LATE EFFECTS OF LEAD POISONING ON MENTAL DEVELOPMENT

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FOREWORD

Lately tragic death of Dr. Lord on Jan. 19, 1943 preceded the completion of the final draft of this paper. It was she who first felt that the minor deviations found on psycologic examination of these children with lead poisoning might be of importance significance for the future. She was also the one who recognized the lead poisoning point of view, without encouragement from any one the first several years.

That lead poisoning occurring in early life usually has a disastrous effect on mental development has not been generally recognized, though the subject of lead poisoning in children has been discussed by many observers. The manifestations of acute involvement of the nervous system have been adequately described, and the gross destructive lesions in the brain consequent to acute lead encephalopathy accompanied by cerebral edema and high intracranial pressure have been recognized. On the other hand, McChesney, for instance, states: "The neurologic manifestations of lead poisoning usually subside without serious consequences if the ingestion of lead is stopped and the removal of lead from the circulation and its deposition in inert form in the bones can be hastened, as described, by the use of a diet high in calcium together with the administration of cod liver oil or viosterol to accelerate the laying down of new bone."

This point of view, which is generally accepted, fails to take into account the effects of lead poisoning on the growth and development of the infantile nervous system. The present observations, in our opinion, demonstrate that this process may be seriously impaired, showing as they do that of 20 children with mild lead poisoning in infancy, only 1 had progressed satisfactorily in school.

The primary requisite for supporting such a contention is the proof of early lead poisoning. Ash, Minot, Pitchall and Reusslof in 1926 published a monograph on lead poisoning and in it outlined standards for establishing the diagnosis based on earlier suggestions of Newman, McConnell, Spencer and Phillips. While criticisms of such an outline were undoubtedly valid, it may serve as a concrete basis for discussion. Of first importance was the recognition of a source of ingestion or inhalation of lead. In addition, at least two symptoms from the following list were required: marked pallor or anemia, colic or obstinate constipation, muscular incoordination, peripheral motor paralysis of the most used muscles.

Mrs. Paul H. Roberts gave valuable assistance in summarizing Dr. Lord's notes on some of the psychological examinations. Dr. Lord's work on this paper was done under a grant from the Children's Fund, and the latter work under a grant from the Commonwealth Fund.

(usually the dorsiflexors of the feet in children), basophilic stippling of the red cells, a lead line on the gums and lead in abnormal quantities in the stools and urine. If two of the foregoing symptoms were lacking, a presumption of lead poisoning could be established by the presence of three of a longer list of less specific symptoms, among which were emaciation, loss of appetite, especially for breakfast, vomiting on eating solid food, abdominal pain, loss of strength, headache, insomnia, mental lethargy, tremor, dizziness, exophthalmos, hyperpnea and articular pains.

Since these suggestions were made, some new criteria for diagnosis have been developed. Vogt, Park-Jackson and Kajdi, Caiey and Kraft and Katz, independently and more or less simultaneously, published papers showing that in children during the period of rapid growth while the process of lead ingestion was occurring lead was deposited in special concentration in abnormally dense bone at the growing ends of the shafts of the long bones and along the growing margins of the flat bones. These deposits formed a radio-opaque band, comparable in density to that of the lead numerals used to mark roentgenograms, and when well developed were very characteristic. When less well developed they could be simulated by the changes of rapidly healing fractures, by deposits of bismuth salts or possibly of other metals and, finally, by the dense bands resulting from the admin-

irradiation of elementary phosphorus in cod liver oil. Typical dense bands at the growing margins of the shafts of the long bones, in conjunction with a history of ingestion of lead, were considered by the various authors as reliably diagnostic of lead. Much of the roentgen evidence in the present series was seen and interpreted by Dr. Vogt.

Another roentgen sign rather nonspecific was the finding of flocculi of radiopaque material in the intestinal tracts of children who had recently been chewing paint. It had been of clinical value mainly in calling to the attention of parents previously unobserved pica. It was, of course, much more useful in outpatient or office practice than in the hospital ward, where such evidence disappeared in a few days.

In relation to diagnosis, it was also clear from the review of Sob and his co-workers that lead in large amounts may be retained in the body, especially in the skeleton, in the absence of any of the clinical evidence of lead poisoning. Although this lead had been regarded as harmlessly stored in the skeleton, they showed that in animals free of symptoms of lead poisoning and protected for months from ingestion of lead small amounts of lead were excreted both by bowel and by kidney for a long time. Since practically all the lead in the bodies of human beings and of animals that had been exposed to lead and then protected from it for a considerable time was in the skeleton, such excretion presupposed...
continual solution and transportation by the blood stream of small amounts of lead from the stores in the bones. The same authors also measured the urinary and fecal excretion of lead by patients recovered from lead poisoning and found it virtually uninterrupted for long periods. The skeletons of persons exposed to lead were found to contain from approximately 200 to approximately 900 mg. of lead, and the rate of combined excretion through bowel and kidney of the recovered patients varied between 0.17 and 0.89 mg. daily. Under these circumstances, it would take the person with the least lead about seven months to excrete at the most rapid rate all the lead stored in the skeleton. Since the person with the least lead was an infant who had chewed the paint from her crib "for only a few weeks," it seems likely that the amounts of lead involved in our cases were of the same order of magnitude. It must also be remembered that in a person with such recent exposure to lead, considerable amounts of lead were contained in organs other than the bones. In addition, the rate of excretion in our patients was probably in the neighborhood of the lowest rates of excretion, approximately 0.1 mg. daily, for Asb showed that treatment with cod liver oil and a high calcium diet (used more or less faithfully for all our patients) reduced the rate of excretion to such levels.

It seems probable that the disappearance of the lead line from the bones of growing children is not to be taken as evidence of complete excretion of lead. It seems more likely that processes of reabsorption and redeposition tend to redistribute the lead more evenly in the bone and thus destroy the roentgenologic evidence. For instance,child (case 11) four years after the cessation of paint no longer had a lead line in her bones by roentgen examination but still showed stippled cells in her blood and new neurologic signs of damage to her nervous system. Another child (case 17) three years after her acute episode of lead
poisoning no longer had röntgen evidence of lead in her bones but in connection with a bout of vomiting again showed slippled cells.

Indeed, Ash and his collaborators in discussing the storage of lead in the bones when they felt it to be relatively harmless, stated: "This desirable situation may not be permanent, for slight changes toward either the alkaline or acid side of the usual hydrogen ion concentration of the organism can readily reduce the stability of the tertiary phosphate." Thus, under chemical shifts common in childhood concentrations of lead known to be insignificant may be recurrently liberated into the circulation.

It is evident, therefore, that the criteria permitting a diagnosis of lead poisoning are ephemeral in relation to the total process of ingestion of lead and its subsequent excretion, from the organism. They depend on the presence in the body fluids or tissues of a certain concentration of lead, and the question of whether the con-

Fig. 4 (cont. 11) - A, 25 years of age, showing osteitic bands at the growing ends of the main at the long bones; B, 5 years, showing nearly complete disappearance of the normal evidence of lead in the long bones; C, at 11 years, showing no manifest evidence of lead in the long bones. At the time presentation C was made, the patient's blood showed normal blood tests, and no cells had been found in the test. She seemed to have a mild microencephaly.


ditions to be discussed are due to the continual circulation of subclinical concentrations of lead derived from the stores in the bones, or to the increase in solubility suggested by Ash 6 or by injury sustained by the developing nervous system at the time of exposure to lead. Possibly all three factors contribute.

