The big question about phenotype matching is, how does it operate? What cues—visual, olfactory, oral, and so on—are involved? And what is the genetic basis? Bateson suspects that the pattern recognition process involved is generally exceedingly complicated. "When you know what the cues are, you can begin to manipulate them," he says. "But none of us knows in any detail what we are dealing with, beyond saying it is visual in one case, for instance, and olfactory in another."

In a theoretical exercise on the possible genetic parameters of kin recognition with Robert Lacy, of Franklin and Marshall College, Lancaster, Pennsylvania, Sherman appears to confirm all too depressingly the complexity of the system. "For example," they write, "34 independently assorting genetic loci with two alleles each are required for full-sib/nonrelative discrimination with a 10% probability of error." Full-sib/half-sib and half-sib/nonrelative discrimination require 66 and 404 traits, respectively, all of which implies an immense amount of genetic information.

An interesting twist on the perception of the phenomenon of kin recognition as a putative specific example of a general method of learning comes from work by Bateson and fellow Cambridge biologist Gabriel Horn. By ablating a tiny part of the chick forebrain—the intermediate part of the medial hyperstriatum ventral (IMHV)—before the bird has been exposed to any imprinting stimuli, it is possible to prevent imprinting from occuring. Similarly, ablation following imprinting more or less expunges the preference that had been acquired.

The intriguing part of these observations is that although imprinting is affected by the procedure, other learning processes are not. This observation implies that this mechanism of kin recognition is a rather specific form of learning, one perhaps designed to protect under normal circumstances a very special and important function. No neurological information exists for other species on this issue, beyond the striking clinical observation that a patient whose IMHV has been damaged in some way has a specific inability to recognize faces.

—ROGER LEWIN

What Is the Risk from Chlorofluorocarbons?

A new Academy report predicts a reduced risk of danger to ozone, but only if certain questionable assumptions are made

The new report from the National Academy of Sciences (NAS) to the Environmental Protection Agency about the potential danger to the ozone layer from chlorofluorocarbons* has some good news and some bad news. The good news is a modest lowering in the predicted depletion of atmospheric ozone as a result of the continued release of chlorofluorocarbons into the environment. The bad news is that the prediction is based on at least one major assumption that may no longer be true.

Furthermore, that modest decrease in atmospheric ozone is actually the result of what Herbert Kaufman of the University of Pittsburgh terms "a precarious balance" between a dramatic decrease in ozone concentrations in the upper atmosphere and an equally large increase at lower altitudes. This rearrangement of atmospheric ozone has the potential to become as troubling as a sharp depletion in stratospheric ozone might have been. The potential hazards are much more complicated than it would appear at first blush.

The most important chlorofluorocarbons (CFC's, often known by the trade name Freons) are CFC-11 ($CFCl_3$) and CFC-12 (CF_2Cl_2). The use of CFC's in aerosols was banned in 1977, but they are still widely used as refrigerants and as foaming agents for polymers. When they are eventually released to the atmosphere, their inertness to most biological processes allows them to be transported to the stratosphere, where they are broken down by sunlight. Liberated chlorine catalytically destroys ozone, which acts as a shield against the sun's ultraviolet radiation. It has been estimated that each 1 percent depletion in ozone would increase the amount of ultraviolet light that reaches the earth's surface by 1 to 3 percent, and that such increases could produce deleterious consequences ranging from decreases in food production to increases in the incidence of cancer.

The projected risk to atmospheric ozone has been reduced with successive reports from the Academy. A 1979 report estimated an eventual depletion of 18.6 percent if release of CFC's continued at the 1977 rate. A 1982 report (*Science*, 23 April 1982, p. 396) predicted a depletion in the range of 5 to 9 percent if emissions continued at the same rate. The new report reduces that estimate still further, to 2 to 4 percent. The changes in the projections arise from two major sources: improved values for rate constants for certain reactions in the atmosphere and the inclusion of other trace gases in the mathematical models used to make the projections.

The determination of rate constants has been a particularly vexing problem. There are at least 192 chemical reactions and 48 photochemical processes that occur in the stratosphere, although only about 150 or fewer of these parameters are actually used in most modeling calculations. Most of those reactions are very fast processes involving highly reactive species, particularly free radicals and atoms in excited states, whose reactions can affect the chemistry of the stratosphere at very small concentrations.

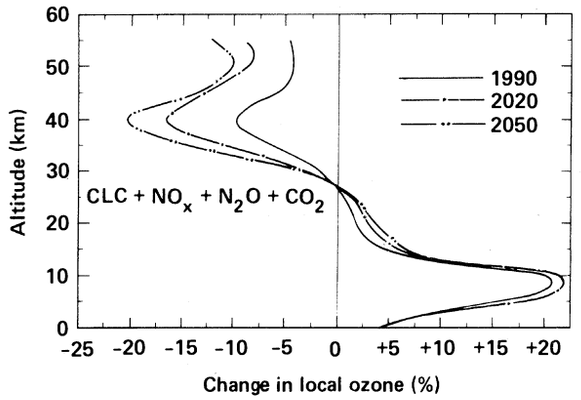
Many of these reactions are very difficult even to reproduce in the laboratory, much less to measure their rates. Determination of those rates has required the development of sophisticated laser-based techniques both for initiating the reactions and for determining the rates. By sheer coincidence, most of the recent refinements in rate constants have tended to reduce the predicted depletion.

