munologically. In addition to RSVα, noninfectious forms of mouse sarcoma-leukemia virus have been reported to have very low levels of DNA polymerase (*13*). None of the infectious forms has been found deficient in this enzyme.

H. HANAFUSA
Public Health Research Institute of
the City of New York,
New York 10016
D. BALTIMORE, D. SMOLER
Department of Biology, Massachusetts
Institute of Technology,
Cambridge 02139
K. F. WATSON, A. YANIV
S. SPIEGELMAN
Institute of Cancer Research,
Department of Human Genetics and
Development, Columbia
University College of Physicians and
Surgeons, New York 10032

References and Notes

1. H. Hanafusa and T. Hanafusa, *Virology* **34**, 630 (1968).
2. T. Hanafusa, H. Hanafusa, T. Miyamoto, *Proc. Nat. Acad. Sci. U.S.A.* **67**, 1797 (1970).
3. H. Hanafusa and T. Hanafusa, *Virology* **43**, 313 (1971).
4. W. S. Robinson and H. L. Robinson, *ibid.* **44**, 457 (1971).
5. D. Baltimore and D. Smoler, *Proc. Nat. Acad. Sci. U.S.A.* **68**, 1507 (1971).
6. S. Spiegelman, A. Burny, M. R. Das, J. Keydar, J. Schlom, M. Travnicek, K. Watson, *Nature* **228**, 430 (1970).
7. Abbreviations: Poly(A), polyadenylate; poly(C), polycytidylate; poly(dT), polydeoxythymidylate; poly(dG), polydeoxyguanylate; dTMP, deoxythymidine monophosphate; dTTP, deoxythymidine triphosphate; dATP, deoxyadenosine triphosphate; dGTP, deoxyguanosine triphosphate; dCTP, deoxycytidine triphosphate; IgG, immunoglobulin G.
8. L. A. Loeb, *J. Biol. Chem.* **244**, 1672 (1969).
9. K. F. Watson, R. C. Nowinski, A. Yaniv, S. Spiegelman, *J. Virol.*, in press.
10. R. C. Nowinski, K. F. Watson, A. Yaniv, S. Spiegelman, in preparation.
11. D. L. Kacian, K. F. Watson, A. Burny, S. Spiegelman, *Biochim. Biophys. Acta* **246**, 365 (1971).
12. A. Weissbach, A. Bolden, R. Muller, H. Hanafusa, T. Hanafusa, *J. Virol.*, in press.
13. P. T. Peebles, D. K. Haapala, A. F. Gazdar, *ibid.* **9**, 488 (1972).
14. S. Spiegelman, A. Burny, M. R. Das, J. Keydar, J. Schlom, M. Travnicek, K. Watson, *Nature* **227**, 563 (1970).
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Polychlorinated Biphenyl Residues: Accumulation in Cayuga Lake Trout with Age

Abstract. *The concentration of polychlorinated biphenyls was shown to progressively increase with maturity in a series of lake trout. The presence of these compounds was determined by column chromatographic isolation, specific detector gas chromatography and mass spectrometry. The relation between fish age and the concentration of polychlorinated biphenyls was highly significant.*

Residues of polychlorinated biphenyls (PCB's) have been reported in fish (*1*), and general environmental contamination by these compounds has been reviewed (*2*). The concentration of DDT residues in a series of lake trout from Cayuga Lake in Ithaca, New York, was found to be proportional to their age (*3*). Since PCB's are similarly stable, fat-soluble compounds, analysis for them was performed on the same series of fish.

The fish were netted in October 1970. Their ages were accurately known, because the fish are annually stocked as yearlings and distinctly marked as to year class. Without evisceration, each fish was mechanically chopped, ground, and thoroughly mixed. Fish samples (5 g) were dried and extracted with hexane in a Soxhlet apparatus for 3 hours. The hexane extracts were concentrated, and PCB's were separated from DDT residues and other constituents by adaptations of the methods (*4*) involving sulfuric acid partitioning and column chromatography on silica gel. Final analysis was made by electron affinity gas chromatography with a column 30 cm long, consisting of 10 percent DC-200 on 100- to 120-mesh Gas-Chrom Q and operated at 185°C. The concentration was estimated by the method of Risebrough (*5*), in which the response of each PCB isomer is taken as equal to that of the corresponding weight of *p,p′*-dichlorodiphenyldichloroethylene (*p,p′*-DDE). This method was sensitive to about 0.25 part per million (ppm) of PCB's in the fish. Analysis of PCB's in five portions of the same fish were 6.4, 6.0, 5.6, 5.6, and 5.3 ppm. The standard deviation for these analyses is 0.427.