It is also to be noted that in most instances by the time the difficulties here presented became evident, the diagnosis of lead poisoning, unless established earlier, could no longer be made with certainty by methods now in use. A recent publication by Fairhall and Keenan 7 describing a relatively simple method for the quantitative determination of lead in urine may render possible the diagnosis of lead poisoning during the long period of excretion of stored lead after the symp-

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Omissions and signs of the more acute phases of poisoning have subsided. The usefulness of this method has not yet been proved by wide application.

During the past several years, a number of children who were admitted to the hospital on account of lead poisoning have been repeatedly examined psychologically.

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Summary Data for 1908

by one of us (E. E. L.) and certain deviations noted. In order to make a systematic study of the matter, the records of the Children's Hospital for the past ten years have been reviewed and 128 cases discovered. The yearly rate of admissions has tended to decline from 27 in 1938 to 3 in 1939; such curves may, however, tend to occur in relation to the interest of the staff in the subject. During
discharged as cured, many have received repeated examination by the psychologist, and of these, 20 have now entered the school system. These 20 form the basis of the present report.

A tabular review of the 20 cases is presented in the table. In all but case 2 an adequate source of the lead ingested was disclosed by history, for this child.
lead poisoning was considered an unimportant subsidiary diagnosis in relation to the acute maladies for which he entered the hospital. In 18 cases the lead was obtained by chewing paint off sills, window sills or furniture. In many instances the parents stated that they had repainted the crib, a practice which would vitiate the use of the crib painted by the most conscientious of furniture makers. The frequency with which children chewed window sills and painted furniture points to the importance of preventing the use of lead-containing paint on sills and all interior finish, on pach wall and on other objects which are in reach of children’s teeth. In 1 instance ingestion of lead appeared to be the result of the use of lead triangle shields by a nursing mother.

From the diagnostic point of view there seemed ample evidence to accept these children as having lead poisoning. All but 1 generously fulfilled the diagnostic criteria outlined in Abb’s article, and, in addition, all had roentgen evidence either consistent with (designated by + in the table) or characteristic of lead poisoning (designated by ++ in the table). The 1 child who did not have conclusive evidence of lead poisoning was a girl of 10 months who was admitted to the hospital because of anorexia and failure to gain weight satisfactorily since birth. Her diet had been irregularly unsatisfactory throughout her life. Soon after she cut her teeth (all she had at the time of admission), she began to chew the paint of her crib. Two days before admission she became irritable. On admission she was a small, irritable baby, continually whimpering and scratching her palms, soles and genitals. Except for a few beads of onions at her left ankle, her physical examination was not remarkable. Cytologic examination of her blood showed no pathologic changes, but roentgenograms of her long bones showed dense metallic shadows at the ends of the shafts of the long bones, considered diagnostic of lead. Treatment by injection of iron and use of an adequate diet for her age supplemented with diuresis sodium phosphate and cod liver oil was supervised for two months in the outpatient department. The itching of the palms and soles continued. While it may be argued that actual poisoning by lead had not occurred at this time, it was clear that she had ingested paint and stored a heavy metal in her bones in the pattern characteristic for lead.

With respect to the nervous system the cases fell into three groups. In the first group, 9 cases, there was no evidence suggesting involvement of the nervous system. In the second group, 3 cases, there was peripheral neuritis, but no clinical sign of cerebral involvement, and in the last group, 8 cases, there was more or less conclusive evidence of encephalopathy. The symptoms and signs among the latter were choked disks, bulging fontanels, hypertrophic tonsils reflexes, convulsions, confusional movements and changes in the spinal fluid. In no case were these symptoms severe, and in every instance they appeared to have cleared completely at the time of the patient’s release from the hospital ward. The presence or absence of evidence of involvement of the nervous system bore no relation to the eventual intellectual development of the children; indeed, the only truly successful member of the group had the most severe encephalopathy encountered among the 20 children.

Considering the early age at which the ingestion of lead began, it was difficult to forecast what the intellectual development of any of the children would have been. When the 20 patients were considered as a group, all mental development, as obtained by history, fell in the normal range. Since most of the individuals began to be exposed to lead during middle infancy, other developmental criteria were not applicable. Detailed developmental histories were not available in all instances, but 8 of the children were reported to have sat alone at an average age of 6.5 months, 14 to have walked at an average age of 14.3 months and 11 to have
been using words at an average age of 15 months. These developmental items applied to 15 of the children; 2 more were 10 months old when admitted to the hospital and must have been active to have obtained their lead; for another child the statement of normal development was not documented; for the nineteenth no developmental data were given, and the twentieth child was first seen when she was 6 years old because of failure to do school work as well as had been expected by her family. It was the opinion of the medical staff that these were "normal children" at the time they were originally seen in the hospital. It was obvious that 1 or 2 unsatisfactory children might be found in any group of "normal children" picked in this way at such an early age, but, on the whole, the expectation of reasonable average progress in school was justifiable for the group. The developmental data also disposed of the suggestion that these infants exhibited signs because of mental defect.

After recovery, their lead poisoning these 20 children made an extremely poor record in competition with their fellows. Their difficulties were in relation to both the intellectual and the emotional spheres. The intellectual difficulties were capable of rather exact analysis, and, since in part the emotional difficulties were dependent on them, they will be discussed first.

With one definite and a second possible exception, none of the 20 children succeeded in school. The causes of their failures were probably manifold. For the group as a whole, at about the time of entrance to school the intellectual ratings averaged 90, with a spread from 67 to 109. The usual correlation between the intelligence quotient and the ability to learn in school did not hold for the group, the second most successful child having an intelligence quotient of 82 while several with quotients above average were unable to do school work. For the only group with intelligence quotients ranging from 67 to 85 slow progress in school seemed well enough explained by the low intelligence level. These children did not show the mental irregularities to be discussed in relation to the children with better intelligence levels, since special defects merged into the general intellectual inadequacy.

Throughout the psychological examination of the children with good intelligence levels and poor scholastic attainment, sensorimotor defects were found in most instances. This is not the place to discuss the tests used to show such defects, since they must be varied to suit the age of the child examined, since they must be given by an experienced psychologist trained in their use, and since they have been well described in the literature of psychology. In brief, however, in the earlier age groups sensorimotor defect was shown by inability to manipulate blocks, to fit forms into holes in a form board and to perform similar acts. In the preschool years inability to copy simple figures, such as crosses, triangles and squares, proved to be important. In the school ages inability to reproduce by memory the designs of the Ellis Visual Designs Test 6 or of the Pintner-Cunningham Test No. 77 to deal with, the block designs of the Wechsler-Bellevue Test 13 to build up the association to pictures necessary for success in the Wood Picture Completion Test 14 were found. All of these tests are designed to bring out a subject's ability

so deal with shape, direction, space and projected imagery. All matters of the utmost importance in a child's success or failure in the fundamental school of techniques. In the grades, inability to learn to write or read or deal with numbers in arithmetic was the result of such defect, even though verbal ability might be good. By contrast, many of the children showed normal or even superior abilities in the language field, and on this account several of the most severely handicapped children made relatively high scores on the Stanford-Binet tests. Such children were frequently sociably responsive, especially in their preschool years, and were considered "bright" by parents and teachers, the latter often stating that the children could do better if only they would try.

