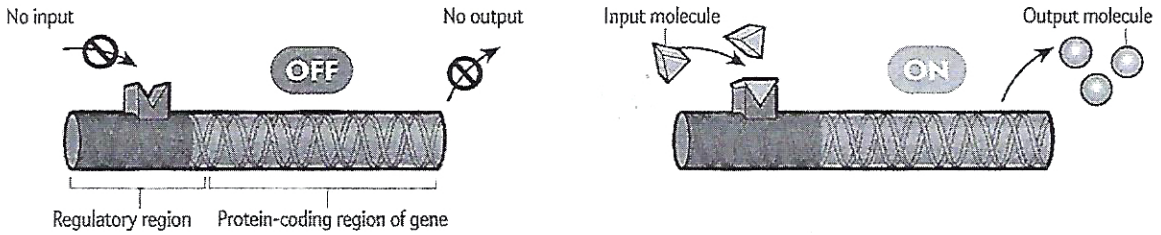
Living Circuits

Genes—and other segments of DNA that switch genes on and off—can be wired together in novel ways. They work like electrical circuits that run household gadgets. These DNA circuits, though, can be placed within living organisms like bacteria to control the microbes' behavior. With that control, synthetic biologists can turn the organisms into living medicine.

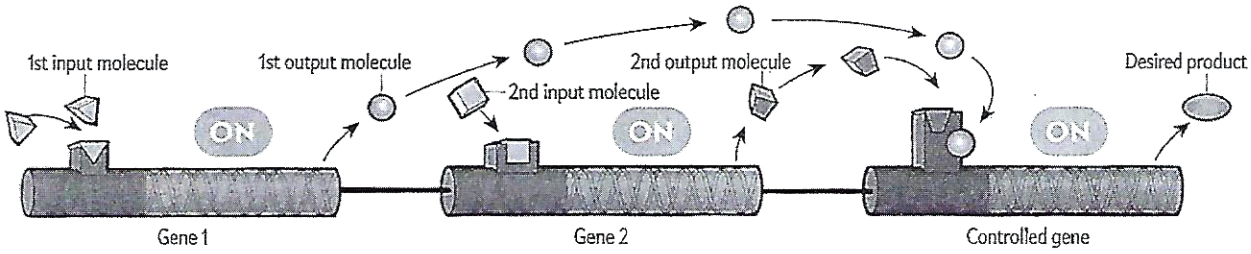
A Simple Switch

In a basic circuit, a gene can be turned on by a particular signal to produce a useful substance. The gene (*orange*) is linked to a regulatory region (*red*). When that region has no input, the circuit is off and produces nothing. But if that region is stimulated by an input molecule (*gray*), it turns the gene on and makes a desired output molecule.



Adding Complex Logic

The switch can be combined with other elements to give biologists more advanced control—logic—over what a microbe does. One example is this "AND" circuit. Gene 1 (*orange*), when switched on, sends output to the controlled gene (*purple*). Gene 2 (*green*), also switched on by an input molecule, sends output to the controlled gene as well. The controlled gene switches on only when stimulated by both gene 1 and gene 2.



Building Bacteria to Fight an Enzyme Disorder

Patients with urea cycle disorder have an enzyme deficiency that lets toxic levels of ammonia build up. Biologists are treating this by making *Escherichia coli* bacteria eat the ammonia. The microbes are engineered to produce large amounts of an amino acid, arginine, and they need to consume ammonia to make it. First a gene (*pink*) that inhibits extra arginine production is turned off. Another gene (*green*) is added, and it switches on when stimulated by a protein called FNR (*yellow*). FNR only does this in a low-oxygen environment such as the human intestines. When the entire synthetic circuit is placed in bacteria, they become arginine-producing machines only when stimulated by ammonia and low oxygen levels. The dual control ensures bacteria do this inside the body, not after they are excreted into the oxygen-rich outside world.