automobile repair shops, 0.13 mg., and in street air, 0.09 mg. to 10 cubic meters. Greenburg [22] has reported that 1.45 mg. of lead daily for two and one-half years has caused poisoning. Teleky [23] states that 1 mg. of lead daily for several months and Legge and Goadby [24] state that 2 mg. daily for several years will cause lead poisoning. While these figures may seem to vary considerably, it is true that lead in the form of vapor is more dangerous than as dust, and the circumstances under which the foregoing estimates were determined were not identical. Certainly it may be concluded that a daily dosage of from 1.5 to 2 mg. is distinctly hazardous and eventually will cause poisoning in most, if not all, individuals. In this connection it should be noted that when lead is in a molten condition fumes will be given off; the higher the temperature, the more fumes; also oxide will form on the surface and get into the air as dust.

CONCLUSION

It may be stated that lead poisoning is very prevalent, though most of it is mild. However, both mild and occasionally severe cases are commonly not recognized. Many cases are diagnosed as chronic appendicitis and even as gallbladder disease, with all too frequent surgical intervention. In connection with industrial hygiene studies, insurance company records show that, with respect to illnesses of more than seven days' duration among wage earners, respiratory diseases greatly outnumber gastro-intestinal diseases. When the ratio is inverted and one is confronted with a situation wherein the gastro-intestinal cases outnumber the respiratory cases, the possibility of lead poisoning should always be considered. JAMA 104:87-90, 1935

THE BIOCHEMICAL BEHAVIOR OF LEAD IN THE BODY

JOSEPH C. AUB, M.D.
BOSTON

In the last ten years, a great deal of work has appeared bearing on the biochemistry of lead. To combine this new knowledge with that summarized in a previous publication [1] is my purpose in this article.

In regard to absorption there is little important new evidence. The experience in industry confirms what has been found in the laboratory [1]—that lead which is inhaled is far more toxic than lead which is swallowed. Of course, it is likewise generally conceded that ingested lead is a hazard.

The form in which lead is transported in the blood stream is of practical as well as scientific interest, as it has a bearing in guiding intelligent therapy. The prevailing opinion had long been that lead was carried as an albuminate, but Fairhall's equilibrium experiments,[1] as well as our blood studies with Reznikoff,[1] convinced us that lead was precipitated in the bones as the very insoluble tertiary lead phosphate and carried in the blood as the more soluble di-lead phosphate. To this view Brooks [2] agreed, but Maxwell and Bischoff [3] and recently Kehoe and Thamann [4] have objected, largely on the basis that lead in the blood stream reacts more with red blood cells than does the phosphate. Maxwell and Bischoff [3] have produced some evidence that lead, when injected intravenously, is carried as a diphosphoglycerate, while Jowett [5] thinks that it forms a complex inorganic phosphate with calcium and chlorine. In a chemical system as complicated as blood plasma, an equilibrium of several such chemical compounds is not unreasonable. Any of these compounds might remain ionized and dispersed in the presence of plasma proteins. But whether it is transported as an inorganic or organic phosphate, it is obvious that lead in the blood stream can exert deleterious effects on body cells.

Of course, some absorbed lead is probably excreted (partly in the urine but mostly in the feces) without ever having been stored. There is a growing accumulation of data obtained by different chemical technics that indicate a small daily lead excretion in the urine in the vast majority of the people in this country and elsewhere.[6] The average result of these observations indicates a urinary excretion of lead of from 0.05 to 0.1 mg. daily in individuals with no unusual lead exposure. This urinary excretion represents lead that has been actually absorbed, but a large percentage of the lead found in the feces has probably never even been absorbed. Because of such repeated observations it must now be agreed that a qualitative demonstration of small quantities of lead in the excreta does not necessarily signify abnormal exposure. According to Barth,[7] a very small amount of lead may even be gradually accumulated in normal bones during advancing years (from 0.02 mg. found in infancy to 0.1 mg. per 3 Gm. of bone ash in the aged).

If larger quantities of lead are inhaled, swallowed or injected, excretion does not maintain an equilibrium, and lead becomes stored. But the extent of possible storage can be ascertained best when a known quantity of lead is injected intravenously. Millet,[8] Kehoe and Thamann,[9] and Aub and Smithwick [10] have shown that but little of this is excreted promptly. For example, the average of six of our cases, studied for forty-six days during the injection period, showed that only 69 mg. of lead was excreted in both the urine and the feces, although 473 mg. of lead as colloidal phosphate was injected intravenously.