One child, as previously intimated, appeared to have recovered completely at 7 years his intelligence quotient was 109 and he was progressing satisfactorily in school. At 25 months, however, he presented intellectual difficulties of a sort that were permanent in other children of the group. He was an attractive, good-natured boy, socially responsive, pleasant, inquisitive and amenable. His understanding of language allowed him to carry out simple commands in the test situations appropriate for a 2 1/2 month old child. He associated the proper pictures with Mother Goose Rhymes, and he liked to listen to verses. In the use of language he was more like an 18 month baby in that he had a vocabulary of only half a dozen words and did not combine words. From the point of view of adaptive behavior, he pushed single blocks imitatively but made no effort to align them. He piled large blocks at home but could not make the necessary adjustments to pile small cubes, being less adequate than most 18 month old babies in this respect. He adapted the circle to the form board, but though he placed the other forms over their holes he could not make the adjustments necessary to insert them, again dealing with shape and spatial orientation like an 18 month baby. With a crayon he scribbled and made strokes as do most babies of 21 months. In summary, he was imitative and acquiescent, but the sensorimotor element in the adjustment of blocks and the fitting of forms into a board was definitely not as advanced as his understanding of language and his social response. As he grew older, these sensorimotor disabilities diminished, and at 7 years he appeared to be intact. His ability as a baby to scribble imitatively with a crayon was not found in any of the other children in the group who were examined early. He was the only child in the entire group who did well in school.

One other child in the group kept up with her class in school with great difficulty. She was a pleasant, docile person, recognized as relatively incompetent by her family. Her intelligence quotient at 7 years was 112, but at 12 years it was only 82. Sensorimotor capacity as shown by the Exs. Memory Test was below the twenty-fifth percentile for her age, and her ability to organize her visual impressions as measured by the Wood Picture Completion Test was in the second decile for her age. Thus her difficulties were most obvious in the sensorimotor sphere, but they were not far out of line as compared with her general intellectual level.

Eleven children were examined when they were between 18 months and 2 1/2 years of age. Each of the 11 exhibited more advanced reactions to language tests than to the tests of sensorimotor control. Seven were using words as well as one would expect for their age, whereas in 4 speech was delayed, but the play with blocks and forms was consistently less adequate than speech. In all but the child already discussed as completely recovered a definite lag in the ability to make indicative adjustments with the crayon was found.

Six children were examined between the ages of 4 and 5 years. They answered comprehension questions well: some counted, and some even named colors. In
each instance there was more than the average difficulty in adjusting blocks in picture puzzles and in reproducing drawings. Two of the children, approaching 5 years, had begun to be interested in making letters, but their copy of letters was disoriented and they were unaware of the displacement. One particularly attractive little girl aged 4 1/2 years made an extremely favorable impression in the ward. She was so friendly and cooperative with the doctors that one of them said, "I should like to adopt that child." On the Stanford-Binet scale she had a mental age of 4 1/2 years and an intelligence quotient of 112. The comprehension questions were answered adequately not only on the Stanford test but on several other tests. Although she matched outline shapes, showing adequate visual perception, she had more difficulty in fitting the blocks in the Spenig form board than most 3 year old children. She had more than average difficulty in block building, and her hand was unsteady as she traced the Fortescue Cross. Although her ideation was good in the drawing of a man and she made a figure with head, arms, legs and arms, the total figure was disconnected. Here again are found good ideation, verbalization and social response for a 4 year old child but less competence than that of the average 3 year old child in the adjustment of forms.

These deficits in the younger children did not in themselves seem more than minor deviations; but when children who still exhibited them encountered the school system, severe difficulties in learning became evident. Two of the children had been promoted each year, in the fourth and seventh grades at 9 and 12 years respectively, but complaints of inattention, restless ness and inaccurate work continued to be made about them. Of the children in the first grade, the comment has been made that they "seem smart enough but do not learn." Another child is "bright but restless and does not concentrate, is learning a few words with help from his mother at home but is having a terrible time with writing." A teacher reported: "He is smart, and I have no complaints. Although the youngest boy in his group, he is going to make his first communion with the others." When this situation was explored a little more fully, it was found by the psychologist that though he was 6½ years old and had an intelligence rating of 96 at the end of the first year in school he did not recognize a single word and had not learned to write his name. He could make numbers, but they were disoriented. In general, these comments reflect the frustration of parents and teachers with these respective verbally able children who because of sensorimotor defects could not learn the techniques taught in the first grade in school. The table summarizes the school situation in regard to all 20 children, and their clinical histories appended afford more detail.

In addition to difficulties in the general intellectual and sensorimotor spheres, other evidences of interference with the normal development of the nervous system were found scattered through the series. For a few children successive psychologic examinations showed significant drops in the intelligence quotient. These drops were felt to be the result of failure of mental development rather than of actual mental deterioration. As a result, though the chronologic age advanced, mental growth did not keep up with it. Cases 4 and 11 are examples. In Case 16 the fall in intelligence quotient was associated with recurrent convulsions and such great variability in intellectual function from day to day that it seemed likely that mental deterioration had actually occurred.

Recent convulsions appeared in 3 of the children, at 4, 4 1/2 and 5 1/2 years of age. Of these, 1 (case 16) showed enlarged ventricle on pneumoencephalographic examination at 12 years of age. One girl who had peripheral neuritis as a baby acquired a positive Babinski sign, first noted when she was 11 years old, and 1 boy, who was discharged from the hospital as well as at 3
years of age, had hypertensive reflexes and sustained clonus at the left ankle when reexamined at 9 years.

Behavior difficulties were common throughout the series. Much of this behavior could be classified as "forced reaction to stimuli in the environment" described by Straus and Wener as an evidence of cerebral damage. It was apparently the result of loss of the normal inhibitory function, thought to reside in the cortex. It was usually described as unreliable impulsive behavior, cruel impulsive behavior, short attention span and the like. It made several of the children friendless and difficult at home and in school. Three were excluded from school on the basis of behavior; 1 for setting fires in the school, another for repeatedly getting up and dancing on the desks and other furniture and the third for sticking a fork into another child's face.

In some children the untoward behavior seemed to occur under any and all circumstances. An example is a boy (case 14) who first came to our attention at 23 months because of irritability. His lead poisoning was diagnosed and treated and he was sent home as cured. From that time on, he presented a severe behavior problem, with crying, irritability, refusal to eat, soiling, wetting and abdominal pain. His mother, a good-natured, kindly, humorous woman who handled him with admirable tolerance and insight, was given many brick talks by the medical staff on how children should be brought up. From time to time he was admitted to the hospital in an attempt to modify his behavior or because of a suspicion of appendicitis. In the wards, his behavior, though not as flagrant as at home, continued essentially unchanged. It was felt that his improvement in the wards was due largely to the fact that a routine requiring much of one person's time could be established for him and in addition to the fact that the nurses and doctors caring for him had no deep emotional attachment to him. Fundamentally he remained irritable, impulsive and distractible, and it was impossible for teachers to deal satisfactorily with him in the group situations in the kindergarten and the first grade.

