AN INVESTIGATION

of the

AETIOLOGY, SYMPTOMATOLOGY & DIAGNOSIS of LEAD POISONING.

(Based on the clinical histories of 100 cases of lead poisoning, including five in a trade in which no case has been previously recorded, and on the records of 85 white lead workers).

Being

A THESIS

for the examination for the Degree of Doctor of Medicine of the University of Glasgow.

By

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CONTENTS.

I.- GENERAL INTRODUCTION.

During the 10 years 1900 - 1910 the number of cases of lead poisoning notified under the Factory and Workshop Act 1901 to the Chief Inspector of Factories and Workshops in England and Wales was redueed by half.[1] But the fact that in 1910 the number notified amounted to no less than 505, of which 38 ended fatally, indicates that there is still a considerable prevalence of (an intoxication) which may now be considered to be preventable. Moreover, it seems that this number does not represent all the cases occuring in England and Wales; for the Factory and Workshop Act only applies to those cases which take place among the employees in factories and workshops, and a large proportion of lead workers are not so employed. Hence it seems probable that in addition to those cases notified to the Home Office a large number of cases of which there is no record occur annually in the country. This is borne out by the fact that although painters accounted for only 13·4% of the 505 cases notified, 49% of a series of 100 consecutive cases (vide infra) were employed as painters.

That there may be considerable difficulty in diagnosing some cases of lead poisoning is shewn by the fact that in 13·4% of the 505 cases notified the diagnosis was not confirmed, and in another 8·3% it remained doubtful.

On account of this difficulty in diagnosing a comparatively common and sometimes fatal disease it was thought that a study of the various factors upon which a diagnosis may be based should be of value. Therefore I have collected the records of one hundred consecutive cases of lead poisoning. Thirty-five of these were patients in a London hospital and the remainder were seen under the Factory and Workshop Act, several being subsequently traced at varying lengths of time and further investigated.

In order that the relative importance of some of the symptoms might be more accurately estimated, it was thought advisable to obtain information regarding the conditio of lead workers who were not and never had been suffering from lead poisoning. This was obtained at a white lead factory in London, where I examined 85 workers on the same day that they had been passed by the examining surgeon as fit to continue to work in lead.

II.- AETIOLOGICAL FACTORS.

In regard to the various aetiological factors involved in lead poisoning, an analysis of my series of cases revealed the following points:

Occupation.-

The varied ways in which people may be exposed to the risk of the absorption of lead into the system in sufficient amount to give rise to ~~the~~ symptoms of poisoning, may be seen from the following table, in which the 100 cases collected have been classified according to occupation:-

Painters	49
White lead manufacturers	23
Accumulator makers	3
Plumbers	6
Printers	4
Ore Crushers	1
Lens Polishers	4
Process artists	1
Bath Chippers	5
Various	4
	100

The painters included colour mixers, carriage and motor body painters, house painters, painters' labourers, etc.

While in some of these the only exposure to lead was in the handling of liquid paint and putty containing lead, in others there was also exposure to the fumes which arise during the burning off of old paint and to dust impregnated with lead. This dust is produced in large quantity during the sandpapering of painted surfaces which in some instances, i.e., motor body painting, takes place between the application of the various coats.

The electric accumulator makers were exposed to lead by having to handle a paste composed of red lead and sulphuric acid.

The workers in white lead factories included two stovemen and one cooper, the others acting as general labourers carrying trays to and from the stoves; so that all were exposed to lead carbonate as dust.

The plumbers all handled metallic lead, red lead, and white lead.

Of the four printers, one was a compositor, one a stereotypists'assistant, one a printer's labourer, and the last washed the type with lye. All handled the type, but were also exposed to the lead-impregnated dust which arises as the result of the friction of the founts of type in the boxes.

The source of lead in lens polishers is the rouge and putty powder which falls on the revolving brushes; while in the case of process artists, the lead is contained in the dust arising from the air brush.

Ore workers are of course exposed to the dust arising during the crushing of the ore. According to Oliver,(2) lead poisoning among those working in lead mines is uncommon in this country as the ore contains lead in almost a pure metallic state.

