ponents in place. But circumstantial evidence to the contrary began to accumulate very soon thereafter. In the early 1970s, for example, experiments in several laboratories (including Noller's) showed that the ribosome could still forge peptide bonds even when individual protein components were removed or deactivated. Somewhat later, University of Illinois microbiologist Carl Woese demonstrated that certain parts of the nucleotide sequences in ribosomal RNA were virtually identical in a wide range of organisms—evidence that those sequences are so critically important to the organisms' survival that evolutionary change is almost impossible. Moreover, Noller and his coworkers showed that those particular stretches of RNA happen to be the ones that lie at the surface of the ribosome, exactly where one would expect to find functional sites. And finally, there was the finding of catalytic RNA ribozymes.

Taken together, says Noller, these findings made it easy to believe that RNA was doing most of the catalytic work in the ribosome, and that the proteins are the scaffolding—exactly the reverse of the original picture. Of course, even the proponents of this view had to acknowledge that the formation of a peptide bond is chemically very different from the RNA splicing carried out by Cech and Altman's ribozymes. But they figured that if RNA could do one kind of catalysis, there was no reason why it couldn't do another. The trick was to prove it.

This is what Noller and his group have now done. They used the straightforward, if technically arduous, technique of extracting all the proteins from the ribosome, and then showing that the remaining RNA still retains most of the ribosome's ability to catalyze peptide bond formation. Noller is the first to point out that the proof is not quite ironclad, since there is always the possibility that some fragment of protein got left behind in the extraction process. In an effort to provide the definitive experiment, he and his co-workers are now trying to synthesize from scratch a ribosomal RNA molecule that has never been in contact with ribosomal proteins to find out whether that new RNA can still assemble amino acid chains.

However, most researchers in the field are already convinced; as Indiana's Pace points out, referring to the specifics of Noller's technique, "proteinase digestion plus phenol extraction is pretty rigorous." He and others are eagerly contemplating the larger implications.

"Now that Harry has pinned down the most important function of the ribosome," says Joyce, "that's a handle to begin asking how the other parts of the ribosome play off the RNA. In the old days—a decade ago—we said, 'What's the RNA doing?' Now we have to ask, 'What are the proteins doing?'

"People are viewing this as an absolutely stunning result. The implications are profound."

–Christine Guthrie

The ribosome does a lot more than make peptide bonds. There are translocation events. There are initiation and termination events. There is the whole business of guaranteeing the fidelity of the translation. So how does the RNA, in concert with the proteins, do all the things it's got to do?"

In addition, he says, the new finding clearly bolsters the RNA World hypothesis, first advanced more than 20 years ago as the solution to a classic chicken-or-egg paradox: Which came first, DNA or proteins? In modern cells, proteins can't exist without DNA because DNA encodes the genetic blueprints for their construction. And yet DNA can't exist without proteins because protein enzymes are required for its replication, self-repair, and a host of other functions. Hence the paradox—and the appeal of the RNA world hypothesis, which cuts through the conundrum by asserting that neither came first: DNA and proteins are both descended from RNA.

The RNA world conjecture gained enormous credibility a decade ago with the proof that RNA can catalyze certain reactions in much the same way that proteins do. And now the new findings make it very tempting to imagine that the modern ribosome—a huge, intricately structured molecule containing some 50 individual protein components and some 5000 RNA nucleotides—is the descendant of a set of primordial RNA molecules that once catalyzed peptide bond formation directly. Indeed, Noller and many other RNA specialists consider it a top priority to find out what else RNA is doing in the modern cell—and, through laboratory experiments with artificial RNA molecules, to find out what else it might have been able to do in primordial cells.

"Obviously," says Joyce, "Harry's finding doesn't speak to how life started, and it doesn't explain what came before RNA. But as part of the continually growing body of circumstantial evidence that there was a life form before ours on this planet, from which we emerged—boy, it's very strong!"

–M. Mitchell Waldrop

ADDITIONAL READING

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ASTRONOMY

Gammas From Heaven

For 20 years astronomers observed gamma rays pour out from an apparently empty point in the sky. According to one popular story, an Italian astronomer named the mysterious source Geminga, which in a Milanese dialect means, "It isn't there." Now Columbia University astronomer Jules Halpern says he has identified the source of the mystery gammas.

Halpern's culprit was already a prime suspect—a faint x-ray source found several years back in the same vicinity by the Einstein satellite. Using data collected by a more recent satellite called ROSAT, Halpern managed to tease out a period of 0.237 seconds in the x-ray emissions from this faint source. The periodicity, he says, shows that it is a compact, fast-spinning dead star known as a pulsar. NASA-Goddard scientist David Bertsch then searched for the same period in the sparse gamma rays collected by the Compton Gamma-Ray Observatory (GRO). He found it.

"We have a definitive identification. The gamma-ray source is the same as the x-ray source," says Halpern. This finding makes Geminga a close relative of only two other known gamma-ray emitting pulsars, the Crab and Vela pulsars. Astronomers have, however, picked up a dozen unidentified gamma-ray sources in recent years, and Halpern thinks these are probably also pulsars.

Theorist Kaiyou Chen of the Los Alamos National Laboratory says the energy comes initially from rotational energy, which is converted to gamma and x-rays in complex processes as a pulsar slows down. The pulses come from hot spots that swing around with each rotation like a lighthouse beacon. Chen says that the periodicity indicates that Geminga is about 300,000 years old—somewhat older than its relatives, the Crab and Vela, which he says will evolve to look more like Geminga, emitting more and more of their energy in the form of gamma rays.

Halpern cautions that scientists still know little about the complex processes by which these pulsars send out energy. But in the past there wasn't much information to work with. Now, with GRO and ROSAT monitoring the sky, Halpern is optimistic that within a year they will have found 100 or more new gamma-ray sources, which will either confirm or contradict all the theories about their energetic life cycles.

–Faye Flam