On the other hand, some of the children acquired behavior difficulties motivated in part, at least, by the frustration resulting from the impact of scholastic disciplines on their intellectual deficits. An example is a girl (case 11) who was first thoroughly studied at 3 years of age because of peripheral neuritis due to lead; at this time no psychologic difficulties were suspected. At 11 years of age she returned to the hospital because of difficulty with school work and emotional disturbances. She was seldom, withdrawn and inactive and her medical examination was found to have positive Babinski signs (a new observation) and stippled cells in her blood. Psychoelectric examination showed sensorimotor defects, and with the assistance of an exceptionally intelligent school supervisor, allowances for her disabilities were made and treatment for lead poisoning instituted. The behavior difficulties smoothed out at once and when last seen, at 15½ years, she was a pleasant, attractive-looking girl, with a quiet and poised manner; getting along fairly well in the eighth grade but unable to do arithmetic. She had repeated two grades, and her family were hoping mildly that she might reach high school. She had made real gains in the specific sensorimotor field, her score of the Ellis Memory Test being normal for her age and her performance with the Wechsler-Bellevue Block Designs and the Wood Picture Completion Test more nearly up to expectation for her age than before. These findings suggested that her psychologic state at the time of her depression was due, in part at least, to a reactivation of her latent lead poisoning.

The conditions imposed by present day culture on children with good intelligence quotients and sensorimotor defects are very difficult. Their excellent verbal capacity and social responsiveness make it seem impossible to parents and teachers that they could not learn if only they would. A good example is presented in case 15. At 8 years the patient was a pretty, outgoing child, large for her age, with an intelligence quotient of 91 and no ability to learn to read or write because of sensorimotor defect. The choice before those responsible for her school planning were three. The first was to keep her back in the first grade, where her large size and advanced age combined with her inability to compete in learning would certainly humiliate her. The second possibility was to put her into the second grade, where the defective preparation and learning defects would be certain to frustrate her. The last possibility was to let her go nominally into the second grade but to protect her from competition with the other children by giving her tutoring in the academic subjects. Such a plan could be worked out only in a tolerant and well-staffed public school system.

Lead poisoning in these 20 children began in infancy. In order to obtain the lead, all but 7 must have developed at an average rate from the motor point of view. None of them exhibited evidence of severe acute encephalopathy, yet only 1 lived up to the promise of his early development. In some, such failure was parallel to a generalized defect in mental development resulting in a readily recognizable lowering of the intelligence quotient. In others, though the intelligence quotient remained well within normal limits, a specific failure of development in the sensorimotor sphere was the outstanding finding.

That failure of intellectual development is somehow connected with improper development of the cerebral cortex is well accepted. Sensorimotor defect has been studied by several observers. Goldman and Scheerer found it especially in relation to abstract design, as an evidence of cortical disease or injury. Wernicke found that failure in his block design tests correlated well with organic cerebral lesions, and Lord and Wood have shown that failure in the sensorimotor sphere was common in a group of children with known cerebral disease and uncommon in a group of children under treatment for psychiatric disturbances. There is ample evidence that the cortex of an infant is not as yet completely active functionally. From the motor standpoint, Kentred showed that inscrutability of infant molesly produced little disability as compared with degeneration of adults, and Byers showed that hemiplegia in early infancy produced a distinctly different clinical picture from that found after the upright posture had been attained. The normal processes of intellectual growth and development are thought to be due to processes of maturation taking place in the cortex. It seems likely, therefore, that the lead in the circulation of an infant in some way interferes with the changes normally occurring in the cortex and in a high percentage of cases prevents the normal growth and development of the cortex.

SUMMARY

A follow-up study of 20 school children who had been hospitalized in infancy or early childhood because of lead poisoning has been presented. None of them...
exhibited telling evidence of malnutrition during their primary admission, and all were adjudged to have made a complete recovery from lead poisoning when discharged from the original hospitalization.

The length of the cycle of ingestion, storage and elimination of lead in relation to the relatively short duration of the symptoms and signs allowing a diagnosis of lead poisoning is emphasized. It seems probable that lead poisoning of the sort here discussed can at present be recognized only by a small percentage of cases.

Failure of the normal processes of growth and development of the victims prevented all but 1 of the 20 children from progressing satisfactorily in school.

Lead poisoning is a serious disease developing from entirely misused hazards, which should be controlled by appropriate legislation.

REPORT OF CASES

CASE 1—A boy of 2 years 4 months was admitted to the outpatient department because of lack of appetite. He was the only child of healthy parents. He ate a 2 months and weighed 13 months but was taking only a little at the time of his first visit. He had showed the point "of everything" when he was younger, though at just what age is not how long was not stated. He was completely out of control of his mother at the time of his admission, necessitating for what he wanted, allowing to give up his bottle and exhibiting impatience and unusual behavior. He had been "poor for a long time."

Physical examination showed the boy to be small and pale but otherwise revealed nothing remarkable. A blood smear showed moderate schistocytes but no stippled cells. His urine was normal. X-ray films of his long bones showed some bony lesions of metaphyseal chondro-dysplasia at the growing ends of the shafts, characterized by lead poisoning. Twenty days of bloodletting with oil and 2 ½ tablets of salt were prescribed, and later 200 and stomacho-rinna was added.

After writing the hospital he continued to chew me pains off without pills and became a 2 bones, but finally his habit stopped spontaneously. At 4 years he was still small but had become very expressive. Psychologic appraisal showed poor speech and considerable difficulty in handling and materials. He received a general mental level below average, with mental retardation due to developmental disabilities. As about this time his mother died of peritonitis and he was boarded out. Tendentive with vitamins B and vitamin D with disodium phosphate was however, carried on. He continued to be rather uncoordinated physically, intellectually and emotionally.

At 5 years he was in the first grade in school, though he had failed to have to read. At home he was difficult and irritable. A psychologic appraisal indicated an intelligence quotient of 25, with special difficulties in the executive sphere. His score on the Wood picture construction test was at the third decile for his sex, and on the Ellis visual design test is at the third percentile for the age level entered.

CASE 2—A boy of 11 years was admitted to the hospital because of projectile vomiting of ten days' duration. He was born normally at 7 years from and well as a baby. His dentition was complete at 14 months, and he began to walk and talk at 2 years. He entered the hospital, Two months before his admission soil fever and running nose developed, one of which continued as chest cold in the case of admission. He was weeks before entry he began to vomit projectile as night, and he continued to do so at the time of admission.

Physical examination showed a pale child with a discharging right ear. X-ray examination showed a closed and curved right tempodee and a broad band of metallic density at the growing end of the long bones, characteristic of lead poisoning. A roentgenogram of the abdominal region must be done. Stool examination, probably normal, in the immediate test. His blood was taken, revealing no anemia (hemoglobin content 23 per cent and 400,000 red cells with many stippled cells on smear and no elevation percentage of polymorphonuclear leukocytes. A manometric test performed on the right side, and treatment with salts, plasma, dextrose sodium phosphate and vitamins in oil was carried out. He did well and was discharged with no sedatives were given in the hospital. This case was psychiatrically observed showed a handicapped child of 11 with no special defects.

