as a standard, was photographically enlarged to an arbitrary length of 10 cm, and the other patterns were adjusted to equivalent migration velocities by reference to their *T. dicoccum* homologs.

The tetraploid pattern invariably comprised two different series of protein fractions, a fast-moving one of broad, widely spaced bands beginning at −10.0 cm and a slow-moving one of narrow, closely spaced bands beginning at −4.0 cm. Owing partly to the degree of band separation obtained, the slower series provided inconclusive evidence on which to categorize the *Triticum* accessions, but in the fast series the tetraploids of the Emmer and Timopheevi groups were readily distinguishable.

The Syrio-Palestinian race of *T. dicoccoides* appears to be the progenitor of the Emmer group. On the basis of regular chromosome pairing in the F_1 hybrids among these tetraploids, there is general agreement that they are all of the genome constitution AABB. Their B genome is thought to have been derived from *Aegilops speltoides* Tauch.

Like *T. dicoccum* (Fig. 1), all species in the Emmer group, including the Syrio-Palestinian race of the wild tetraploid, gave a pattern with eight bands in the fast series with centers at −9.7, −9.0, −8.1, −7.4, −6.9, −6.0, −5.0, and −4.3 cm. Frequently the band at −8.1 and sometimes that at −6.9 were double. The species were essentially identical also with respect to the density of the individual bands. That at −9.0 was the densest, and those at −6.0 and −5.0 were the faintest, except in *T. carthlicum* and *T. turanicum*, where the band at −5.0 sometimes was nearly as dense as that at 9.0.

The Transcaucasian race of *T. dicoccoides* is apparently the progenitor of the Timopheevi group. Hybrids among these tetraploids also exhibit for the most part regular chromosome pairing, but F_1 hybrids between members of the Timopheevi and Emmer groups are highly sterile (*5*), owing to failure of pairing among chromosomes presumably of the second genome (*10*). For this reason, the Timopheevi tetraploids were originally assigned the presently controversial genome formula AAGG.

Like *T. timopheevi*, all species of the Timopheevi group, including the Transcaucasian race of *T. dicoccoides*, showed six bands in the fast series with centers at −9.7, −8.1, −7.4, −6.0, −5.5, and −5.0 cm. That at −7.4 was sometimes visibly double, and occasionally a band appeared at 4.0, or in *T. paleocolchium* at −4.3. All the species of this group also resembled *T. timopheevi* with respect to density of the successive bands.

The Emmer (AABB) and Timopheevi (AAGG) groups showed five or, infrequently, six homologous bands among the first ten band loci in the fast series. The bands at −9.0 and −6.9 were absent from all species of the Timopheevi group, and that at −4.3 was absent from all except *T. paleocolchium*. The bands at −5.5 and −4.0 were absent from all the Emmer species. These dissimilarities at four or five loci presumably are partly, but not wholly, attributable to the second genome. From many sampled accessions of the diploid wheats, the A genome showed only two bands (Fig. 1D) in the fast series, at about −5.0 and −4.0, but a recent southeastern Anatolian collection (Fig. 1E) showed an additional band at the critical locus −9.0.

Thus, the electrophoretic patterns confirm cytogenetic evidence that the Emmer and Timopheevi groups stem, respectively, from the Syrio-Palestinian (AABB) and Transcaucasian (AAGG) races of their wild progenitor, *T. dicoccoides*. Harlan and Zohary (*6*) suggested that Emmer (*T. dicoccum*) was domesticated in the upper Jordan Valley where the Syrio-Palestinian race is vigorous and abundant. However, Helbaek (*11*) reported both wild and cultivated Emmer (dating from 7000 B.C.) from archaeological excavations at Jarmo in Iraqi Kurdistan. The only accession of *T. dicoccoides* electrophoretically analyzed from that area was of the Transcaucasian race. Apparently, therefore, more information regarding the prevalence of the two races in the wild tetraploid populations of the Fertile Crescent is needed. Such information, readily obtainable by electrophoretic methods, could provide further clues to the area of first domestication of Emmer, as well as to the origin and affinities of the B and G genomes.

