of rapidly factoring large prime numbers, a task that is fiendishly difficult on conventional computers and so forms the basis for much present-day cryptographic data security. Unfortunately, for those desiring a quick way to crack codes, experimental realization of a quantum computer will present some extreme challenges (*3*). Nevertheless, recent work by Turchette *et al.* (*4*) and Monroe *et al.* (*5*) show that progress is being made in the laboratory.

Turchette *et al.* (*4*) have explored the possibility of implementing a quantum logic element in the form of a cavity resonator containing a single cesium atom interacting with individual photons. The cesium, prepared by optical pumping of an atomic beam, can either stay in the ground state or absorb circularly polarized light. A strong beam of light entering the cavity modifies the way a probe beam interacts with the atom. The result is an intensity-dependent phase shift between the left and right circular components of the probe beam that gives rise to conditional quantum dynamics, thus laying the foundation for photonic quantum logic circuits. Instead of a beam of atoms, Monroe *et al.* (*5*) make use of a single trapped beryllium atom to construct their prototype quantum logic gate. The result is a two-bit controlled "not" quantum gate, which, when combined with single-bit operations, is the basis for a universal logic element.

Now that quantum gates can be built, crucial issues related to the decoherence produced when quantum logic elements interact with the real world can be studied. Though a working quantum computer is far off, these experimental results are encouraging and move quantum logic from the realm of theory onto the benchtop.

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