At the age of 11, the psychological appraisal showed an intelligence quotient of 75, with no special defects. In school he was in the second grade, having retained the first grade.

V. The transmission used in this preceding case enabled 70000 U. S. P. units of vitamin D per gram.
Case 4.——A boy of 18 months was admitted to the outpatient department because of irritability and crying at night as if in pain. His development was normal. He sat up at 7 months, walked at 13 months and was using words at 18 months. When about 1 year of age, he began to chew the paint off his crib and had continued to do so. In spite of this, he was sent home as presenting a behavior problem.

Eight months later he was readmitted with the same complaints and vomiting. His crib had been covered with cloth, but he had taken to chewing the paint off window sills. Routine microscopes of his long bones showed a narrow band of intussusception at the growing ends of the long bones, but in spite of letters to his parents he did not report for treatment for six more weeks. At this time his hemoglobin content was 40 to 50 per cent and a blood smear showed no stippled cells. Cord blood (1/2 ounce [15 cc.] daily) and dibasic sodium phosphate were prescribed, and a further warning about ingestion of lead was given to the parents. A month later roentgenograms showed much more pronounced metallic deposits at the growing ends of the shafts of the long bones.

A few weeks later vomiting recurred once or twice daily, and the boy became irritable. Though he had been prevented from chewing paint, it was discovered at this time that the pipes in his home were leaden. He still had a secondary anemia (hemoglobin content 50 per cent and 4,000,000 red blood cells), but on several examinations no stippled cells were found. At this admission, when he was 2 years old, he was seen by the physician, who found his development below the standards for the 2 years, in contrast to his chronologic age. He was discharged from the hospital; treatment with dibasic phosphate, vitamin D and phenoxybutil was continued at home, and the health department was advised to do what was necessary to free the drinking water from lead.

At 8 years and 4 months he had difficulty in getting on with other children because of his unreliable, impulsive behavior. He had not acquired his first grade technique, in spite of two years of instruction, and was not able to write his name. Psychologic appraisal indicated a mental age of 6 1/2 years and an intelligence quotient of 82.

Case 4.——A girl of 2% years was admitted to the hospital because of temper tantrums and abdominal pain occurring during the nine months prior to admission. Her development had been average. She sat at 6 months, stood at 8 months and talked at 15 months. From the time she was 9 months old she exhibited marked pickiness, and until the time of admission she continued to chew paint from her crib, the furniture and window sills. At about 20 months she began to have attacks of screaming and banging her head, which lasted fifteen to ninety minutes, made her blue and tremulous and left her exhausted. During the two weeks before her admission she had complained of abdominal pain and vomited projectile vomiting several times. Although she began to use single words at 15 months, she was using only single, rather unintelligible words at the time of admission.

Results of the physical examination and laboratory investigation were not remarkable. Routine microscopes of the long bones showed dense bands along the diaphyseal margins, consistent with lead poisoning.

In the hospital she fell out of bed and was taken home on this account by the parents. Four years later, at the age of 6%, she returned, having been excluded from school because she danced on the furniture in the classroom and because of similar uncontrollable attacks. In addition, she was cruel to animals, hit people for no reason, refused to eat the food, spilled and ran away by hopping street cars. In the interim the father and mother had had several times and divorce proceedings had been instituted. She was unable to get on with other children because she always insisted on having her own way. A large variety of punishments had failed to control her.

Psychologic investigation showed an intelligence quotient of 91 (Terman L.), but a marked lead mental content. She could not apply herself to any problem for more than a very short period, and she was unable to learn in school situations, even with individual instruction. Her auditory memory span was extremely short. She could repeat only three digits correctly. She could not learn a two line nursery rhyme. She could not learn the names of the individual letters comprising her name, though she could print her name. She was excluded from school because she danced about on the desks and pianos.

Case 5.——A boy of 17 months was admitted to the hospital because of diarrhea and vomiting of short duration. He had been born normally and had developed normally, sitting up at 6 months and walking at 13 months. At the time of his admission speech had not developed. He had had frequent bouts of diarrhea and vomiting, usually accompanying infections of the upper respiratory tract, which had begun when he was 2 months old. For some months before admission he had been to be showing the paint off his crib, which was made of metal.
On admission to the hospital he showed mild dehydration and was dehydrated. Except for slight evidence of rales, the physical examination showed no abnormality. Two days later his blood pressure showed a few sauced wires. Serologic tests of his blood at this time showed a narrow band of increased density at the ends of the diaphragm, consistent with lead poisoning.

He was treated for delirium and was kept on a diet with added vitamin B complex and cod liver oil (15 drops), 360 mg of ascorbic acid (50 grains [0.33 Gm.]) daily and calcium lactate (30 grains [0.19 Gm.]) daily.

He returned a year later with the same complaints and though he was 2½ years old he had not acquired speech. In view of his mother's efforts he had continued to chew paint. Physical examination showed a cyanotic, unresponsive child who continued to be lead about and keep it with his hands for some time after admission. His gait seemed definitely unsteady, but otherwise nothing remarkable was found.

His blood showed a mild secondary anemia, and on roentgenographic examination may times the normal amount of lead was found in the blood. After three weeks of treatment with cod liver oil (2 droppers, 7.35 ml.) daily and a high calcium diet, the lead was found to be greatly diminished. Roentgenographs of his long bones still showed heavy bands at the ends of the proximal.

His irregularity diminished, but psychological examination showed that he did not use words and showed motor and sensoria disturbance.

A few weeks later he returned with an acute upper illness and a digestive upset which subsided quickly. At this time his blood serum showed a trace of lead on spectrophotometric examination, while the diet showed a good deal more. It was reported that his pica had disappeared.

At 2 years and 8 months he was examined, growny and dehydrated after several days of projectile vomiting. His face was hypostatic, and the cuticle was poorly adapted. Otherwise the results of the examination were unremarkable. A lacunar purpuric was not done, but the other usual laboratory procedures yielded no abnormal conditions. Some- times aspects of his bones no longer showed any compensatory deposits of bone.

At 4 years and 5 months he was examined and was apparently well, though he recovered without incident. After this he was transferred to the psychiatric ward for appraisal. His language development was normal for his age, but he had difficulty in the use of it, and adjustment of forms and bases, diagnostic of confusional conditions. He has remained for psychological check-ups from time to time because he has been intermittently to the hospital. At 4½ years his mental age (Stanford-Binet) was 29½ years and his intelligence quotient was 150, but it was impossible for him to do any of the cube designs which are usually satisfactorily dealt with at 6 years. He was not progressing in reading or writing.

Case 6—A girl of 5 years and 9 months was admitted to the hospital because of vomiting of six days' duration. Her own nose was bloody and that of the family were bleeding except that she still had the paint off her crib and had polished several times of plow from lanol in about six months before admission to the hospital. She had entered school in the first grade eight months before, and disappointment was expressed because of her inability to read as well as had been expected. There had been seen previous bouts of vomiting of two days' duration brought on by a blue bottle. She had not been admitted six months before admission. About six months the vomiting had been seven times, twice at once, twice that four times, and twice that four times.

