which estimates of the atmospheric sulfur component entering river runoff range from $50{,}000 \times 10^9$ to $70{,}000 \times 10^9$ g/year.

Berner (*3*) also gives an estimate of the annual rate of emission of volcanic sulfur (from volcanoes, fumaroles, and hot springs) which enters rivers. This amounts to about 8000×10^9 g/year.

Table 2 shows that the total rate of runoff of sulfur from rivers estimated by summing the components is in quite good agreement with the rate estimated by the use of Livingstone's (*4*) data corrected for the present rate of fertilizer application. The two numbers are not wholly independent, however, because the sulfur cycles (*5–7*) are artificially balanced.

On the basis of information presented here, it may be seen that, in fact, the rate of mobilization of sulfur in the environment by man is approximately twice that by natural weathering processes. Furthermore, it is evident that the proportion of sulfur in the global environment from pollution sources is increasing. Because of the errors in the computations, the report by Bertine and Goldberg gives the impression that the rate of anthropogenic sulfur emissions is much smaller (by a factor of 40) than the weathering rate. Clearly this is not the case.

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In his criticism of our report Friend (*1*) has overlooked our basic premise in the development of the amounts of material potentially mobilized about the environment as a result of the combustion of fossil fuels: "Thus far, we have assumed that the elements are accommodated in either the fly ash or the bottom ash during the combustion process and are not introduced as volatile species to the atmosphere. Clearly, selective volatilization can introduce the readily distillable materials into the atmosphere at concentrations far above those indicated in Table 1" (*2*, p. 233). We reemphasized our concern on this point later in the report: "Such elements could be introduced in amounts as much as 20 times greater than those shown in Table 1, if the effects of selective volatilization override the two correction factors" (*2*, p. 234).

Our intent in the report was to demonstrate the impact of fossil fuel combustion on a large number of elements, not to treat each element individually. Obviously, such elements as sulfur, phosphorus, and arsenic will be dispersed in much higher amounts than indicated in table 1 of (*2*) in view of the ready volatility of their compounds.

It is curious that Friend does not cite the paper by Koide and Goldberg (*3*) which precedes the paper given as his reference 3, and treats the dispersion of sulfur in detail. In the paper by Koide and Goldberg the calculation given in Friend's table 1 is made, and, in addition, an argument is presented that the combustion of fossil fuels is now introducing slightly more sulfur into the atmosphere than such natural processes as volcanism and the oxidation of hydrogen sulfide derived from organic matter. This latter process cannot be neglected in any consideration of man's impact on the sulfur cycle such as that given by Friend.

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20 January 1972

An Improved Treading Device for Tethered Insects

A useful actograph ("orientometer") has been described recently (*1*), which employs a revolvable Ping-Pong ball that is supported on three ball bearings (*2*) as the moving substrate on which a tethered insect can walk. A drawback of the apparatus is the relatively high friction at the bearings, which creates drag and slows the responsiveness of the ball and which may lead to premature exhaustion of the insect. Even larger, potentially more powerful insects are handicapped, because they rest with their weight on the ball and add to the load on the bearings. Moreover, on its three-pronged prop, the ball is unstable and a larger insect suddenly activated may simply kick it away. These limitations can be overcome by supporting the ball on an air cushion, generated by directing an airstream through a funnel onto the ball from beneath (Fig. 1). If the rate of airflow is adjusted to compensate precisely for the added weight of the insect, the ball can be maintained in suspension, stably afloat, freely rotatable, and almost free of drag. Thus modified, the apparatus lends itself well to measurement of directional tendencies and response times of tethered insects (*3*).

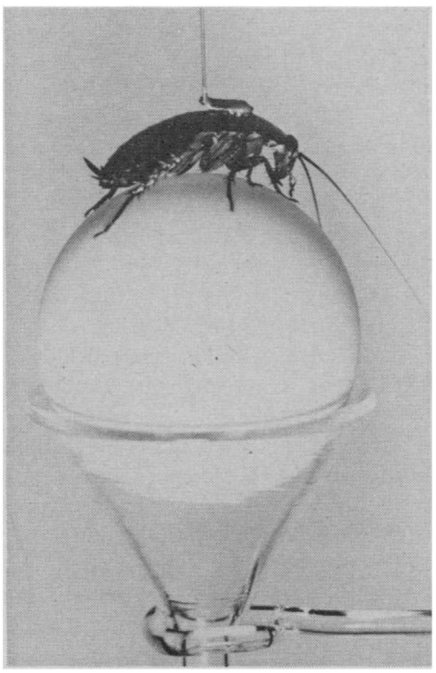

Fig. 1. Tethered insect "walking" on a revolvable Ping-Pong ball suspended on an air cushion (the airstream, directed on the ball from beneath, "floats" the ball just above contact with the funnel). The wire tether glued to the insect is inserted loosely (*1*) into the open end of a capillary tube.

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Reference and Notes

1. W. B. Kerfoot, *Science* **162**, 477 (1968).
2. They are tips of ball-point pens.
3. Supported by NIH grant AI-02908 to T. Eisner.

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