Bath Chippers.-

No case of lead poisoning occuring among bath chippers has hitherto been recorded. The five cases in my series occured during the year 1911, one being notified in April and the other four between August and October. All five were working for the same employer and in the same workshop. In each case this was the first attack of lead poisoning, but in two men who had been following this occupation for eight years there was a history of repeated attacks of gastro-intestinal derangement, which however did not necessitate any medical treatment, nor did it involve absence from work for more than a day or two. Both these men, whose ages were 54 and 31 years respectively, had been employed in the same workshop since it was opened seven years previously. Of the others, one aged 27 had been employed for six years, and two aged 27 and 25 respectively

had been working as bath chippers for only two months. Although the room measured 6,400 cubic feet, the height was only 8 feet. There were two windows, each measuring 3 ft. by 2 ft. situated high up in the same wall, only part of them being above the level of the ground. The door was situated in the wall opposite to the windows but opened into a small area at the back. Thus it is obvious that no proper means of ventilation was provided. The number of men at work at the same time in this room varied. Sometimes there ~~was~~ were as many as 10 all engaged in the same work, while at other times there were as few as three. It was the duty of these men to prepare old baths for the process of re-enamelling. This they did by chipping and scraping off the old paint and finishing off with sandpaper. Before others proceeded with the enamelling, these men had sometimes to apply the first coat of paint, called the "stopping coat". During the process of sandpapering the old paint, much dust arose, and no precautions were taken either to limit its amount or to facilitate its early escape from the workshop. The quantity of dust produced was so great sometimes that the men swept it up themselves and removed it from the room instead of leaving it to the individual who cleaned the premises after work had ceased for the day. That some danger was attached to the work was known, for a lavatory with hot water, etc. was provided

for the employees and, to give them time to wash, they were allowed to stop work five minutes before meal hours. As far as could be ascertained the men made use of these facilities. No food was allowed to be taken in the workshop. These precautions must have ~~been~~ reduced to a minimum the amount of lead ingested with the food, and this would indicate that the poisoning in these cases was most probably the result of inhalation. This assumption is borne out by the fact that a sample of the dust taken just after these cases occured was found on examination to contain 55% by weight of lead, and that no further cases of poisoning have occured since the introduction 9 months ago of improved ventilation and of a wet process which minimises the amount of dust.

One man among those classed as "various" fitted lead tops to bottles in a battle factory. Of the other three, one was a cabdriver, one a sweep, and one a horsekeeper. As it was their custom to drink ale as soon as the public houses were opened in the morning, and as no other source of infection could be traced, it was presumed that poisoning was due to the ale having taken up lead while standing in the pipes over-night. These cases occured some time ago, before this source of poisoning was generally recognized.

