the complex internal structure of molecules makes them difficult to cool with lasers. In work now in press at *PRL*, Pillet and his colleagues Andrea Fioretti, Daniel Comparat, and others succeeded by first photoassociating pairs of ultracold cesium atoms in a trap. Photoassociated molecules usually don't survive long, because the internal energy left over after the atoms come together rips the pair apart. But Pillet says that the cesium molecules rapidly shed this extra energy by emitting a photon, which—a lucky peculiarity of cesium—stabilizes them. At that point, they are close enough to be held by the usual valence bonds, and the union is essentially forever. "That's beautiful," says Hulet of the experiment. "The ultimate goal would be not only to make ultracold molecules but to trap them" by some other means, he says. That could lead to studies of novel chemical reactions, extremely precise molecular spectroscopy, or even Bose-Einstein condensation of molecules.

As those fresh directions open up, other researchers have been studying the gentle collisions that are the first step toward a BEC, the quantum-mechanical fluid that forms when the right kinds of atoms are cooled in a sufficiently dense cloud. "It's essential to understand these cold collision processes if you're going to do Bose-Einstein condensation," says Phillips. He explains that a single number describing the trapped atoms, their "scattering length," determines much of the behavior of the resulting BEC. The scattering length gauges how two passing atoms interact as they briefly linger in each other's vicinity; the length depends sensitively on the very weakest binding state the atoms could have and still stick together.

That number—although often virtually impossible to calculate—can be measured by photoassociating a pair of ultracold atoms and then forcing them apart with another laser pulse, as Hulet and many others have shown. Others have recently confirmed theoretical predictions that the length is not immutably fixed for a given atom. A group led by Wolfgang Ketterle of the Massachusetts Institute of Technology reported in the 12 March issue of *Nature* that they had observed a "Feshbach resonance," in which applied magnetic fields could make the weakest bound state weaker or stronger, totally altering the character of a sodium BEC. Although that work was done with the BEC fluid itself, Daniel Heinzen of the University of Texas, Austin, and several colleagues have seen a Feshbach resonance more recently in ultracold collisions of rubidium-85 atoms.

For devotees of this kind of stately atomic opera, the season has just opened. "I suspect that what everybody is going to do is keep their eyes open for really juicy things to measure," says Phillips.

–**James Glanz**

NEUROBIOLOGY

Flying by the Seat of Their Halteres

The fly is the Ferrari of the insect world. It specializes in high-speed maneuvers as it pursues mates or dodges fly swatters, darting around obstacles 10 times faster than a blink of an eye. Now researchers may have uncovered the guidance system responsible for these acrobatics: a pair of Tootsie Pop–shaped organs on the fly's back called halteres.

The fly responds so rapidly to what it sees that researchers once thought the visual system in its brain must connect directly to its flight muscles. But the new results suggest that this neural hot line may run instead through the halteres, vestigial wings that until now were supposed to function only as gyroscopes that help stabilize the insect in flight. The findings, reported on page 289 by neuroethologist Michael Dickinson of the University of California, Berkeley, and his colleagues suggest that halteres both stabilize the flight and guide its twists and turns. If so, "it's going to [lead] to a rewriting of how flight control works," says Dickinson.

WAI PANG CHAN

M. SPRINGER / GAMMA LIAISON

Rear steering. Flight control in both tethered *(bottom)* and free-flying blowflies may work through the halteres (arrow).

This new picture of fly flight control is "interesting and exciting," says R. Meldrum Robertson, a neurobiologist at Queen's University in Kingston, Ontario, Canada. But beyond that, he adds, the work also provides intriguing insights into how this modern insect's sophisticated flight system evolved from the neural connections in the fly's four-winged ancestor.

Researchers have known for decades that the fly steers based on what it sees, rather than, say, by what it smells. To find out more about how it does that, the Dickinson team, building on work done in Germany, studied how visual cues affect wing movements. The researchers tethered flies to a thin rod and surrounded them with a screen displaying moving patterns of dark and light stripes. The flies took off, flying as if moving through a real landscape.

