ing compartments, or potential wells. Adjustable vertical barriers divide these wells in half. A particle loaded into, say, the left half of a well corresponds to 0 and into the right half to 1.

In the downhill loading step, an incoming bit (0 or 1) waits in its own well to meet a well returning from the top of the ski lift. This returning well is initially in the 0 state. If the incoming bit is 1, its well induces the barrier in the returning well to lower temporarily and forces the particle in the returning well to pass from the left to the right half. Then, the original incoming well is reset so the value of its bit is 0.

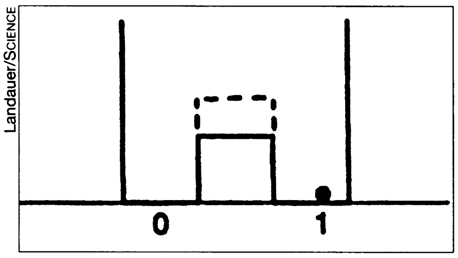
The freshly loaded well next travels back up the ski lift to the unloading area, where its bit is copied to a receiving well. The unloaded well is reset to 0 and returns downhill to repeat the information transfer cycle.

In principle, each of the operations involved in this scenario and in his other proposals involves no expenditure of energy, Landauer argues. Instead of getting thrown away, the bits are, in effect, recycled. Moreover, the basic setup does not require that the signals overcome background noise.

"These are not practical schemes," Landauer admits. They may, however, stimulate others to invent communication systems that make better use of energy than those now available.

For example, it may be possible to use the timing or angle of polarization of photons to achieve an effect similar to that underlying Landauer's quantum ski lift model of a communication link.

Even if his theoretical models are unachievable in practice, Landauer notes, it is still worthwhile knowing that no physical law prohibits extremely low energy communication. *— I. Peterson*



Landauer/SCIENCE

Potential well divided in two by an adjustable barrier, with a particle loaded into the right side to represent 1.

Romanian cave contains novel ecosystem

A cavern isolated from the rest of the world under a Romanian cornfield nourishes the first known ecosystem of its kind, three biologists report this week. The 48 animal species—including 33 new ones—found in Movile Cave are part of a food chain that draws sustenance solely from energy-rich molecules in rocks instead of from the power packed in the sun's rays.

Almost all life systems on Earth depend on photosynthesis—directly or indirectly—to fill their metabolic needs. Most animals that live only in caves rely to some extent on photosynthesis because they consume decayed plants swept down from the surface, says Brian K. Kinkle, a microbiologist at the University of Cincinnati.

Scientists have discovered other ecosystems that derive their energy purely from chemical sources, such as bacteria living underground (SN: 10/21/95, p. 263) or deep-sea communities that feed off mineral-rich hydrothermal vents. However, the Romanian cave is unique, Kinkle says, in that it contains the first known land animals not tied to photosynthesis.

The biologists analyzed the animals' diet by taking specimens of bacteria, fungi, and small invertebrates and comparing the ratios of four nonradioactive carbon and nitrogen isotopes. The results showed that the animals live on fungi and bacteria floating on water that partially fills the cave, Kinkle and his colleagues report in the June 28 SCIENCE. These microorganisms consume hydrogen sulfide from the rocks.

The scientists see Movile Cave as a biological time capsule. It was sealed off more than 5.5 million years ago, they say, and its creatures have evolved into specialized, self-sufficient forms. The only thing they need from above is oxygen, which leaks into the cave via minute cracks.

Thomas C. Kane, a biologist at the University of Cincinnati and report coauthor, said he was excited by "not just finding a new species—that happens every day—but finding 33 new species."

The discoveries include grazers such as four species of isopods, or pillbugs, six springtails, a millipede, and a bristletail. Among the new species of carnivores are two pseudoscorpions, a 2-inch-long centipede, a worm-sucking leech, four spiders, and a water scorpion.

That such a diverse community can feed itself in a cave's perpetual night is news to other scientists, too. Larry Lemke of NASA's Ames Research Center in Mountain View, Calif., says Movile qualifies as an excellent "Mars analog site."

Lemke works on the design of new missions to search for life on the Red Planet. Scientists now hold that life may have existed there 3.5 billion years ago, when the planet was warmer and wetter (SN: 8/27/94, p. 137). If that life still survives, it would have to be underground, where liquid water could exist, as it does in Movile Cave.

"Movile Cave is interesting because it seems to be truly closed to outside sources of organic material," notes Lemke. *— E. Skindrud*

Ancient world gets precise chronology

Scholarly debate and uncertainty have dogged efforts to specify precisely the years when various ancient civilizations thrived in the lands bordering the eastern Mediterranean Sea. An ongoing analysis of tree-ring evidence, described in the June 27 NATURE, promises to bring unprecedented exactitude to the calendar of ancient history.

New data from this project yield an exact chronology of eastern Mediterranean cultures from 2220 B.C. to 718 B.C., a time span that encompasses the rise and fall of early urban centers in Mesopotamia and Egypt, as well as the emergence of societies in Greece and Rome.

"Tree-ring dating now offers the route to a new, absolute chronology of the Old World that is independent of existing assumptions, gaps in evidence, and debates," asserts a scientific team headed by Peter Ian Kuniholm, an archaeologist at Cornell University.

Although this line of investigation will probably generate a reliable time line for archaeological sites in the eastern Mediterranean, doubts still remain about the dating sequence currently proposed by Kuniholm's group, writes Colin Renfrew of the McDonald Institute for Archaeological Research in Cambridge, England, in an accompanying comment.

Prior attempts to devise chronologies for early civilizations in the Near East and Egypt relied largely on recovered documents, such as clay tablets, which outline regional successions of kings and other royal figures. Three different chronologies have been proposed on the basis of such information.

Kuniholm and his colleagues aimed to calibrate a sequence of radiocarbon dates using tree rings from a variety of ancient timbers, most of which came from modern-day Turkey. They identified what they called a floating chronology of 1,503 years, a slice of time from around the second millennium B.C. that could not be pinned to exact years.

The scientists then obtained 18 high-precision radiocarbon dates from a juniper log at a Turkish archaeological site. A statistical comparison of these measurements to radiocarbon measurements from Europe and North America, all of which have established calendar dates, resulted in a chronological sequence for the eastern Mediterranean.

That estimate still contained a slight margin of error. Confirmation of the new chronology emerged with the observation at another Turkish site of exceptional growth in tree rings that correspond

Continued on p.406