The report cites at least six different reactions whose rate constants have recently been revised dramatically. One example is the reaction

$$O + HO_2 \rightarrow OH + O_2$$

which removes odd oxygen atoms while converting hydroperoxide into the more reactive hydroxyl radical, which in turn reduces the concentration of ozone in the upper stratosphere. Working with such radical-radical reactions in the past has been very difficult because both highly reactive species must be produced and monitored accurately and sensitively. In 1983, three separate groups used

**Causes and Effects of Changes in Stratospheric Ozone: Update 1983* (National Academy Press, Washington, D.C., 1984).



One scenario

Time dependence of the vertical distribution of ozone concentration as calculated by Donald Wuebbles of Lawrence Livermore National Laboratory.

new techniques to demonstrate that the rate constant for this reaction is actually 50 percent higher than the value that had previously been used.

Another example is the reaction

$$OH + HO_2NO_2 \rightarrow H_2O + NO_2 + O_2$$

which leads to a net decrease in ozone loss. This reaction was believed to be minor, but a determination of the rate showed that it is fast enough to be very important. Adjustments have been made to several other rate constants also.

Another set of experiments has shown that the absorption of ultraviolet light of wavelengths from 200 to 242 nanometers is about 25 to 50 percent smaller than had been determined in earlier laboratory experiments. The photolysis reaction

$$O_2 + h\nu \rightarrow O + O$$

is the immediate source of the free oxygen atoms that combine with oxygen molecules to form ozone. Very small absorption coefficients, such as that of oxygen for ultraviolet light, are extremely difficult to measure: it requires either very long optical pathlengths (many kilometers) through the sample or high oxygen pressures. Long pathlengths tend to be impractical and high oxygen concentrations give inflated values for the absorption coefficient because of interactions between oxygen molecules. The new value was obtained by actual measurements in the atmosphere. Even with the lowered absorption coefficient, virtually all ultraviolet light is removed from sunlight, but the radiation penetrates deeper into the atmosphere than had been expected and ozone is formed at different altitudes.

If the mathematical models include only the continued release of CFC's at present rates, they predict a significant depletion of ozone. But the concentrations of several other trace gases in the atmosphere are also increasing. The concentration of CFC-22 (CHF_2Cl), for example, is small but is increasing by more than 6 percent per year. The concentration of methylchloroform (CH_3CCl_3) is about 60 percent that of either CFC-11 or CFC-12 and is growing by 9 percent per year. And the concentration of carbon tetrachloride is now about the same as that of CFC-11 and is growing by about 2 percent per year. A sharp increase in the release of CFC-22 or a continued increase in the release of methylchloroform or carbon tetrachloride could cause significant decreases in ozone. Increased use of supersonic jets would also result in depletion of ozone because of injection of N_2O into the stratosphere.

Other trace gases could have the opposite effect. Projected release of NO and NO_2 into the atmosphere by subsonic jets is expected to increase ozone by about 1 percent. The concentration of methane is increasing by about 2 percent per year; a doubling of methane would increase the ozone concentration by about 3 percent. The concentration of carbon dioxide is increasing by about 0.6 percent per year and a doubling would increase ozone by 3 to 6 percent.

When the effects of all these trace gases are incorporated into the models, several conclusions can be drawn. If it is assumed that releases of CFC's, methylchloroform, and carbon tetrachloride remain constant at 1980 levels, that N_2O increases at 0.2 percent per year, that CO_2 continues to increase by 0.6 percent per year, and that emissions of NO and NO_2 from airplanes increase by a factor of 6 by 1990, the models predict that the concentration of ozone will not change significantly.

But those assumptions are not realistic. If it is assumed that release of methylchloroform and carbon tetrachloride continues to increase at the present rate, then the current estimate of 2 to 4 percent depletion results. But even that may be unrealistic, for the most important assumption is that release of CFC's will continue at the 1980 rate. Four years ago that might have been a valid assumption, but no longer.

The simple fact is that CFC's have very beneficial uses. Virtually nothing else is as efficient in refrigeration and air-conditioning units and as free from immediate hazard. CFC's used in foaming polymers also have nearly ideal insulating properties and are nonflammable. Industry and environmentalists may also have been swayed by the progressively less pessimistic reports issued by NAS.

As a consequence, industrial production of CFC's in the Western world, which dropped significantly between 1975 and 1980, has begun rising once again. Eastern bloc countries have apparently never reduced their production of CFC's, so worldwide use is now rising. If it continues to rise, says Kaufman (a member of the panel that prepared the report), the effects from CFC's could overwhelm those of other trace gases and a 10 to 12 percent reduction in ozone might be the result.

Even if CFC production should merely remain constant, the mere fact that the total atmospheric concentration of ozone will remain more or less constant is not necessarily reassuring. In fact, most of the reactions that deplete ozone tend to be centered in the stratosphere, while those that restore it are centered much closer to the ground in the troposphere. The net result is that the concentration of ozone at 40 kilometers might decrease by as much as 20 percent (a 3 percent decrease has already been observed), while the concentration at 10 kilometers could increase by a little more than 21 percent. At the very least, the panel argues, "increasing concentrations of ozone in the lower atmosphere . . . pose potential risks to air quality over the surface of the globe." Perhaps more important, these changes could have significant effects on atmospheric transport processes and weather. They may also have an impact on the magnitude of the greenhouse effect that is predicted to occur as a result of increasing CO_2 concentrations.

This will certainly not be the last word on chlorofluorocarbons. In particular, the current state of knowledge about the chemistry of the troposphere is probably about where stratospheric chemistry was perhaps 5 years ago. Most of the models that have been used for predicting ozone concentrations, furthermore, have been one-dimensional, considering only variations with height. As more sophisticated two- and even three-dimensional models are developed and implemented, it should be possible to obtain a much better picture of potential effects on climate and weather. The debate on CFC's thus has the potential to be carried into the next decade and potentially into the next century.—**THOMAS H. MAUGH II**