22. Greenburg, L.; Schaye, A. A., and Shlionsky, H.: Pub. Health Rep. **44**: 1666 (July 12) 1929.
23. Teleky, L.: Arch. f. Gewerbepath. u. Gewerbehyg. **5**: 132-137, 1933.
24. Legge and Goadby: Lead Poisoning and Lead Absorption, London, Edward Arnold; New York, Longmans Green & Co., 1912.

Read before the Section on Preventive and Industrial Medicine and Public Health at the Eighty-Fifth Annual Session of the American Medical Association, Cleveland, June 13, 1934.

1. Aub, J. C.; Fairhall, L. T.; Minot, Anne S., and Reznikoff, Paul: Lead Poisoning, Medicine Monographs, Baltimore, Williams & Wilkins Company **7**, 1926.
2. Brooks, John: The Interaction of a Finely Divided Lead Suspension with Blood Serum, Ringer Solution and Aqueous Phosphate Solution, Biochem. J. **21**: 766, 1927.
3. Maxwell, L. C., and Bischoff, Fritz: The Reaction of Lead with the Constituents of the Erythrocytes, J. Pharmacol. & Exper. Therap. **37**: 413 (Dec.) 1929.
4. Kehoe, R. A., and Thamann, Frederick: The Behavior of Lead in the Animal Organism: III. Colloidal Lead Compounds, J. Lab. & Clin. Med. **19**: 178 (Nov.) 1933.
5. Jowett, Maurice: The Reaction of Lead Compounds with Serum and Serum Models, Biochem. J. **26**: 2108, 1932.
6. Badham, C., and Taylor, H. B.: Lead Poisoning, extract from the Report of the Director-General of Public Health, New South Wales, for the year ended 31st December 1925. Kehoe, R. A.; Edgar, Graham; Thamann, Frederick, and Sanders, Lester: The Excretion of Lead by Normal Persons, J. A. M. A. **87**: 2081 (Dec. 18) 1926. Fretwurst, F., and Hertz, A.: Quantitative Determination of Lead in Feces and Urine and Its Significance in the Diagnosis of Lead Poisoning, Arch. f. Hyg. **104**: 215, 1930. Litzner, S., and Weyrauch, F.: Untersuchungen über den Bleigehalt des Blutes und Harns, seine Beziehungen zum Auftreten klinischer Krankheitserscheinungen sowie seine diagnostische Bedeutung, Arch. f. Gewerbepath. u. Gewerbehyg. **4**: 74, 1932. Kehoe, Robert; Thamann, Frederick, and Cholak, Jacob: On the Normal Absorption and Excretion of Lead: I. Lead Absorption and Excretion in Primitive Life, J. Indust. Hyg. **15**: 257 (Sept.) 1933.
7. Barth, E.: Investigation of the Lead Content of Human Bones, Virchows Arch. f. path. Anat. **281**: 146, 1931.
8. Millet, H.: The Excretion of Lead in Urine, J. Biol. Chem. **83**: 265 (Aug.) 1929.
9. Kehoe, R. A., and Thamann, Frederick: The Behavior of Lead in the Animal Organism: II. Tetra-Ethyl Lead, Am. J. Hyg. **18**: 478 (March) 1931; footnote 4.
10. Aub, J. C., and Smithwick, R. H.: Lead Treatment of Cancer, New England J. Med. **208**: 310 (Feb. 9) 1933.

Once lead is absorbed, there is a characteristic distribution in tissues, which is approximately the same for inorganic,[11] organic[9] or colloidal lead,[12] no matter what the route of absorption. It is distributed throughout the viscera, but to the greatest extent in the liver, spleen and kidneys immediately following absorption. After a very few days, however, it gradually collects almost entirely in the bones. It is interesting that even a relatively stable organic compound such as tetra-ethyl lead should behave like other lead compounds (Kehoe) in spite of its great solubility in body lipoids.

The crux of the whole problem of lead poisoning, just as for other heavy metals such as radium[13] or mercury,[14] lies in the great avidity with which the bones take up these metals. Circulating lead may cause tissue damage, but lead stored in the bones produces no deleterious effects except probable caries in the teeth. The problem of treating lead poisoning is the problem of controlling the deposit and excretion of lead from this skeletal storehouse.

