sential ingredient—sunlight—became available. That unleashed an abundance of chlorine in its destructive form, driving Arctic ozone into a sharp decline that continued into March, according to Joe W. Waters of the Jet Propulsion Laboratory, where the stratosphere is monitored through the Upper Atmosphere Research Satellite. (Waters and his colleagues reported their Arctic observations in the 15 April issue of *Nature*.)

Even with all that help, the Arctic depletions still didn't rival the Antarctic ones. Because ozone concentrations are normally relatively high over the Arctic, notes Stolarski, even extensive ozone destruction is unlikely to create a "hole" there. It's like taking the top off a mountain, he says; you've lost something, but you're a long way from digging a hole. But the resulting pool of ozone-depleted air, Stolarski thinks, flooded south over populated areas in late winter and early spring during the annual vortex breakup, augmenting the effects of the volcano.

After that one-two punch, the ozone layer is likely to be down for the count. Researchers say the 9% decline in ozone at mid-latitudes will be with us into summer, along with the resulting 12% or so increase in harmful ultraviolet. If you haven't already heeded doctors' warnings about overexposure to the sun, all the more reason to put on that hat and slather on the sunscreen.

–Richard A. Kerr

CHEMISTRY

How to Drive Nucleic Acids Up a Tree

When chemist Masad J. Damha and his colleagues set out to study the curious branched RNA molecules found in the cell nucleus, they never imagined they'd find themselves in a hotbed of polymer science. But not only is that exactly where their artificially structured RNA has landed them; their work shows signs of heating up the field even more. And in the final twist, this foray into unfamiliar territory may end up leading the McGill University researcher and his colleagues back to the answers they had sought in the first place.

As the group reports in the 24 March issue of the *Journal of the American Chemical Society*, they've succeeded in training RNA to form an intricate branching molecule known as a dendrimer. Until now, dendrimers—which have already energized a new subdiscipline of polymer science (*Science*, 29 March 1991, p. 1562)—have been made of nonbiological ingredients, notes Donald Tomalia, a leading dendrimer researcher at the Michigan Molecular Institute in Midland. Damha's work, he says, is "the first time that biological polymers have been synthesized in this architectural form." And while ordinary dendrimers have already begun catching the eyes of industrial chemists for everything from catalysis to drug delivery, these biodendrimers may turn out to be just the thing for fishing for DNA or RNA fragments—a common challenge in biomedicine.

Damha had set out in the late 1980s to uncover the role of the branched RNA structures that form in the nucleus during the production of messenger RNA (mRNA), the linear molecules that carry genetic information to the cell's protein-making factories. Although scientists have known about these "forked" and "lariat" shaped RNA intermediates for about a decade, they have yet to determine how these structures take part in the molecular cutting and pasting process that produces mRNA.

Damha and his colleagues realized that probing the branched RNA (bRNA) molecules systematically would be a whole lot easier if there were a ready and abundant source of them. The minuscule amounts and fleeting life of naturally produced bRNA makes cells a poor source. So Damha (then at the University of Toronto) and his Toronto colleagues decided to synthesize their own bRNA molecules chemically.

The Canadian chemists' first task was to develop a chemical procedure in which automated synthesizers, which normally produce linear RNA or DNA molecules, could create branched versions instead. They directed a commercial synthesizer to build up pairs of identical nucleotide chains from nearby anchor points on a solid surface. Once the chains reached a preset length, the machine introduced another nucleotide. This one, an adenosine, was chemically modified so that it would link to and join the ends of the pairs of nucleotide chains. The results: V-shaped RNA molecules, or, if the chemists directed the synthesizer to continue adding building blocks to the vertex of the V's, Y-shaped RNA molecules. That much they reported last December in *Nucleic Acids Research*.

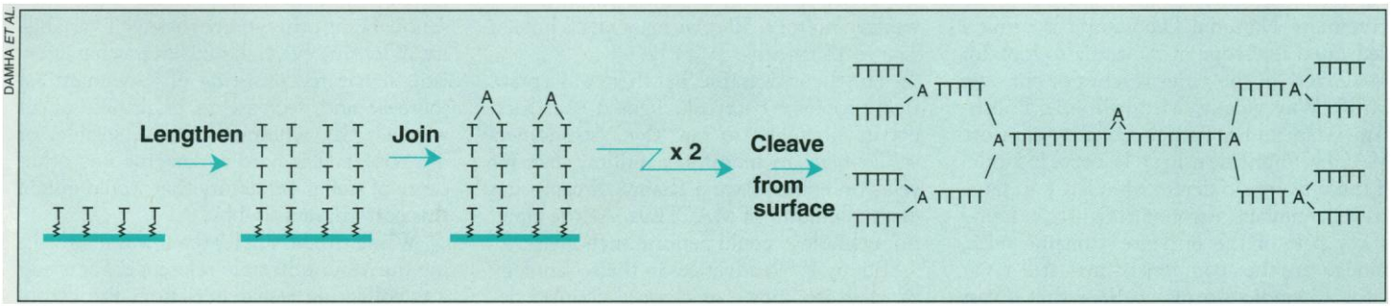
Even before they had had a chance to study their synthetic forks and lariats, Damha and University of Toronto graduate student Robert Hudson decided to push the synthesis process several steps further. They now start with many more chains—so far, as many as eight of them—and iterate the process of chain-extension and chain-joining until the chains converge into one. The resulting, much more intricate, structures fall squarely into the dendrimer category. The researchers are now developing a divergent approach, in which the molecules grow by branching outward from a core.

Because of the unique, biological character of the branching RNAs, Damha and other dendrimer growers speculate that they will be more than a structural curiosity. For one, the dendrimers' multiple arms, each with an identical genetic message, may prove especially effective at capturing and binding matching nucleotide sequences. That could open the way to using them as "antisense" agents, which can turn off genes by intercepting and deactivating mRNA or DNA, says Damha. Or, says Tomalia, dendrimers based on RNA or other nucleic acids could be designed as diagnostic tools, if they were built with sequences complementary to those of say, pathogenic agents such as viruses.

As for the original mystery about the RNA forks and lariats in normal cells, Damha thinks that the dendrimers may help out there as well. They might serve as selective fishing hooks capable of snagging those RNA curiosities from a cellular digest. "In a sense, we are still quite unaware of the potential of these [structures]," says Hudson.

–Ivan Amato

DAMHA ET AL.



All together now. In a scheme for creating branched RNAs, chains are extended, joined with modified adenosine nucleotides, and extended again.