Physical examination showed a tall, pale, dehydrated girl with teeth in poor condition and a pronounced fist line on the gums. Her hand showed no alternation, and it was noted that she was found to be very emotional. Her hands showed a secondary anemia (hemoglobin content of 35 per cent and 180,000 red cells), and about 2 per cent of the red cells were stained. Spectrophotometric examination of her blood and spinal fluid showed a large and definitely pathologic anemia of lead present. The total protein content of the spinal fluid was at its peak in half of the patients. Otherwise the fluid was unremarkable. Roent- genograms of the long bones showed some density at the growing ends of the shafts of the long bones, definitely pathologic to allow a definite roentgen diagnosis in each patient. A roentgenogram of the abdomen yielded much dense accoutrement in the kidneys, consisting of opaque with filling of bowels.

Treatment with sodium phosphates and milk did not alleviate the vomiting, and because of continued dehydration and sickness she was given physiologic solution of sodium chloride compatible with 10 per cent solution of glucose intravenously. Two hours after she had a generalized convulsion, which was relieved forty-five minutes after its onset by phenylhydrazine given intravenously. She was then treated with sodium bicarbonate, milk, estranged

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fruit juices and spirits. She gradually improved and was discharged on the twenty-second hospital day, eating well. At the time of discharge an increase in density of the dense bands at the ends of the shafts of the long bones was noted on roentgen examination.

A psychologic examination given the day before her discharge showed an intelligence quotient of 100 and adequate response to all tests.

Two years later she was seen in the outpatient department because of nervousness and crying in her sleep. Her physical examination and her blood showed no abnormalities, and roentgenograms of her long bones showed faint stars of the previous dense bands in the diaphyses.

At 12½ years she was considered a nervous person by her father, but she was doing passing work in the seventh grade in school. Mental tests revealed an intelligence quotient of 82, with no significant deviations.

Case 7—A girl of 10 months was admitted to the hospital because of poor appetite and refusal of food since birth and irritability for two days. She was born normally at full term, and was 7 pounds 7 ounces (3390 Gm.). Since birth she had eaten poorly and gained slowly. Change in juice and cod liver oil had been refused or rejected, apparently quantitatively. Since cutting two teeth (time untraced), she had chewed its paint off her crib.

On physical examination she was a small, irritable baby, incessantly scratching her palms, soles and genitals. There was ill-maintained nude clothes on the left, but otherwise results of physical and neurologic examinations were unremarkable. Her blood showed no anemia and no stippling.

Roentgenograms of her long bones, taken because of the suspicion of scurvy, showed a line of increased density at the growing ends of the diaphyses, characteristic of lead poisoning. She was treated with an average diet, cod liver oil and diphosphate sodium phosphate, which she took well, but the scratching of her palms and soles continued in the hospital and for the two months during which she was followed in the outpatient department.

She was seen at long intervals because of infections until she was 6 years old, when the school sent her back to the hospital because she was irritable, nervous and insomniac. At 9 years she returned with the same complaints, to which was added the statement that in spite of an adequate intelligence rating she would not do her school work. She was considered to present a serious behavior problem and had been referred to a remedial reading class. Her attention span was very short. Her intelligence quotient was 103 (Stanford-Binet), but appetimeter tests were not given.

Case 8—A boy of 19 months was first seen at the hospital because of poor appetite and loss of weight. His family history and his past history were not remarkable. At about 14 months he stood up and chewed paint off his crib, and since then he chewed it from window sills and other box. Although he walked alone at 14 months, he did not walk alone until he was 23 months old, apparently because of loss of strength.

Two years and 2 months he was admitted to the hospital because of refusal of food and violent behavior, consisting of tearing up toys, defecating on the breakfast table and the like. Physical and neurologic examinations revealed nothing remarkable. Laboratory examination revealed no abnormalities of the urine, blood or spinal fluid. Roentgenograms of the long bones showed broad bands of increased density at the ends of the long bones, consistent with lead poisoning.

Psychologic examinations were given at 2½ and 2½ years. On the second examination the Wechsler subtests were read: "In the past five months the child shows considerable advance in vocabulary, but there has been little or no advance in his ability to manipulate blocks and forms or to use a crayon adequately." At 6½ years he had a mental age of 6½ years (Stanford-Binet) and an intelligence quotient of 105. In spite of this, he had not learned to read at all. For example, he read "boy, cat, dog, play" as "black, red, gray.

Case 9—A boy of 2½ years was admitted to the outpatient department because of failure and eating paint and dirt. He was the third child of healthy parents, was born at term by forceps delivery and seemed vigorous at birth. He cut his first teeth at 6 months, walked alone at 14 months and was using words purposefully at 16 months. From the time he stood up, at 10 or 11 months, he chewed the paint off his crib and window sills. He was irritable and cranky.

On physical examination he was pale and difficult to manage. His blood showed a hemoglobin content of 35 per cent; his urine contained a slight trace of albumin, and roentgenograms of his long bones showed dense bands at the growing margins of the bones, characteristic of lead
PROVINCIAL. He was put on a high caloric diet with added iron and muriate, and vigorous attempts were made to increase his weight. The figures were unsatisfactory, however, and the patient died of emaciation.

A year and 3 months after his admission to the hospital he was discharged, but returned to the hospital with symptoms of relapse. He was admitted to the hospital on the 3rd of May, 1924, and was discharged on the 3rd of June, 1924, after a total of 40 days' confinement.

Physical examination showed no evidence of tuberculosis, either in the lungs or the pleura. The chest was clear, and the heart was normal. The liver and spleen were not palpable. The blood pressure was normal. The urine was negative for sugar, red blood cells, and bacteria. The hemoglobin was 70%, and the erythrocytes numbered 4,400,000 per cubic millimeter. The differential count showed a leukocyte count of 7,000, with 60% neutrophils, 30% lymphocytes, and 10% mononuclear cells.

The patient was a thin, undernourished child, who was able to walk and stand without assistance. He was able to eat and drink without difficulty. The temperature was normal, and the pulse rate was 80 per minute. The respirations were 20 per minute. The chest was clear, and the heart sounds were normal. The liver and spleen were not palpable. The blood pressure was normal. The urine was negative for sugar, red blood cells, and bacteria. The hemoglobin was 70%, and the erythrocytes numbered 4,400,000 per cubic millimeter. The differential count showed a leukocyte count of 7,000, with 60% neutrophils, 30% lymphocytes, and 10% mononuclear cells.

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Byers-Lord—Late Effects of Lead Poisoning

Op this occasion she showed pronounced weakness of all her voluntary muscles, with complete paralysis of her diaphragm, demonstrated by fluoroscopic examination. There was no evidence of intracranial pressure. Her tendon reflexes were abolished except for both biceps jerks, which could be obtained. Sensation seemed unimpaired. Her Hb was 13.8 per cent. 130 red cells and a mild secondary anemia. Roentgenograms of her long bones showed narrow dense bands at the growing ends of the shafts of all the long bones and, in addition, there were well-defined areas of density proximal to these suggesting recurrent lead poisoning. Her spinal fluid was not remarkable.

