less, and the deep western boundary current therefore stands out clearly. Within the current itself there is evidently a concentration of flow very close to the ridge, because the isotherms descend 200 to 300 m within about 30 km of it—and this is virtually the total depth change for isotherms in the interval 3000 to 3500 m.

Of the other properties measured, the silica values most usefully supplement and clarify the temperature structure. In the western part of the West Australian Basin a slight silica maximum was generally found in the depth interval 3 to 4 km, the maximum values being about 130 μg-atom/liter or a little greater, as contrasted with values of 120 to 125 μg-atom/liter in the bottom water. Immediately adjacent to the Ninetyeast Ridge, however, where the isotherms descend so abruptly, the values in the interval 3 to 4 km are lower and the maximum is absent. This pattern is strikingly like that observed in the deep western boundary current of the subtropical South Pacific (*4*), although on a reduced scale. The latter distribution has been explained (*5*) in terms of a boundary-current field having (i) a concentrated northward flow close to the western boundary from about 2000 m to the bottom, carrying water from the Antarctic with a relatively low silica concentration; and (ii) a weaker flow farther to the east that is northward at great depth but southward above about 3600 m, transporting water with a relatively high silica concentration from the North Pacific in the interval 2000 to 3600 m. Since the deep northern Indian Ocean, like the North Pacific, is a source of high-silica water (*3*), the silica distribution observed in the West Australian Basin suggests a qualitatively similar velocity structure for the Ninetyeast Ridge current.

Geostrophic estimates of the volume transport of the current depend, of course, on the choice of a "level of no motion." If the meridional velocity component is assumed to be zero at 3000 m, just above the levels where isotherms slope downward to the east, then the density field gives a net transport of 7×10^6 m^3/sec northward, through a section extending from 3000 m to the bottom, and 600 km to the east of the ridge. The silica distribution, however, suggests a more likely surface of zero velocity as lying at 3000 m within about 30 km of the ridge and at 3700 m (just below the silica maximum) farther to the east. Calculated on this basis, the net transport below the zero-velocity surface, and, again, within 600 km of the ridge, works out to be 4×10^6 m^3/sec (northward). Both figures are comparable to previous estimates (*2*) of the transport of the deep Madagascar current: 4 to 5×10^6 m^3/sec. The maximum calculated speed in the Ninetyeast Ridge current is found at the base of the zone of steeply sloping isotherms adjacent to the ridge and is 6 cm/sec.

The scheme of deep circulation originally proposed by Stommel and Arons (*1*) postulated boundary currents only along the western sides of oceans because, for simplicity, it disregarded the ridge systems that divide oceans into multiple basins. If these ridges rise high enough above the ocean floor, however, they can prevent deep flow between the basins and require separate circulation systems in them. It is then a consistent refinement of the theory that each such basin should have its own western boundary current; and the Ninetyeast Ridge current, supplying the deep water of the West Australian Basin, is clearly one. Whether the Central Indian Basin is also supplied by that current—some part of it perhaps passing across the Ninetyeast Ridge—is not yet clear.

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Wood Versus Fossil Fuel as a Source of Excess Carbon Dioxide in the Atmosphere: A Preliminary Report

Abstract. *If the amounts of wood consumed in deforestation to increase agricultural land and as firewood in underindustrialized countries are added to the amount consumed by the money economies as forest products, the estimates of the net amount of wood removed from the biosphere in this century should be revised upward. The per capita ratio of the weight of carbon from net wood burned to the weight of carbon from fossil fuel burned in this century has been at least 0.1 and may have approached 1.0.*

The recent reports of a worldwide shortage of firewood (*1*) led to the suggestion that the amount of wood burned may have been underestimated; particularly questionable is the conclusion that the combustion of fossil fuel was the major cause of the buildup of CO_2 in the atmosphere (*2, 3*). Garrels *et al.* (*4*, p. 308) have recently reviewed the CO_2 cycle through geologic time, stating that "we hope someday to be able to simulate the real world with a model sufficiently complex that the results obtained from it will have some valid predictive value." Even the primary production of the biosphere is not sufficiently well understood (*5*). A preliminary reexamination of the scant data available on deforestation indicates that there has been a substantial underestimation of the net CO_2 produced from deforestation. This underestimate arises from an overemphasis on data from routine economic statistics and an inaccurate extrapolation to the whole world of the more comprehensive data from the few highly industrialized countries with money economies.