The team found that the various wing steering muscles respond to the stripes, exhibiting one pattern of activity when the stripes shift sideways and another when they move up and down. Even though this meant, Dickinson says, that "there had to be a way for visual information to affect these steering muscles," years of electrophysiological studies found no evidence of a direct, functional connection between the visual system and the flight muscles. "It was so disturbing," he recalls. "I was racking my head to understand what was going on."

Then, in about 1994, he came across a paper from 1947 that described in great detail a small set of muscles at the base of the halteres. These muscles are equivalent to the wing's steering muscles, Dickinson says, but they had no known function. Out of curiosity about what they might do, his lab team monitored their electrical activity while moving striped patterns in front of the fly.

To their surprise, the researchers found that specific muscles stiffened, depending on whether the stripes were moving vertically, sideways, or diagonally. "Very robust visual information [is] going to the halteres," says Dickinson. To him, this result indicates that the vibrating halteres could be acting as way stations, receiving visual cues and then relaying signals to the wing steering muscles.

He notes that the halteres do have the necessary neural connections, as researchers had shown in studying their role as gyroscopes. If the fly rotates or starts to tumble while flying, the halteres are deflected by the changes in the forces acting on them. This activates some 300 sensory neurons at the haltere base, which send a strong signal directly to the nerves controlling the wings' steering muscles. The muscles in turn stiffen and alter the wing beat to prevent rolling, pitching, or yawing.

Dickinson's new scenario proposes that visual information—another fly moving through the air, for example—triggers the same pathway by causing the haltere steering muscles to stiffen. The stiffening activates the sensors at the base of each haltere, and they in turn send a revised message to the wing's steering muscles, one that might translate into "turn left," as well as "rotate the body 5 degrees." "It's a different way to think about halteres," comments Cole Gilbert, a neuroethologist at Cornell University in Ithaca, New York.

Gilbert's team has additional results supporting this new view. The position of the head relative to the rest of the body also influences the flight path, and his group recently found that sensors in the neck that monitor head position relative to the thorax in the fly relay that information not just to the wings but also to the halteres.

A dual role for the halteres makes sense from a functional standpoint, Dickinson says. Instead of having to override the stabilizer system in the halteres, which tends to keep a fly flying straight, signals from the brain telling the fly to change course may work through the stabilizer system. As a result, the fly can change course in less than 30 milliseconds, without disabling its gyroscope.

This setup would also be consistent with evolution's penchant for tinkering with preexisting circuitry, Robertson adds. Most researchers think that the fly's ancestors had two pairs of wings and that during evolution the rear pair degenerated into halteres. This improved the fly's maneuverability by helping it keep from tumbling out of control as it zips about. But the neural connections that originally allowed the two pairs of wings to coordinate their activities may have been retained and refined as this new function evolved. "You can really see how evolution has exploited circuitry in the brain that was there in a much more primitive system to create a system that looks very, very different," says neurobiologist Heinrich Reichert at the University of Basel in Switzerland.

Still, Dickinson has yet to prove that the haltere is relaying flight commands to the wing. For one, despite Dickinson's failure to detect input from the fly visual system to the wing steering muscle, neurobiologist Nicholas Strausfeld at the University of Arizona in Tucson has described a physical connection between the visual parts of the brain and the wing steering muscle. The role of that connection is unclear, but its existence means that direct input to the wing muscles can't be ruled out.

To try to confirm his new ideas, Dickinson hopes to show that the haltere steering muscles do influence the wing steering muscles. And he may not be alone in his efforts. "It's such an interesting idea," Robertson says, "that now people will go out and try to find evidence for or against it."