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Respiratory Exposure to Lead: Epidemiological and Experimental Dose-Response Relationships

Abstract. *Epidemiologic studies of blood lead levels in general and occupational groups show a logarithmic regression on estimated atmospheric exposure. Experimental results at the same and higher levels show a dose-response relationship which fits the same regression. The data imply that long-term increases in atmospheric lead will result in predictably higher blood lead levels in the exposed populations.*

Lead poisoning as an occupational hazard has been known and described for centuries. Its clinical manifestations include loss of muscle tone ("wrist drop"), intestinal colic, anemia, spontaneous abortions, and mental retardation. There is extensive literature on exposures and levels of lead in blood and urine above which toxic symptoms are likely to occur (*1, 2*). Specific biochemical lesions, such as that of blocking of delta-aminolevulinic dehydrase, are now known to affect porphyrin metabolism and the synthesis of hemoglobin (*3*). Recently reported are effects on the sodium and potassium activated adenosine triphosphatase of erythrocytes (*4, 5*).

The average daily intake of lead from food and beverages in the United States is now estimated at about 0.30 mg per day, with less than 10 percent of this being absorbed from the intestinal tract (*1*). In addition, some lead is inhaled and absorbed through the respiratory tract; the relative importance

of this respiratory exposure is a matter about which there is some dispute. It is to this question that the present paper is addressed.

Most lead which is ingested by the oral route is excreted in the feces; of the portion retained, most is stored in bone. Stored lead is generally regarded as inert, but it may be mobilized during periods of severe body stress. While there are important exceptions, the level of lead in the blood is generally taken as an indication of the amount of lead stored in the body. Blood lead levels do not always correlate well with biochemical evidence of metabolic effect.

Since the introduction of tetraethyl lead as a motor fuel additive in 1923 there has been a widespread dissemination of atmospheric lead from motor vehicles. This material, predominantly inorganic, is of relatively small particle size. In atmospheric samples in Berkeley, 50 to 80 percent by weight of atmospheric lead was found in particles smaller than 1.0 μ equivalent diameter. Systematic sampling for atmospheric lead has been carried out on a limited scale by the National Air Sampling Network since 1953. These data indicate that Los Angeles levels are about twice as high on the average as levels sampled from other metropolitan areas (*6*, *7*). While some atmospheric lead comes from such sources as industry, smelting, incineration, and combustion of coal, the strong correlations in many cities of atmospheric lead with motor vehicle traffic and with other motor vehicle pollutants, such as carbon monoxide, indicate that at least in urban areas motor vehicles are a major source of atmospheric lead (*8*).

In recent epidemiologic studies, cigarette smokers have been shown to have slightly but consistently higher values of blood lead than noncigarette smokers (*9*). This can be traced to lead and arsenic in leaf tobacco grown in soils on which lead arsenate sprays were formerly used. Cigarette smoke is also known to retard ciliary clearance of particles impacted in the tracheobronchial tree, which could tend to increased absorption of inhaled lead.

A considerable body of data on blood lead levels in general population samples became available recently with the publication of the *Survey of Lead in the Atmosphere of Three Urban Communities* (the "Three-City Study") (*6*). This study reports on a series of atmospheric lead measurements at a number of locations in Cincinnati, Los Angeles, and Philadelphia, and also reports blood lead measurements for various defined population groups in these cities.

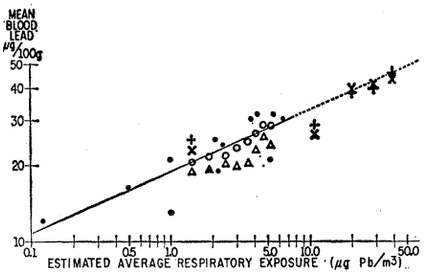

Fig. 1. Mean blood lead for epidemiologic and experimental respiratory exposures, with regression from epidemiologic data only. ●, Epidemiologic data; ×, +, ○, △, experimental subjects.