It was the original contention of Aub and Anne Minot[1] that the direction of the lead stream is similar to that of the calcium stream—that, when calcium is being deposited in the bones, circulating lead is also deposited in the bones; and, when calcium is being pulled from the bones, some stored lead is also liberated.[1] This relationship has been extensively investigated by most laborious metabolic observations. The patients received daily the same diet, similarly prepared throughout their low calcium periods of observation. Their total excretions were collected in three-day periods and analyzed for lead by Fairhall's method. The rate of the lead stream could thus be followed. But the magnitude of this lead stream, it must be remembered, is apt to be relatively small. An adult dying of chronic lead poisoning probably has not more than 1 Gm. of lead stored in the entire body, and nearly all of this is in the skeleton. After removal from exposure, such stored lead is normally but slowly excreted. The charts of a few of our unpublished observations are reproduced here to indicate the size of this excretion in cases of lead poisoning while the patients were hospitalized on a rigid, constant, metabolic regimen.[14a] The first value, determined in chart 1, indicates the rate of lead excretion during the subsidence of an acute lead colic. This chart shows how closely that rate of excretion is again approached during deleading and indicates that the rate of excretion is of a very different order from that ascribed to food and the "normal" lead contacts of daily life. In contrast to this, chart 2 indicates that lead may be pulled from the bones two years after every known exposure has ceased. The large excretion during this first course of deleading indicated that the patient had had a considerable previous exposure and storage.

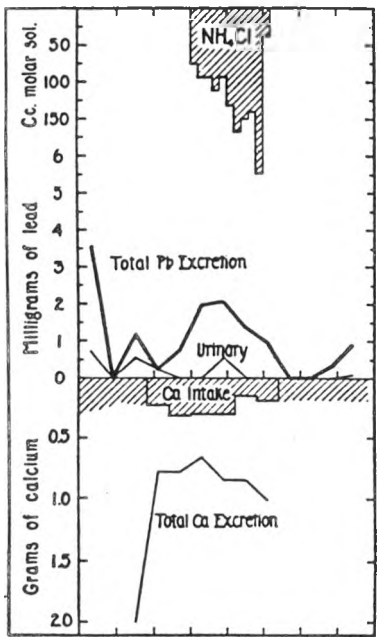

Chart 1.—The first value indicates the lead excretion as acute lead colic was subsiding during high calcium medication. Later, the sustained increase in lead excretion, which accompanies a low calcium diet plus ammonium chloride, is well shown. The chart shows that the increased excretion is largely fecal.

In these two observations the effect of medication is obvious when superimposed on a diet already low in calcium. But the increase of lead excretion is not invariable. We have had one patient, maintained through a long period on a low calcium diet, in whom the lead excretion was not further increased by adding ammonium chloride, even though the calcium excretion was somewhat accentuated. But the usual result is that increased excretion of bone calcium is accompanied by stored lead.

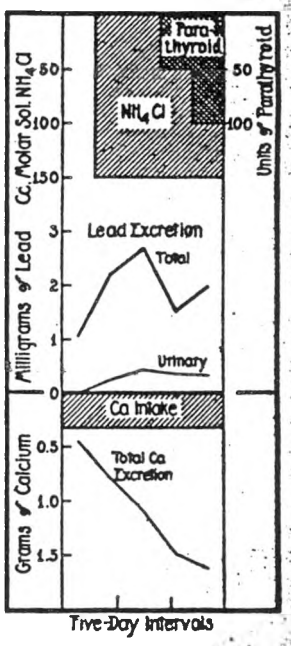

Chart 2.—Lead excretion in a young man removed from all industrial lead exposure for eighteen months. He had a toxic amblyopia but had received no previous treatment for lead poisoning. The first period indicates the excretion during low calcium diet alone, with subsequent addition of ammonium chloride and parathyroid extract-Collip. The recorded units of parathyroid extract were the old units (five times stronger than in the new 1934 nomenclature).

In our experience, any method that increases calcium excretion also increases the lead excretion. No deleterious effects have resulted since we have learned to apply medication in amounts gradually increased over a period of a week or ten days.

The value of these therapeutic suggestions can best be gleaned from the experience of others, and recent reports in the literature in this regard have been predominantly favorable.