Table 1 contrasts the annual per capita consumption of fossil fuels and wood in the United States and Brazil for 1970. The direct commercial usage estimates in the money economies are well documented (*6, 7*). In the United States the net loss of forest land to agricultural purposes in the period from 1962 to 1970 was estimated by the U.S. Forest Service to be 500,000 acres (2000 km^2) per year (*6*). The forest land lost to urbanization, the construction of highways and reservoirs, and the increased recreational uses of forests is as difficult to estimate as the amount of wood cut and burned by the rural poor, including moonshine distillers. At the upper limit, we estimate that, excluding the commercial forest products industry in the United States, some 0.2 metric ton of carbon in wood are lost annually per capita in clearing and noncommercial activities. If we take this upper limit of 0.2 ton per capita and assume that the managed forests in the United States are near a steady-state condition (plantings equal cuttings plus losses), it would appear that the carbon from net wood loss in the United States is at most only 2 percent or so of that from fossil fuels. Such, however, is not the case in most of the world.

In Brazil (see Table 1), at least 75 percent of the direct cutting is for firewood and the per capita consumption of other forest products is low (*8*). By contrast, the clearing of forests for agriculture and pastureland has been carried out on a vast scale in this century and is now proceeding at an accelerated rate in the Amazon forests. In 1910, 60 percent of the area of the State of São Paulo (250,000 km^2) was covered with virgin forest; by 1950, only 20 percent was still so forested and clearing was continuing at only a slightly slower rate (*8*). In the State of Paraná in the period from 1953 through 1963, an average of over 3 percent of the 1953 forest area of 65,000 km^2 was cleared each year with the burning of the felled trees, causing an annual economic loss estimated at 25 billion cruzeiros [currently equal to more than U.S. \$2.5 billion (*9*)]. Inventories based on aerial photography in these two relatively small states lead to a very minimal estimate of an annual consumption from clearing of 2 tons of carbon in wood per capita in 1970. For Brazil as a whole, including the large-scale forest clearing in the Amazon, the estimate (Table 1) of an annual consumption of 3.0 net tons of carbon in wood per capita from clearing must be considered a minimum that may be too low by as much as an order of magnitude. Reforestation in Paraná is estimated at 10 percent of the cuttings (*8*), and only in very recent years has reforestation reached 20 percent of the cuttings in São Paulo. The replacement estimate for Brazil of 1.0 ton per capita per year (Table 1) must be considered a maximum, and hence the ratio of the net wood loss to the fossil fuel loss of 5.0 must be considered a minimum.

Table 1. Estimates of the annual per capita consumption of carbon wood and fossil fuels for 1970 (in metric tons).

Source of carbon	United States	Brazil
Direct wood cuttings		
Energy	0.3*	1.0
Material	1.2	0.3
Residues	0.3	0.2
Clearing of wood	0.2†	3.0†
Total	2.0†	4.5†
Replacement of wood	1.8†	1.0†
Net loss	0.2 max.†	3.5 min.†
Fossil fuel	9	0.7
Wood net loss/ fossil fuel loss	0.022 max.†	5.0 min.†

*For the most part, industrial use at sawmills and paper mills. †Estimates.

In 1970 the world consumption of fossil fuels was close to 1.2 tons per capita per year (the Brazilian figure is below the world average because Brazilian planners estimate that two-thirds of the population is economically inactive and because Brazilian power production is 90 percent hydroelectric). The consumption of firewood in Brazil (1.0 ton per capita per year) is approximately equal to the consumption estimated for several unindustrialized countries (*1, 10*). Per capita consumption of fuel, like per capita consumption of food, cannot be reduced below certain levels. In order that an individual obtain the needed 2000 kcal of energy from food per day, it is necessary in much of the world to consume 3 to 4 kg of wood per capita per day to cook the rice, wheat, and other foods and also to provide the heat for modest amounts of metalworking, ceramic firing, distilling, and other similar cottage industries. Rapidly increasing population has depleted not only food supplies but also wood supplies, both of which lead to deforestation. Although the net global loss is difficult to estimate, the net loss in Brazil alone suggests that the minimum global loss is 0.1 ton of carbon from wood per capita per year. It would appear only prudent to conclude that the net global loss is between 0.1 and 1.0 ton of carbon from wood per capita per year. It follows that the CO_2 produced from net deforestation or the draining of the "cellulose reservoir" is essentially equal to the CO_2 that has been produced by the combustion of fossil fuel throughout this century.