Table 1 summarizes the estimated exposures and mean blood lead derived from these and related sources. In general, fixed sampling sites were used; the extent to which they actually represent the population exposures is open to some question but these represent reasonable estimates.

As the report noted: "there appears to be an orderly progression in blood lead values according to the most likely concentration of lead in the atmosphere to which these groups were exposed." The data in Table 1 fit reasonably well to a logarithmic dose-response regression, Fig. 1.

Those who have studied experimental exposures to atmospheric lead have stressed the fluctuations in urine lead and blood lead levels which result from individual variability in the amounts of lead ingested with food and beverages. However, we are not dealing with individuals but with groups of people and the nature of dietary intake of lead in different urban areas of the United States could be presumed to be fairly similar. Also, there is no a priori reason why policemen, garage mechanics, and aircraft workers would be expected to have diets whose lead content varied in the same fashion as their respiratory exposures.

It is generally agreed that the amount of lead ingested in food and beverages by the average United States resident is in the neighborhood of 0.30 mg per day. It has been estimated that in Cincinnati the average adult has a respiratory ingestion of 30 to 40 μg per day. Kehoe has taken the sums of the two values for ingestion to arrive at an average adult intake of 0.33 mg per day (*10*). With respect to the formulation of possible standards for lead content for ambient air, he has stated (*11*): "So long as a larger quantity of lead is absorbed by the average

Table 1. Blood lead levels and estimated ambient air and occupational exposures of selected populations. Source: U.S. Public Health Service (*6*) and State of California, Department of Public Health, Environmental Hazards Evaluation Unit.

Type of population	Estimated exposure (μg/m^3)			Mean blood lead (μg/100 g)	
	Occupational	Ambient	Average*	Male	Female
Populations without known occupational exposures					
Remote California mountain residents		0.12		12	9
Composite rural U.S.		0.5		16	10
Suburban Philadelphia		1.0		13	13
Composite urban U.S.		1.0		21	16
L.A. aircraft workers		1.9		19	17
Pasadena city employees		2.2		19	12
Downtown Philadelphia		2.4		24	18
Populations with known occupational exposures					
Cincinnati policemen (all)	4.7	1.4	2.1	25	
Cincinnati traffic policemen	12.8	1.4	3.8	30	
Cincinnati auto test lane inspectors	14.8	1.4	4.2	31	
L.A. traffic policemen	16.5	2.2	5.2	21	
Cincinnati garage workers	21.1	1.4	5.5	31	
Boston Sumner Tunnel employees	44.5	1.1	6.3	30	

* For populations with known occupational exposures, the average is a weighted average of presumed occupational and ambient exposure. Ambient exposures are estimated only and were not necessarily measured at the same times and places at which the populations were exposed.

Table 2. Mean blood lead for experimental exposures to atmospheric lead (micrograms of lead per 100 g of blood). Source: Kehoe (*12*) and State of California, Department of Public Health, Environmental Hazards Evaluation Unit.

Respiratory exposure			Observed blood lead				Expected blood lead‡ (μg/100 g)
Exposure level (μg Pb/m^3)	Number of hours per week	Estimated average* (μg Pb/m^3)	Average blood lead (μg/100 g)	Number of periods†	Average blood lead (μg/100 g)	Number of periods†	
			Subject N.K.		Subject S.S.		
10	0	1.4	20.4	7	18.6	5	20.0
10	10.5	1.9	21.4	4	19.3	6	21.5
10	21.0	2.5	21.7	6	20.2	4	23.0
10	31.5	3.0	23.2	4	19.8	4	24.1
10	42.0	3.6	24.6	4	20.2	4	25.2
10	52.5	4.1	26.5§	4	23.0¶	4	26.0
10	63.0	4.6	28.5	4	25.5	4	26.7
10	73.5	5.2	28.5	4	23.8	4	27.5
			Subject L.D.		Subject J.S.		
150	0	1.4	22.4	21	24.5	13	20.0
150	10.5	10.7	26.0	4	28.5	4	32.8
150	21.0	20.0	39.2	4	38.2	4	38.2
150	31.5	29.3	40.8	4	39.8	4	41.9
150	42.0	38.6	43.5	4	44.8	4	44.8