A definite diagnosis of peripheral neuritis due to lead was made, and an atony was made for two days to cause evacuation of the lead with use of ammonium chloride, but she vomited so severely that this was abandoned and treatment with several lactates and 10 per cent oil started, and she was transferred to the neurologic ward, where she was given massage and exercises in a task. While she received this treatment her mental state showed slowing slowly, and after three months of treatment her blood still showed 2.3 per cent stipped cells.

Two years later, at 7 years of age, she was seen in the outpatient department in response to a follow-up letter and was thought to be entirely well. Roentgenograms at this time still showed faint bands of density some distance behind the growing ends of the long bones, thought to be due to the old deposits of lead.

Four years later, when she was 11, she was returned to the hospital because of difficulty with school work and emotional disturbances, depressor in character. She had been free of physical symptoms in the meantime. Physical examination showed slight paleness, slight weakness of the right side of the face, lively tendon reflexes and persistently positive Babinski signs on both sides. Her blood showed a secondary anemia (hemoglobin 50 per cent and red cells 4,000,000) and a few stipped cells. Her urine showed a very slight trace of albumin. Roentgenographic examination of her blood, urine and spinal fluid showed about one hundred times the concentration of lead found in normal persons. In spite of these results, roentgenograms of the long bones showed no evidence of lead deposits. Encephalograms showed no gross evidence of cerebral damage. Treatment for lead poisoning was again instituted, and continued continuously with her Willings were arranged.

At 15 years she was a quiet, well-painted girl, growing along happily but slowly in the eighth grade, though totally unable to do arithmetic. The family hoped she might get into high school and possibly finish it, but they were no longer pushing her scholastically.

Repeated psychologic examinations were made. At 15 years her mental age (Stanford-Binet) was 65 years and her intelligence quotient 108. The test showed irregularities and inability to copy the square at the 4-year level, and her hand was tremulous as she traced the Pyramus cross.

Her poor memorization control was further shown by her inability at 65 years to copy letters in opposite lines.

At 15 years her intelligence quotient was 92 (Stanford-Binet), but in the Stanford scores her paragraph meaning score at grade 2.8, her auditory memory was poor, and her tenacity capacity as tested by the Ellis Visual Design test was very poor (score 31). At 3 years she was in again. The Stanford test score dropped, and memory tests were given once more. She had made a real gain in this respect. Her average for her age on the Ellis Visual Design test. She succeeded in three of the five work designs, though they were more than usually difficult for her. On the Wood Patterning Completion test her score was 112, which was the third decade for her age.

Case 12—At 4 years old girl was admitted to the hospital because of anemia, less of weight and progressive weakness of eight weeks' duration. She was the fourth child of healthy but dissent parents and did well throughout infancy. She was admitted at 6 months, walked at 14 months and talked at 18 months. Food was noticed by the mother at the beginning of the present attack; the child broke bits of plaster off the wall and ate them. No certain consumption of pain was remembered. Weakness developed rather rapidly over the period of the months so that she could not support her weight or hold up objects.

Encephalograms showed a weak, encephalized little girl with great muscular weakness but no complete paralysis. The diagnosis barely moved actively at all. All tendon reflexes were diminished. There was marked bilateral wrist drop and toe drop. Sensation to "pin" and to touch appeared intact. No evidence of intracranial pressure was found.

Roentgenograms showed a secondary anemia (hemoglobin content 12 per cent and red blood cells 3,300,000) and about 1 stipped cell per high power field. Sensation to"pin" and to touch appeared intact. No evidence of intracranial pressure was found.

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The patient remained for two months in the hospital on a high calorie diet with added iron and coal liver oil. Her anemia improved fairly rapidly, but her weakness was still
crippling. She remained in a convalescent home another four months. Two months before her discharge from the home she was walking well, and at the time of discharge she was walking well and seemed healthy.

Vomiting and abdominal pain were recurrent during the next four months, and five months later she became severe and were accompanied with return of the peripheral edema. She was readmitted to the hospital unable to stand, and with respiratory embarrassment severe enough to require the use of a Drinker respirator.

Physical examination and laboratory examination showed conditions similar to those noted previously, except that all were more pronounced. Roentgenograms of her skull showed beginning separation of the central suture. Her diaphragm was completely paralyzed, and the costophrenic angles were flattened from the elevated diaphragm. Her blood pressure was 120 systolic and 70 diastolic.

Carcinoma of the brain is a disease of the elderly. The patient was 66 and had been followed for a long period of time by the hospital's staff. The diagnosis of carcinoma of the brain was made on the basis of the roentgenograms and the patient's history.

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At about the time he learned to sit up he began displaying pits, using several steaks of paint off the available portions of his crib, carriage and perks railing. He also had eaten cloth, paper and all sorts of rags, rubber and canine stools. He had worn out his shoes, and the soles were numerous gapped cells on sores. Roentgenograms of the long bones showed heavy bands of density at the ends of the shafts, diagnostic of lead poisoning. His spinal fluid was not remarkable. Psychologic examination showed poor intellectual development at that time, which was steady improvement in intelligence with two months, and a second time the process of a finger, b) graduated as it was done, and b) steadily improved in language ability.

Nine months later he was again admitted because of encephalitis, frequent sitting and walking history, and was utterly against "like that of a little baby, but learning to walk." His hair showed a secondary anemia but no edema, and roentgenograms of his long bones still showed metallic deposits. Anencephalics showed increased spinal fluid and normal ventricular outlines. In the ward his behavior improved, but he was in a condition that of a 30 to 35 month old child than that of one of 22 months and his conversation and attention were poor.

The moment he returned home his behavior returned to its former low level. Vomiting and abdominal pain appeared in the head, and he became so weak that he was unable to sit up and his general condition was poor.

At six years he was admitted to the hospital with a severe tuberculous condition, for which treatment became necessary. He was treated with siccans for six days to three months maintaining observations of the dosage between 10 and 15 mg. per hundred cubic centimeters of blood. Twelve days after the use of siccans was stopped, an infiltration developed, from which he died in sixteen days.

Case 13—A girl of 24 years was admitted to the hospital because of vomiting of three and one-half months duration. Her father had been treated for siccans for two years. The date of infection was unknown. Her mother was well, and there were five older children; of whom three were well. The oldest child had died, and the child had pneumonia. He was removed.

The patient was then well, and well and well on bottle feeding. She had had irregular amounts of orange juice and cow's milk. Her behavior was normal at term and well on bottle feeding. She had had irregular amounts of orange juice and cow's milk. Her behavior was normal at term. She was removed.

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She had shown no signs since the previous admission to the hospital. The convulsion was controlled with ether and paraldehyde, and the signs were for bilious, because results of physical examination were unremarkable. Cerebral excretion of her spinal fluid and blood yielded no remarkable results. Roentgenograms of her long bones showed no degenerations to be found at the end of the long bones but no metallic bands. After recovery from the convulsion she was found to be well and to read aloud, although she could copy words readily. On the Wood Picture Completion test her associations were so simple that the results were bizarre and uncorrelated. She failed in all the tests devised appropriate for 6-year-old children. She did picture puzzles well and the average 6-year-old child. On the Peabody Classification Test she made a group of unpredictable errors, perseverating from one design to the next.