The clinical value of high calcium therapy to quiet the toxic episodes of lead intoxication[15] has been confirmed by Badham and Taylor,[6] Belknap,[16] Wiegeldt,[17]

11. Aub, Fairhall, Minot and Reznikoff.[1] Weyrauch, F.: Distribution of Lead in the Organism After Intravenous Injections, Ztschr. f. d. ges. exper. Med. 75: 706, 1931. Behrens, Behrend, and Baumann, Anny: Zur Pharmakologie des Bleis: IX. Mitteilung, Ztschr. f. d. ges. exper. Med. 82: 16, 1933.

12. Bell, W. B.: Some Aspects of the Cancer Problem, New York, William Wood & Co., 1930.

13. Gettler, A. O., and Norris, Charles: Poisoning from Drinking Radium Water, J. A. M. A. 100: 400 (Feb. 11) 1933.

14. Young, A. G.; Taylor, F. H. L., and Merritt, H. H.: The Distribution and Excretion of Mercury, Arch. Dermat. & Syph. 21: 539 (April) 1930.

14a. The upper blocks in all charts represent medication expressed in cubic centimeters of molar solution given daily by mouth. The base line of the remainder of the charts is the middle horizontal line marked 0. The chart extends both above and below this line—the farther from this middle base line, the higher the value. Above this middle base line is shown the lead excretion expressed as lead excreted by three-day periods. The lighter line is the urinary excretion, the heavier line the total excretion in both urine and feces. Below the middle base line the charts extend downward and indicate the calcium metabolism. The calcium intake is hatched below the base line. When fenced in, it indicates a low calcium intake averaging 100 mg. of calcium daily. The areas that have no enclosing block lines indicate a diet ample in calcium. The calcium excretion represents the total calcium in both urine and feces by three-day periods.

15. Aub and Smithwick.[2] Bauer, Walter; Salter, W. T., and Aub, J. C.: Studies of Calcium and Phosphorus Metabolism: X a. The Use of Calcium Chloride to Relieve Peristaltic Pain, J. A. M. A. 96: 1216 (April 11) 1931.

16. Belknap, E. L.: Lead Poisoning: The Diagnosis and Treatment of Its Most Common Toxic Episode, Lead Colic, Wisconsin M. J. 28: 346 (Aug.) 1929.

17. Wiegeldt, cited by Teleky, L.: Moderne Therapie der Bleivergiftung, München. med. Wchnschr. 78: 354 (Feb. 27) 1931.

Leschke [18] and Koyranskiy,[19] and by many in personal communications. It is the type of therapy that can readily be judged by its striking clinical effects. Nothing more dramatic in treatment can be desired than the rapid subsidence of lead colic following the slow intravenous injection of 10 cc. of a 20 per cent solution of calcium gluconate. Reduction of lead excretion by a high calcium diet has been confirmed by Litzner, Weyrauch and Barth.[20]

Increase of the excretions of heavy metals by the liberation of calcium stores has also been extensively studied, and our results were confirmed in one particular or another by many authors. Litzner, Weyrauch and Barth [20] confirmed the influence of sodium bicarbonate but were unable to confirm the effect of acidosis. They determined lead excretion only in the urine, and it has been our experience that most of the increased lead excretion appears in the feces. Certainly, urinary lead alone is not an adequate test for total lead excretion. The other publications have shown that acid-producing substances,[21] parathyroid extract,[22] and large doses of viosterol [23] increase the rate of excretion of lead, radium [24] and mercury.[14] In five cases of lead colic studied with Dr. Marion Ropes, we could determine no influence on lead excretion from daily injections of 1 cc. of sodium thiosulphate. This agrees with the negative results on animals of Curtis and Young.[25] Shelling [26] has also shown by growth curves in rats that phosphate may be important in regulating the deposit of lead. This may well be the case also in children, in whom the normal diet tends to be high in calcium but relatively inadequate in phosphorus. In adults, however, the average diet is low in calcium and the phosphate intake is more than adequate, so that the calcium intake is the easy one to control.