Table 1 lists the concentrations of PCB's in the lake trout as a function of their age, length, and weight. The correlation coefficient for PCB concentration as a function of age was 0.86 and was highly significant. The correlation coefficients relating PCB concentration with length and weight for fish 2 years and older were 0.85 and 0.80, respectively. The weights and lengths of the year-old trout were not recorded. The relation between the concentration of PCB's in the lake trout and their age is shown in Fig. 1; the curve represents the best fit of the data and has the equation:

$$\mathrm{PCB} = 1.031\, e^{0.259a}$$

where *a* is age. Figure 2 shows gas chromatograms of PCB's in a 12-year-old lake trout and of Aroclor 1254 standard (a mixture of chlorinated biphenyls containing 54 percent chlorine) to illustrate the similar peak retention times. The relative peak heights of individual PCB isomers in the chromatogram did not vary with age of the fish. This would indicate that there is no selective metabolism or storage of specific PCB isomers as the fish mature. Combined gas chromatography–mass spectrometry was used to verify the presence of the various PCB isomers in a 12-year-old lake trout (PCB's, 26.2

Table 1. Residues of PCB's in Cayuga Lake trout as a function of maturity; J, juvenile.

Age (years)	Sex	Length (cm)	Weight (g)	PCB (ppm)
1	J			0.6
1	J			1.6
1	J			0.5
1	J			1.2
2	J	27.7	181	2.0
2	J	28.7	226	1.3
2	J	33.5	407	2.5
3	J	44.5	815	2.2
3	J	44.5	725	2.4
3	J	41.1	770	1.2
4	J	53.8	1310	3.5
4	J	50.3	1160	4.1
4	J	55.1	1359	5.1
5	M	61.0	2030	5.7
6	M	63.5	2440	3.4
6	M	66.4	2850	9.7
6	F	68.3	2310	8.6
7	M	63.5	2260	4.0
7	M	68.9	3300	5.5
7		59.7	1990	10.5
8	F	75.2	3390	17.5
8	M	71.6	2805	13.4
8	F	69.0	3300	4.5
9	F	71.2	3390	30.4
11	M	80.3	4200	12.4
12	M	71.6	2535	13.4
12	M	75.5	3120	26.2
12	F	70.6	3440	7.4

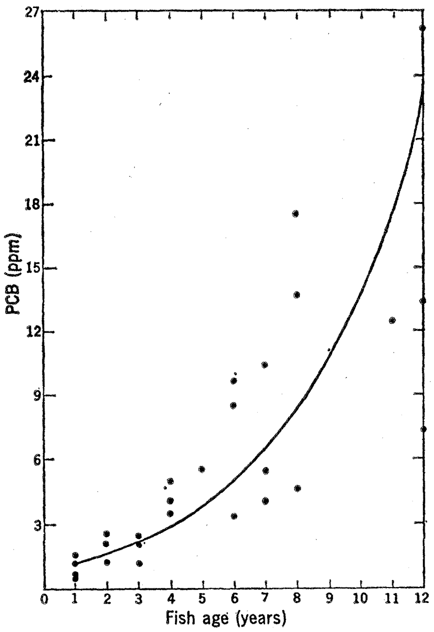

Fig. 1. The concentration of PCB's in Cayuga Lake trout as a function of age.

ppm). The mass spectra obtained from both a Perkin-Elmer 270 and a Finnigan 1015 quadrapole gas chromatograph–mass spectrometer were essentially identical with the mass spectra of the corresponding isomers of Aroclor 1254 standard.

There are many sources of PCB's in the environment, and it is not known what combination of these leads to contamination of Cayuga lake trout. The increase in PCB concentration with trout age is the same trend noted for DDT residues in this series of fish. The larger variation in PCB concentrations among individual 11- or 12-year-old fish may be due to greater differences among foraging, metabolic, and excretory capabilities of these older fish.

CARL A. BACHE
Pesticide Residue Laboratory, Cornell University, Ithaca, New York 14850
JAMES W. SERUM
Department of Chemistry, Cornell University
WILLIAM D. YOUNGS
Department of Natural Resources, Cornell University
DONALD J. LISK
Pesticide Residue Laboratory, Cornell University

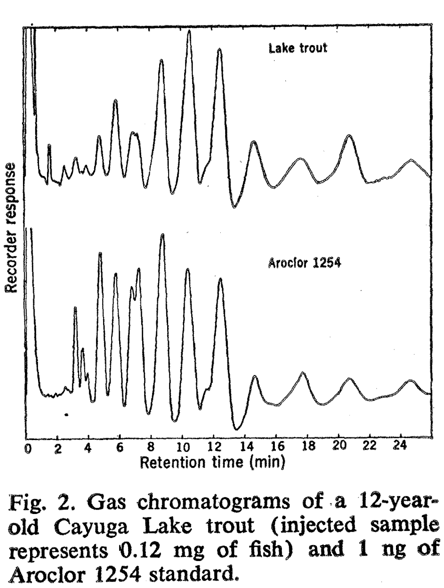

Fig. 2. Gas chromatograms of a 12-year-old Cayuga Lake trout (injected sample represents 0.12 mg of fish) and 1 ng of Aroclor 1254 standard.