The cellulose reservoir or commercial timber has been estimated to represent 20 to 25 percent of all photosynthesized material (*3*). The relationships of this cellulose reservoir to the other reservoirs in immediate contact with the atmosphere are diagramed in Fig. 1, in which the following assumptions are made: (i) that the exchange of CO_2 and dissolved hydrocarbons between the upper and lower ocean is too slow to have exhibited any significant response to the burning of fossil fuel and wood during this century [for an opposing hypothesis, see Oeschger *et al.* (*11*)]; (ii) that the substantial biomass represented by such forests as the Amazon and Mato Grosso are in a steady-state condition and cannot substantially add more biomass, including cellulose, per unit area; (iii) that the CO_2 accumulated in the atmosphere in this century is equal to an increment of about 15 percent (280 to 323 parts per million or some 5×10^{15} moles); (iv) that the amount of CO_2 produced from the burning of fossil fuel in this century is about four times the atmospheric increment; (v) that in this century the net drain of the cellulose reservoir produced at least 25 percent of the amount of CO_2 derived from fossil fuel combustion; and (vi) that most of the excess CO_2 from fossil fuel and net wood burning has gone into rapid circulation between the atmosphere and the terrestrial biomass with a net lowering of the mean residence time of carbon in the land biomass.

Figure 1 represents only one description or model of the short-term (10 to 100 years) circulation of CO_2 into and out of the atmosphere. Alternative models (*12*), including the removal of CO_2 to the deep ocean (*11*), are also viable hypotheses within the limitations of the scant data. The model shown in Fig. 1, which illustrates the net loss of carbon from the biosphere over the long term, accounts for the fact that the biosphere has removed most but not all of the excess CO_2 produced by the combustion of fossil fuel and unreplaced wood, producing an essentially nonequilibrium condition fundamentally related to rapid population growth and a reduction in the number of

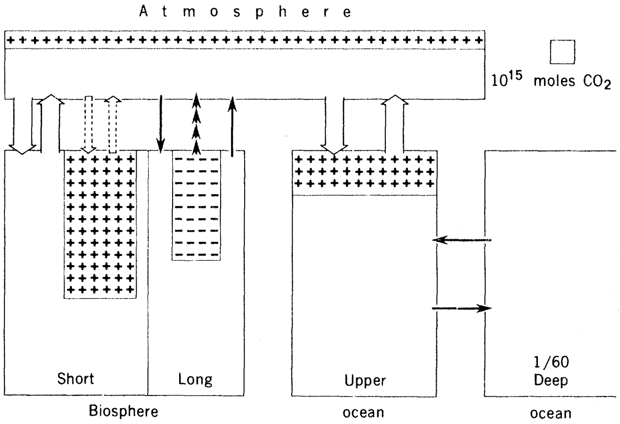

Fig. 1. Simplified model of the CO_2 cycle. The short-residence-time biosphere, including the oceanic biomass, is hypothesized to be increased in mass (shown by +) and in photosynthesis and respiration fluxes (dashed arrows). The long-residence-time biosphere or cellulose reservoir is hypothesized to show a net loss (shown by −) through an unbalanced transfer of CO_2 to the atmosphere (short arrows). According to this greatly simplified model, the increased CO_2 concentration in the atmosphere (shown by +) is in secular chemical equilibrium with the enlarged short-residence-time biosphere. Reservoir size is proportional to area in units of 10^{15} moles of CO_2, as shown in the scale at the upper right), except fot the deep ocean reservoir, which is 60 times larger than shown.

trees extracting CO_2 from the atmosphere. This model implies that, without concurrent deforestation in this century, the buildup of atmospheric CO_2 in the atmosphere would have been very minor at best. The draining of the cellulose reservoir has no effect on earlier interpretations of the Suess effect in which the ^{12}C and ^{13}C from fossil fuel dilute the ^{14}C in the atmosphere; on the average, the ^{14}C in the carbon of the cellulose reservoir is equal, within experimental error, to that in the atmosphere.