CASE 16.—A girl of 45 years was admitted to the hospital because of convulsions which had first appeared when she was 4 years of age. Her family, birth and past history were not remarkable. She walked at 13 months and used whole words at 18 months. She had been brought up to chew food, furniture and newspaper since she was 2 years old. For some time she had had a poor appetite and suffered constipation. Infantile convulsions had accompanied high fever at 4, 6, 8, and 12 years.

Results of her physical and neurological examinations were not remarkable. Laboratory studies showed no abnormalities were the cold secondary amylase (permanganate 10 per cent). Roentgenograms of her long bones showed a broad band of increased density at the end of the long bones, consistent with long-standing lead poisoning. A diagnosis of lead poisoning was made and treatment with vitamin D and a high vitamin diet instituted.

Statistical convulsions recurred during the ensuing three years, but from 8 to 10 years of age she was free of them. At 10 years sudden recurrent attacks of grasping and hiccups developed, which were accompanied by convulsions lasting a matter of minutes, and from 12 years of age she again had recurrent frank convulsions. Pneumoneumograms showed symmetrical enlargement of the lateral and third ventricles in a ventral vault of average size and were interpreted as indicative of diffuse cerebral atrophy.

Psychologic examinations were made at various ages. At 5 years her intelligence quotient (Stanford-Binet) was 80, with pronounced retardation, and she exhibited difficulty in learning new material in spite of the adequate rating. At 8 years similar results were obtained. At 12 years she gave a very poor and irregular performance on the Terman test, her results indicating an mental age of 8 years and an intelligence quotient of 65. She could deal with the Wechsler subtests or comprehension at the 7-year level, while she succeeded with high items of compre- hension at the 9-year level. On the Wood Picture Completion test she did as well as a 9-year-old.

A dramatic contrast to her low rating she attained high grade scores in the subjects on the Metropolitan Achievement tests. Although her actual test performance was so confused that it was almost impossible to analyze her education or to determine how her teachers' attitudes toward her affected her abilities.

CASE 17.—A girl of 16 years was admitted to the hospital because of convulsions and a rash. Her mother had observed that she was chewing wood at 1 year and 10 months. One week later, in appeared when she was 3 years of age, she had a convulsion which lasted for several days. Her local physician administered a saline solution in her blood, and referred her to the hospital, where roentgenograms of the long bones showed dense bands at the end of the phalanges, consistent with lead poisoning.

A year later she was read as far as her family knew, except that she remained healthy and often. When the convulsions were severe, at 3 years, her local physician again treated without effect. She was admitted to the hospital, where pneumonograms of the long bones showed dense bands at the end of the long bones, consistent with lead poisoning.

At 5 years and 3 months she demonstratedata EEG, consistent with lead poisoning. At 5 years and 1 months she demonstrated a fairly high level of consciousness lasting one or two minutes, sometimes accompanied by falling and involuntary vomiting and usually followed by drowsiness for several minutes.

Pneumoneumograms at this time showed normal ventricular outlines. Roentgenograms of the long bones showed no evidence of lead, although stippled ends had been noted three months before.
A year later he returned because of pain, irritability and loss of appetite. At this time he was definitely known to have pain off objects, though his family tried to prevent him. The weight of the leg had not returned.

Physical examination disclosed nothing remarkable except pallor, which was continued by a hemoglobin content of 50 per cent; a red cell count of 2,600,000 and a smear showing moderate anemia but no stippled cells. Roentgenograms of the long bones again showed dense bands at the growing ends of the shafts. He was discharged on a high calcium diet with iron and ammonium citrate and red liver oil (3 drachms 117 grains daily). In a month his hemoglobin content was 80 per cent and his red cell count 4,000,000.

At 12 years he returned to the competent department because of anemia. He gave a general impression of being stilted. His mother gave the following report of his school progress:

"He started to school at the age of 5 years. He spent two years in the first grade. The next year he had a teacher at home. The following year he spent in the second grade. He will never have the fifth grade in the fall." Periodical tests have not been given.

Case 20—A girl of 3 years was admitted to the hospital because of vomiting and abdominal pain of three months' duration. Her father and mother were separated at the time. Her birth and early development had been normal. She walked at 15 months and talked at 14 or 15 months. From the age she began to move about she showed anything and everything, including pain from her ribs and from windpipe. About three months before her admission to the hospital she began to vomit, and the vomiting increased in frequency. A month later abdominal pain, irritability and pallor supervened. One month before admission a consultation was held. During this period a gradual loss of weight occurred. She had complained of headache during the few days before admission.

On physical examination she was dull and droopy. Her optic disks were noticed slightly, and her skull was bitemporal on percussion. Her tonsils reduced everywhere hypostatic, and Babinski signs were elicited on both sides.

Her hemoglobin level was 90 per cent; her red blood cell count was 2,600,000; and her blood urea showed anemia and 8 to 10 stippled cells per high-power field. Her spinal fluid was under increased pressure and contained 18 cells per cubic millimeter and 108 mg. of total protein per hundred cubic centimeters.

Roentgen examination showed heavy bands at the growing ends of the long bones, consistent with lead poisoning, over a long period of time, with an especially heavy recent deposit.

Increasing listlessness and vomiting continued in spite of treatment with hydropenic solution of dextrose (20 per cent) and dextrin.Nolte phosphates, and on her fifth hospital day intermittent decompression was performed.

Frequent lumbar punctures were performed, with the removal of large amounts of spinal fluid (up to 200 cc. on one day), during the next few weeks. After that the patient gradually became interested in her surroundings, her vomiting stopped and she made a rapid recovery during the last two weeks of her stay. Six weeks after admission she was playing "impossibly" in bed, but phlebographic examination showed a general lack of intelligence around 3 rather than approaching 4 years, with special disabilities in the field of spatial relationship. She was discharged on the thirty-first day in the hospital, weak and underweight but able to walk and showing an active interest in life.

In spite of her mother's efforts she continued to eat paint at home, scraping at the paint off the wall before she was caught. A year later she was again admitted because of vomiting and abdominal pain. Her decompression wounds were healing, but her optic disks were still pale. Her gums were quite reddish-pink. Her hemoglobin content was 53 per cent and her red blood cell count 3,500,000; with marked anemia and many stippled cells on smear. Roentgen examination of the bone showed a level "very much below anything found in normal children." Roentgenograms of her long bones showed wide bands of lead deposit with recent resorption at the growing ends. Roentgenograms of her skull showed no evidence of pressure. A lumbar puncture showed fluid that appeared increased pressure, with 6 monocytes per cubic millimeter and a total protein content of 46 mg. per hundred cubic centimeters. She was discharged on a high calcium diet and 10 grams of combined fish liver oil daily, and with assurance that she would be protected from paint in the future.

She was seen later when she was 9 years and 6 months of age in response to a follow-up letter. Although she was friendly and outgoing, she was doing badly in school in the third grade, had a mental age of 7/2 years and an intelligence quotient of 80, with special defects in spatial orientation. Her score on the Ellis visual design test was 1.5, which was below the calibrated level for her age.

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