It thus appears that the overwhelming evidence of the past ten years confirms the view that the lead stream and the calcium stream run in the same direction whether these substances are being deposited in the bones or liberated into the blood and into the excreta. To understand this mechanism thoroughly one must turn to the metabolism of bone. It has been demonstrated [27] that bone can be considered roughly divisible into two functional elements. The hard cortical bone acts as the body's support. The trabeculae, scattered through the marrow, particularly at the epiphyses, act as the readily available supply of calcium for body needs. It is this relatively small lace-like trabecular structure, with its large blood supply, which is depleted when calcium is demanded by the body—or refilled when calcium is stored.[27] The hard cortex, which constitutes most of the bone with its relatively small blood supply, probably metabolizes at a fairly constant rate. In the trabeculae, lead is stored in relatively high concentration. This we [28] showed by analyses some years ago, and it has recently been dramatically confirmed by Behrens and Baumann [29] by means of their beautiful pictures of radioactive deposits. It is largely the salts in these trabeculae that are liberated in time of calcium need.

However, it is essential to realize that probably not all the calcium and lead that is liberated from this bone is excreted. There is x-ray evidence to indicate that it may circulate and be redeposited in bone, especially in childhood, for the roentgenograms of Vogt [30] show that

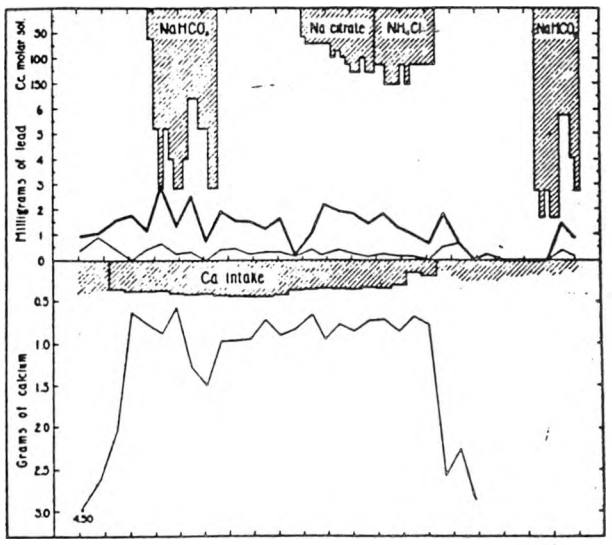

Chart 3.—Lead excretion determined for three and one-half months in a patient whose acute symptoms of lead poisoning subsided before the observation was started.

the lead gets repeatedly dissolved and redeposited along the epiphyseal line of growth. It is because of this great avidity of growing bone for salts, as well as the difficulties precipitated by calcium deficiencies, that deleading therapy seems an unwise and unsuccessful procedure in children.

The present problem of treating lead poisoning lies not in the methods, for efficient methods exist. The problem that remains to be decided is Should deleading be undertaken or avoided? If rapid deleading is to be avoided, it is necessary simply to give a large calcium intake in the diet. This lowers the body's demand on calcium stores, so that calcium is even stored, and the only excretion of bone calcium (and lead) comes from the normal metabolism of the bones. Obviously, this is the method that should be used during any toxic lead episode.

18. Leschke, E.: Fortschritte in der Erkennung und Behandlung der wichtigsten Vergiftungen, München. med. Wchnschr. **78**: 1657 (Sept. 25) 1931.

19. Koyranskiy, B. B.: Lead Poisoning—Calcium Chlorate in Prophylaxis and Therapy, Sovet. vrach. gaz. 647 (June 15) 1932: abstr. J. A. M. A. **99**: 1304 (Oct. 8) 1932.

20. Litzner, S.; Weyrauch, F., and Barth, E.: Untersuchungen über Bleiausscheidung durch bestimmte Kostformen und Arzneimittel beim Menschen, Arch. f. Gewerbepath. u. Gewerbehyg. **2**: 330 (July 6) 1931.

21. Tcharny, A., and Israilewitsch, E.: Zur Pathologie des Stoffwechsels bei Bleivergiftung des Organismus: IV. Einfluss der Salssäure auf die Veränderung des Phosphor und Calciumumsatzes bei experimenteller Bleivergiftung, Arch. f. Gewerbepath. u. Gewerbehyg. **2**: 56 (May 5) 1931. Rabinowitch, I. M.; Dingwall, Andrew, and Mackay, F. H.: Studies on Cerebrospinal Fluid: II. The Occurrence of Lead in Cerebrospinal Fluid, J. Biol. Chem. **103**: 725 (Dec.) 1933.