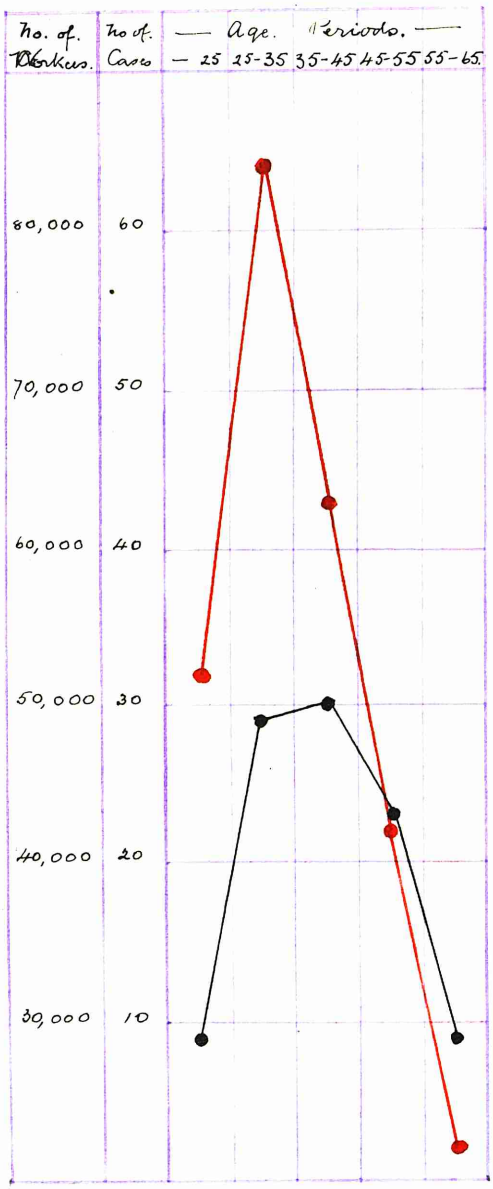
Lead-Impregnated Dust.-

As the probability of contracting lead poisoning

varies enormously in the different sub-divisions of the same trade, it was thought advisable to classify the cases as far as possible in such a way as to indicate the actual mode of infection. In one class have been considered those who only handled metallic lead, paints in the wet state, etc., and in another those who were also exposed to lead-impregnated dust. The information available permitted of this being done in 73 of the 100 cases. Twenty of the 73 belonged to the former class and 53 to the latter. Although the longest and shortest periods of work prior to the onset of symptoms of poisoning were similar in both instances, viz., 30 - 40 years and about two months respectively, the average period of employment varied within wide limits. For those not exposed to lead dust the average was 16·3 years, while in those exposed to dust it was 9·3 years. This difference of no less than 5 years indicates that trades involving exposure to lead dust, besides producing a greater incidence of cases, are likely to give rise to poisoning sooner than those trades in which there is no such exposure. This demonstrates the supreme importance of careful supervision of the means employed to ventilate factories and workshops in which lead dust is liberated.

In the two classes, i.e. the dusty and non-dusty occupations, the average age of the affected was practically

Chart. No I



The Black indicates the no. in the Series of 100 cases.

The Red indicates the no. of Lead Workers in England and Wales (Census. 1901)

the same, viz. 37·2 years in the former and 38·7 in the latter. I would submit that an adequate explanation of this similarity of ages combined with the difference in the period of employment is furnished by the fact that dust workers include a large number of white lead workers whose work is more or less unskilled, and being known to be dangerous is not likely to attract young men wishing to learn a trade. This is well shown by my series of cases, in which no lead worker was below the age of 35 years when symptoms of poisoning manifested themselves.

2. Age.

In the accompanying chart the black line represents the cases in my series according to the frequency with which they occurred during the various age periods. It will be seen that the majority of the cases were between 25 and 55. To more accurately estimate the relative frequency of lead poisoning at the various ages, it has been thought necessary to compare these figures with the number of workers employed at these ages. From the census returns for the year 1901, those for 1911 not being available yet, the number of lead workers in England and Wales was obtained. Their numbers at the various age periods are represented in the chart by the red line. It will be seen that although almost as many of my cases occurred between the ages 25 and 35 as between 35 and 45, many more workers were

employed at the former age. Also, although fewer cases occurred between 45 and 55, the decrease in the number of cases at that age was not in proportion to the decrease in the number of workers. My series of cases then indicates that lead poisoning is most likely to occur between the ages 35 and 55. On the other hand, as fewer cases relative to the number employed at the same age period occurred under the age of 25, the series indicates that at this period a worker is least likely to be attacked.

But Oliver[3] is of the opinion that "young adults are more liable to lead poisoning than men and women of maturer age" and he quotes 191 cases notified to the Home Office between January and October 1898. The distribution of the 191 cases being as follows:-