–Elizabeth Pennisi

ATMOSPHERIC CHEMISTRY

Ozone Loss, Greenhouse Gases Linked

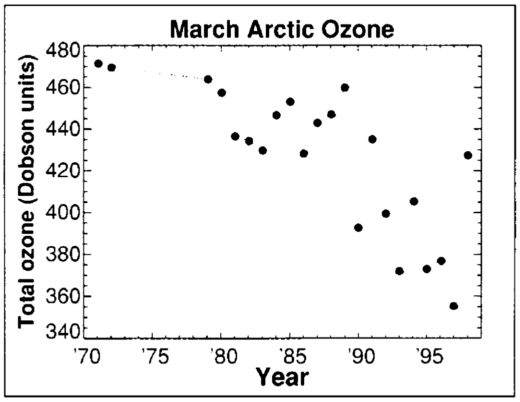
Buffeted by scores of news accounts, the public has sometimes mixed up global warming, which is fueled by heat-trapping gases in the lower atmosphere, and stratospheric ozone destruction, spurred by voracious chlorine compounds like chlorofluorocarbons. Now a computer model suggests there may be a real connection between the two processes. For the first time, a single model has combined greenhouse warming and ozone depletion in a long-term simulation, and the results are sobering: Greenhouse gases and chlorofluorocarbons together may be ganging up to destroy ozone.

In the wake of global controls on ozone-destroying compounds, most observers expected that the annual Antarctic ozone hole would fade, and the more modest Arctic ozone losses diminish, as atmospheric chlorine declines. But in this week's issue of *Nature*, a group from NASA's Goddard Institute for Space Studies (GISS) in New York City reports that their model indicates that during the next few decades, greenhouse gases will trigger a springtime ozone hole over the Arctic, much like the one now over the Antarctic.

Atmospheric researchers are taking these results seriously, although they caution that the model is rather crude. "It's a bold calculation and an important result," says atmospheric physicist Paul Newman of NASA's Goddard Space Flight Center in Greenbelt, Maryland. "But it's a really soft result," because the model is relatively simple. Still, the recent behavior of Arctic ozone tends to support the result. Says ozone researcher Ross Salawitch of the Jet Propulsion Laboratory in Pasadena, California: "I think they may be on to something."

The link between ozone destruction and greenhouse gases involves temperature, but cooling rather than warming. Stratospheric chlorine-ozone reactions in polar regions are catalyzed by icy cloud crystals that form only in the most extreme cold. The colder it gets and the longer that cold persists into the spring—when the other key ingredient, sunshine, appears—the more ozone will be destroyed. Greenhouse gases warm the lower atmosphere, but they can also cool the polar stratosphere by radiating heat to space and by changing atmospheric heat transport.

When GISS modelers Drew Shindell, David Rind, and Patrick Lonergan ran their global ocean-atmosphere climate model with ozone chemistry included, they found that projected increases in greenhouse gases progressively chilled the model's wintertime stratospheric temperatures over the poles by 8° to 10°C. Arctic ozone losses, rather than declining in step with decreasing chlorine, worsened until the 2010s and then slowly recovered. During the worst years, up to 65% of Arctic ozone was destroyed, a larger proportion than in the current Antarctic ozone hole. The same process would delay healing of the Antarctic ozone hole, but it would cause minimal additional ozone loss because the hole there is already so severe.



SOURCE: P. A. NEWMAN/NASA/GSFC

A hole in the making? Although it bounced back this year, ozone has been declining over the Arctic.

Researchers are intrigued by the model results but note that the only way a modeler can find enough computer time to project this far into the future "is to use a rather crude model," as Newman puts it. One concern, for example, is that some other models wouldn't produce as much greenhouse-induced reduction in the heat delivered to the polar stratosphere. Still, even though the GISS model "is fudged up and has a lot of patches," says stratospheric modeler Jerry D. Mahlman of the Geophysical Fluid Dynamics Laboratory in Princeton, New Jersey, "their punch lines are all plausible."

What's more, the GISS model simulation of the 1990s resembles what actually happened—the wintertime Arctic stratosphere has gotten progressively colder and more depleted in ozone. In the spring of 1997, ozone loss was already half as severe as the gloomiest model projection, for around 2015. But as if to show how hard it will be to sort out the effect of greenhouse gases in the real world, Arctic ozone losses this spring dropped to near zero, presumably because of natural climate variability. Given all these uncertainties, the best result of the GISS study, says Newman, may be the enhanced awareness that two great human alterations of the atmosphere—greenhouse warming and ozone depletion—are indeed interdependent.

–Richard A. Kerr