One may obtain refined estimates of the amounts of CO_2 released to the atmosphere by the burning of wood in the past century by analyzing certain polycyclic aromatic compounds contained in glacier ice or sediments. Polycyclic aromatic hydrocarbons formed during nonindustrial burning of wood are distinct from those formed by either living organisms or the burning of fossil fuel (*13*); hence, they may provide a useful molecular tracer.

Prudent concern for the future would suggest the need for (i) further reexamination of the quantitative aspects of net deforestation and wood burning as they affect the amount of CO_2 in the atmosphere and atmospheric inputs and outputs (*14*); (ii) reexamination of the possible effects of the buildup of atmospheric CO_2 (*15*); and (iii) evaluation of the potential benefits of reforestation, not only for esthetic purposes but also as a way of stabilizing the wood biomass and atmosphere, providing a steady-state source of material and fuel.

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Prevention of Autoimmunity in Experimental Lupus Erythematosus by Soluble Immune Response Suppressor

Abstract. *Young NZB/W mice, treated with injections of soluble immune response suppressor (SIRS) (supernatant from mouse spleen cells exposed to concanavalin A), showed decreased immunoglobulin levels, less antibody to cell nuclei, less proteinuria, and less renal pathology as compared with NZB/W mice receiving a control preparation. Thus, SIRS administration beginning at an early age appears to be an effective therapy of the autoimmune disease in NZB/W mice.*

NZB/W mice have been used as an animal model of human systemic lupus erythematosus (SLE) because animals of this strain exhibit pathologic and immunologic changes characteristic of this disease. Thus NZB/W mice develop antibodies to cell nuclei (antinuclear antibodies) (*1*), occasional Coomb's positive hemolytic anemia (*2*), immune complex glomerulonephritis (*1*), proteinuria (*1*), and vasculitis (*1*). As a result of the similarity between NZB/W mice and patients with SLE, an understanding of the mechanism responsible for the autoimmunity in NZB/W mice as well as the development of a rational therapeutic scheme for the autoimmunity in NZB/W mice is likely to have important consequences for the understanding and treatment of human SLE.

Evidence has accumulated implicating loss of suppressor T cell activity as an important underlying factor in the pathogenesis of the autoimmune disease in NZB/W mice (*2, 3*). This evidence includes data obtained in our laboratory (*4*) showing that suppressor T cells can be induced by concanavalin A in cultures of spleen cells obtained from normal animals and from young NZB/W animals, but not from concanavalin A–stimulated spleen cells obtained from adult NZB/W animals. Moreover, normal cells and cells from young NZB/W animals could be induced by concanavalin A to form a soluble immune response suppressor, whereas adult NZB/W spleen cells produced much less of this material. Finally, although spleen cells from young and adult NZB/W mice differ in their suppressor cell potential, cells from both sources could respond equally to suppressor signals in that concanavalin A–exposed normal cells or supernatants derived from such cells caused equivalent suppression of pokeweed mitogen-stimulated immunoglobulin synthesis by young and adult NBZ/W cells. These studies, in conjunction with others, point to the fact that NZB/W mice lose suppressor T cell activity as they age, yet retain the capacity to respond to negative regulatory signals. These observations suggest the possibility that such mice could be treated with the suppressor T cell product, soluble immune response suppressor (SIRS). Accordingly, we set up a clinical trial to determine whether the in vivo administration of SIRS could prevent the development of the manifestations of autoimmunity that are observed in untreated NZB/W mice.

A group (60) of 4-week-old female NZB/W F_1 mice (NZB female × NZW male animals) were segregated into four subgroups. Group A was treated with the supernatant of concanavalin A–activated spleen cells from adult BALB/c animals (BALB/c SIRS); group B was treated with the supernatant of concanavalin A–activated spleen cells of young (4-week-old) NZB/W spleen cells (NZB/W SIRS). Group C was a control group to validate the adequacy of the removal of concanavalin A from the supernatants. The animals of this group were treated with supernatants of BALB/c spleen cells exposed to concanavalin A for only a few minutes. Finally, the animals in group D were untreated. Animals treated with supernatants of concanavalin A–activated spleen cells (SIRS) were injected intraperitoneally three times weekly with 0.5 ml of absorbed supernatants of the cultured spleen cells prepared according to a method adapted from that of Rich and Pierce (*5*). Every 6 weeks three animals (so designated from the beginning of the study) in each group were killed and studied. The effects of administration of supernatants of spleen cells incubated with concanavalin A (SIRS) on the se-