References and Notes

1. J. H. Koeman, M. C. Ten Noever De Brauw, R. H. DeVos, *Nature* **221**, 1126 (1969); S. Jensen, A. G. Johnels, M. Olsson, G. Otterlind, *ibid.* **224**, 247 (1969); V. Zitko, *Bull. Environ. Contam. Toxicol.* **6**, 464 (1971).
2. D. B. Peakall and J. L. Lincer, *BioScience* **20**, 958 (1970); A. L. Hammond, *Science* **175**, 155 (1972).
3. W. D. Youngs, W. H. Gutenmann, D. J. Lisk, *Environ. Sci. Technol.* **6**, 451 (1972).
4. D. L. Grant, W. E. J. Phillips, D. C. Villeneuve, *Bull. Environ. Contam. Toxicol.* **6**, 102 (1971); D. Snyder and R. Reinert, *ibid.*, p. 385.
5. R. W. Risebrough, in *Chemical Fallout*, M. W. Miller and G. G. Berg, Eds. (Thomas, Springfield, Ill., 1969), pp. 5–23.
6. We thank G. A. Maylin for allowing use of the mass spectrometer.

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Atmospheric Carbon Dioxide: Its Role in Maintaining Phytoplankton Standing Crops

Abstract. *The rate of invasion of carbon dioxide into an artificially eutrophic Canadian Shield lake with insufficient internal sources of carbon was determined by two methods: measuring the carbon : nitrogen : phosphorus ratios of seston after weekly additions of nitrogen and phosphorus, and measuring the loss of radon-222 tracer from the epilimnion. Both methods gave an invasion rate of about 0.2 gram of carbon per square meter per day. The results demonstrate that invasion of atmospheric carbon dioxide may be sufficient to permit eutrophication of any body of water receiving an adequate supply of phosphorus and nitrogen.*

The atmosphere is frequently considered to be an insignificant source of CO_2 for phytoplankton production (*1*). Yet, by adding phosphate and nitrate we have been able to increase by almost two orders of magnitude the standing crop of phytoplankton in a small Canadian Shield lake which has extremely low concentrations of natural dissolved inorganic carbon (less than 0.6 mg/liter in the epilimnion in midsummer). The lake appears to have obtained the carbon necessary to produce the algal bloom from the atmosphere (*2, 3*). We report here measurements of the invasion rate of atmospheric CO_2 into the waters of this experimentally enriched lake. The results were obtained between 4 and 18 August 1970.

Lake 227, a small oligotrophic lake in the experimental lakes area of the Fisheries Research Board near Kenora, Ontario, was enriched with 0.34 g of phosphorus (as Na_2HPO_4) and 5.0 g of nitrogen (as $NaNO_3$) per square meter per year in 1969, and 0.48 g of phosphorus (as H_3PO_4) and 7.2 g of nitrogen (as $NaNO_3$) per square meter per year in 1970. The chemical additions were made in 17 weekly increments in 1969 and 21 weekly increments in 1970. The midsummer phytoplankton standing crop, as measured by chlorophyll *a* concentrations, increased from 1 to 3 μg/liter in 1968 (before fertilization) to 50 to 100 μg/liter after the additions. The uptake of CO_2 by this phytoplankton caused an increase in the *p*H of the euphotic zone from normal values of 6 to 7 to values ranging from 9.5 to 10.2 during summer, so that very little of the dissolved inorganic carbon was present as gaseous CO_2 (*2, 3*). The concentration of dissolved inorganic carbon ($\Sigma CO_2 = CO_2 + HCO_3^- + CO_3^{2-}$), however, did not change greatly after fertilization. The midsummer concentrations of total CO_2 in the epilimnion ranged from 20 to 50 μmole/liter (0.24 to 0.60 mg/liter). As a result of the high *p*H and low concentration of CO_2, the partial pressure of CO_2 in epilimnetic waters (calculated from the *p*H, total CO_2 concentration, and temperature) was far below that of the atmosphere (Fig. 1); this created a pronounced concentration gradient from the atmosphere into the lake.

It is impossible to calculate the magnitude of CO_2 exchange between the atmosphere and the water from the difference in partial pressures alone.