22. Hunter, Donald, and Aub, J. C.: Lead Studies: XV. The Effect of the Parathyroid Hormone on the Excretion of Lead and of Calcium in Patients Suffering from Lead Poisoning, Quart. J. Med. **20**: 123 (Jan.) 1927.

23. Flinn, F. B., and Smith, Adelaide R.: The Effect of Viosterol on the Excretion of Lead, J. Indust. Hyg. **15**: 156 (May) 1933. Taylor, N. B., and Weld, C. B.: The Mobilization and Excretion of Calcium Following Overdosage with Irradiated Ergosterol, Brit. J. Exper. Path. **13**: 109 (April) 1932.

24. Flinn, F. B.: Elimination of Radium Salts from the Human Body, J. A. M. A. **96**: 1763 (May 23) 1931. Flinn, F. B., and Seidlin, S. M.: Parathormone in the Treatment of "Radium Poisoning": A Preliminary Report, Bull. Johns Hopkins Hosp. **45**: 269 (Nov.) 1929.

25. Curtis, A. C., and Young, A. G.: Effect of Sodium Thiosulphate on the Excretion of Lead, J. Lab. & Clin. Med. **13**: 628 (April) 1928.

26. Shelling, D. H.: Effect of Dietary Calcium and Phosphorus on Toxicity of Lead in the Rat: Rationale of Phosphate Therapy, Proc. Soc. Exper. Biol. & Med. **30**: 248 (Nov.) 1932.

27. Bauer, Walter; Aub, J. C., and Albright, Fuller: Studies of Calcium and Phosphorus Metabolism: V. A Study of the Bone Trabeculae as a Readily Available Reserve Supply of Calcium, J. Exper. Med. **49**: 145 (Jan.) 1929.

28. Aub, J. C.; Robb, G. P., and Rossmeisl, Elsie: The Significance of Bone Trabeculae in the Treatment of Lead Poisoning: Lead Studies 17, Am. J. Pub. Health **22**: 825 (Aug.) 1932.

29. Behrens, Behrend, and Baumann, Anny: Zur Pharmakologie des Bleis: X. Mitteilung, Ztschr. f. d. ges. exper. Med. **82**: 251, 1933.

30. Vogt, E. C.: A Roentgen Sign of Plumbism, Am. J. Roentgenol. **24**: 550 (Nov.) 1930.

But should deleading be undertaken after the episode has subsided? To help in this decision, one must remember that:

1. Lead is stored in relatively large quantities in the area of bone readily available for liberation.

2. The liberation of this store is an obvious factor in the onset of toxic lead episodes during metabolic upsets.

3. This liberated lead may not be excreted but may circulate and be redeposited. (No one knows the extent of this possibility.)

Therefore, in favor of deleading is the possibility of reducing, under controlled conditions, the lead contamination in the bone trabeculae and then replenishing the trabeculae with uncontaminated calcium. Against deleading is the consideration that it may be desirable to avoid the liberation of lead, which can be kept largely stored in the bones during good health. From the theoretical point of view, deleading seems advantageous in order to avoid sudden liberation of this lead in time of metabolic stress. From the practical point of view the answer is dependent on which procedure will advance most promptly to a recovery of health. In my experience, following the ordinary toxic lead episode, a vigorous course of deleading is usually followed by a prompt recovery to normal health — a recovery that is more rapid and much more complete than when a continued deposit of lead stores is maintained. In lead palsies, I have the impression that thorough deleading approximately halves the period of disability. This opinion, formed from many observations, may possibly be altered, but the biochemical knowledge on which this treatment is based seems to be thoroughly established, not only for lead but also for several other related heavy metals.

695 Huntington Avenue.

NORMAL ABSORPTION AND EXCRETION OF LEAD

ROBERT A. KEHOE, M.D.
FREDERICK THAMANN, CH.E.
AND
JACOB CHOLAK, CH.E.
CINCINNATI

A recent series of articles in another journal has detailed the methods and the major results of our studies of lead absorption and lead poisoning during the past ten years.[1] So far as they are concerned with normal lead absorption and excretion, the results may be summarized briefly as follows: 1. Two groups of native Mexican Indians, whose mode of life and environment were devoid of opportunities for contact with the lead-containing products of highly organized and industrialized populations, were found to have lead in their blood and to excrete lead in their feces and urine, as a consequence of the occurrence of lead in the soil and hence in vegetation and animal products employed as food. 2. Various groups of healthy children and adults in the United States, with no occupational exposure, were shown to have lead in their tissues and in their excreta chiefly because of regular ingestion of lead with their foods. 3. The rate of lead excretion among Americans is higher than that observed in people living under simpler and more natural conditions (native Mexicans), in correspondence with the higher lead content of certain American foodstuffs. 4. Evidence was obtained that the ingestion of these "normal" amounts of lead does not result in steady accumulation of lead in the body. Apparently an equilibrium is reached after a time, so that a substantially constant concentration of lead remains in the tissues, and lead output becomes equivalent to lead intake.