* Estimated average for each experimental period assumes 1.4 μg of lead per cubic meter in ambient air between experimental exposure sessions. † Each period consists of 28 days with eight determinations of blood lead; only the average for these determinations was shown in the source. The averages given here are the averages of the period averages. ‡ Expected blood lead in micrograms per 100 grams of blood calculated from the regression derived from the Three-City Study data (*6*) ($\log_{10}$ blood lead $=$ 1.265 $+$ 0.2433 $\log_{10}$ atmospheric exposure). § A 14-day vacation interrupted exposure just prior to this experimental period. ¶ A 21-day vacation interrupted exposure just prior to this experimental period.

citizen from food and beverages than from the air . . . the control of atmospheric lead cannot be expected to obviate a potential lead hazard to the general population, since it does not concern itself with the principal source of such hazard."

However, various studies, including those done by Kehoe, have shown that less than 10 percent of lead ingested is absorbed from the gastrointestinal tract, while 25 to 50 percent of respiratory intake may be retained and absorbed. This would give estimated absorptions of less than 0.03 mg per day from oral ingestion and, for Cincinnati, 0.01 to 0.02 mg per day from inhalation. From this, it appears that the average quantity absorbed from the alimentary tract and that absorbed from the respiratory tract may be of similar magnitude. In addition, it appears that place to place variability in respiratory exposures may be greater than previously thought, with some persons receiving relatively large exposures. For example, in parts of Los Angeles total respiratory exposure may be double the amount estimated for Cincinnati.

Data were recently published on experimental exposures of four subjects to atmospheric lead for increasing numbers of hours per week (*12*). Results of exposures to both 10 and 150 μg/m^3 are shown in Table 2. The exposure to the lower levels is seen to be associated with a small increase in the blood lead levels in both subjects studied. Figure 1 shows the data from both tables plotted on a logarithmic scale. The line drawn represents the calculated regression *based on epidemiologic data alone*. It is clear that a good fit is obtained for the experimental data read from charts in Kehoe (*12*).

The close correspondence between the experimental and epidemiologic data makes it seem likely that the relation shown is one of general validity for populations having a dietary, beverage, and cigarette-smoking intake characteristic for American males. Such variations as are introduced by dietary fluctuations apparently are averaged out by taking adequately large populations or, in experimental studies, by taking a sufficiently large number of samples and sample periods. The duration of time during which respiratory exposure occurs, as a fraction of the total week, does not appear to be as important as the total respiratory dose. It is interesting to note that extrapolation toward lower exposures would indicate a substantial blood lead level even for respiratory exposures well below the lowest rural values observed; this suggests that about 10 μg of lead per 100 g of blood would be expected from alimentary lead alone. However, as with any regression, extrapolation must be cautiously interpreted.

The occupational groups included in these data are those exposed to motor vehicle exhaust. It does not necessarily follow that the exposure to lead in other occupations would necessarily fit this same pattern of relationship, since the particles may be sufficiently large that the proportion absorbed through the respiratory tract was smaller than with the particulate lead from motor vehicle exhaust.

It seems clear that for many urban residents the total quantity of lead absorbed from the respiratory tract is of the same order of magnitude as that absorbed from the gastrointestinal tract, that increased respiratory exposure within the range observed in community air pollution is capable of producing materially increased storage of lead in the body, as reflected in the blood lead level, and that further increases in atmospheric lead will result in higher blood lead levels in the population in a predictable relationship.

Effects on health of this increased storage may or may not be present. Studies in man looking for effects on specific enzymes such as delta-amino levulinic acid dehydrase and on red blood cell membrane Na-K activated adenosine triphosphatase are clearly indicated.

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