From the Kettering Laboratory of Applied Physiology in the University of Cincinnati.
Read before the Section on Preventive and Industrial Medicine and Public Health at the Eighty-Fifth Annual Session of the American Medical Association, Cleveland, June 13, 1934.

1. (*a*) Kehoe, R. A.; Thamann, Frederick, and Cholak, Jacob: On the Normal Absorption and Excretion of Lead: I. Lead Absorption and Excretion in Primitive Life: II. Lead Absorption and Lead Excretion in Modern American Life; III. The Sources of Normal Lead Absorption; IV. Lead Absorption and Excretion in Infants and Children, J. Indust. Hyg. **15**: 257-305 (Sept.) 1933; (*b*) Lead Absorption and Excretion in Certain Lead Trades, ibid. **15**: 306-319 (Sept.) 1933; (*c*) Lead Absorption and Excretion in Relation to the Diagnosis of Lead Poisoning; ibid. **15**: 320-339 (Sept.) 1933.

TABLE 1.—*Distribution of Analytic Results Obtained on Nine Normal Subjects*

Milligrams of Lead	24 Hour Samples of Food	24 Hour Samples of Feces
0-0.09	424	516*
0.10-0.19	421	500
0.20-0.29	171	303
0.30-0.39	64	149
0.40-0.49	40	87
0.50-0.59	17	35
0.60-0.69	8	14
0.70-0.79	5	7
0.80-0.89	3	6
0.90-0.99	2	2
1.00-1.40	14	10
1.50-1.99	1	..
2.00+	6†	2†
Total	1,176	1,631
Mean	0.176‡	0.193‡
Probable error of mean	±0.004	±0.003
Standard deviation	±0.180	±0.169

* Of this number only sixty failed to show lead.
† Eliminated in calculation of mean.
‡ Calculated on a wider distribution of results.

TABLE 2.—*Means and Their Probable Errors of Observations on Nine Normal Subjects*

Subjects	Lead in Urine		Lead in Feces	
	Mg. per Liter	Mg. per 24 Hours	Mg. per Gm. Ash	Mg. per 24 Hours
J. H.	0.017 ± 0.001	0.027	0.027 ± 0.001	0.15 ± 0.01
S. J.	0.025 ± 0.002	0.021	0.040 ± 0.002	0.21 ± 0.01
C. H. no. 1	0.022 ± 0.001	0.025	0.090 ± 0.003	0.23 ± 0.01
C. H. no. 2	0.029 ± 0.002	0.028	0.123 ± 0.006	0.31 ± 0.02
J. McS. no. 1	0.026 ± 0.001	0.032	0.064 ± 0.004	0.22 ± 0.01
J. McS. no. 2	0.022 ± 0.001	0.026	0.057 ± 0.003	0.19 ± 0.01
J. A. B.	0.020 ± 0.002	0.020	0.061 ± 0.003	0.19 ± 0.01
H. G. R.	0.015 ± 0.001	0.014	0.069 ± 0.003	0.16 ± 0.01
L. S.	0.024 ± 0.001	0.020	0.053 ± 0.002	0.18 ± 0.01
E. C.	0.014 ± 0.001	0.014	0.040 ± 0.002	0.16 ± 0.01

In the course of the work from which these conclusions were derived, certain healthy young men with negative occupational histories were kept under observation for months, during which their lead intake with food and drink (exclusive of water) was measured by analyzing duplicate twenty-four hour food samples and their daily lead output in feces and urine was determined. Nine such subjects have now been included in our observations. The results have yielded a consistent picture of normal lead ingestion and normal lead excretion, as measured by the analytic methods that we have described.[1a] The results are grouped in tables 1 and 2 in such a manner as to bring out the facts that we wish to introduce as points of departure for the further observations to be described.