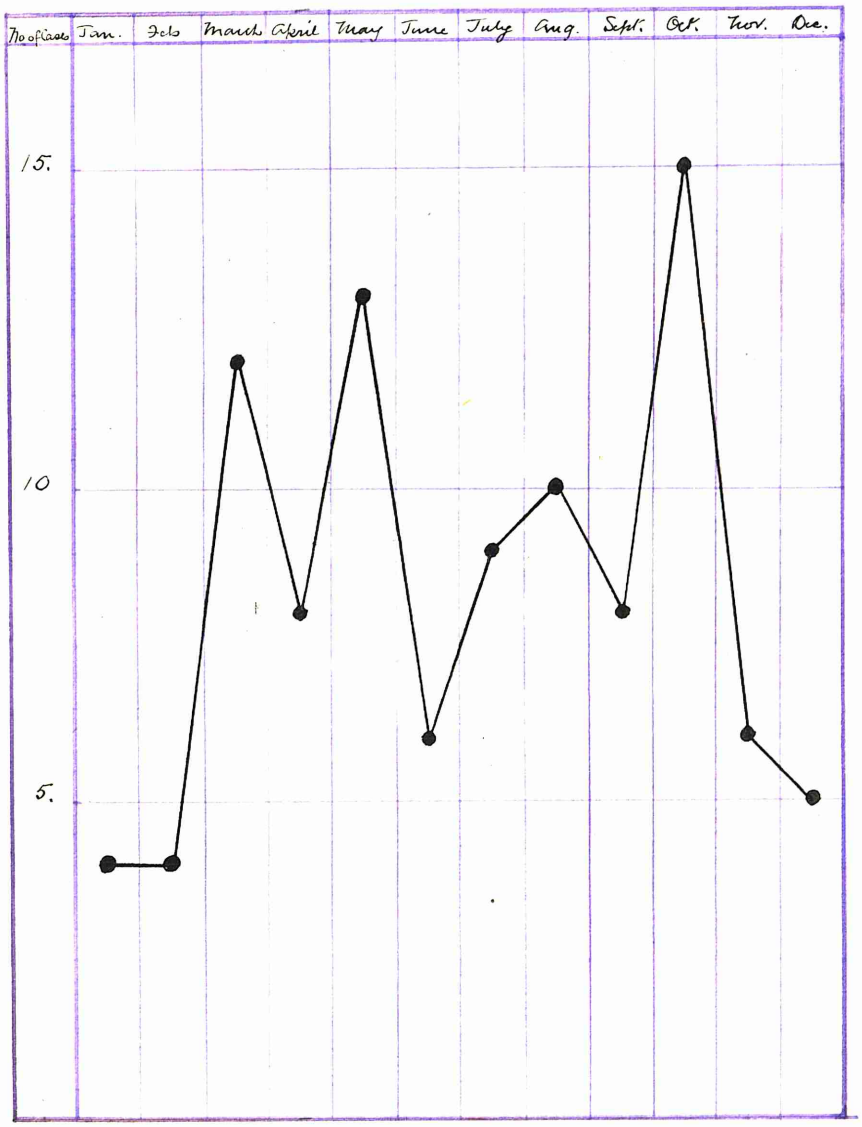
Under 20.	20 - 30.	30 - 40.	40 - 50.	50 - 60.	Over 60.
7	84	58	24	15	1

On the other hand, Tanquerel[4] in 1084 cases found the greatest incidence between the ages of 30 and 40, his figures being

20 - 30.	30 - 40.	40 - 50.	50 - 60.
244	445	277	118

and Legge[5] states that the average age of cases of lead poisoning occurring in England and Wales among earthenware and china workers is 37 years. The average age is not, strictly speaking, comparable with the mode, i.e. the age

Chart. No. II



To indicate the no. of cases occurring in the various months of the year, in the Series of 100 cases.

at which most cases are likely to occur; but as more workers would be employed at an age far below 37 than at one much above 37, the fact that sufficient cases did occur in later life to keep up the average to 37 shows the incidence to have been greater then. Osler[6] also states that the largest number of cases occur between the ages of 30 and 40, and Verhaeghe[7], while investigating the health conditions of the painters of Lille, found that they were most frequently ill between the ages of 30 and 35 years. It is also worthy of note that, besides there being more workers employed at the earlier age periods, among them are many who may be ignorant of the conditions of their employment and the results it may lead to, and many who are careless and soon affected. That this is so is borne out by Legge's statement[7a], based on the returns of cases notified to the Home Office, that lead poisoning occurs with greatest frequency during the first and second years of employment at work involving exposure to lead.

3. Seasonal Variations.

Chart No.II shows the series of cases as they occurred in the various months of the year. The occurrence of fewer cases during the winter months is marked. Tanquerel[8] found that the greatest number of his cases occurred during June, July, and August, and he was of opinion that the number of sick labourers in the works he visited

was greater during the warm months of the year than in the cold seasons. Heat, he suggested, predisposed to plumbism either by favouring the dissemination of lead, or by rendering more permeable the different organs by which lead enters into the system. Edsall[9] recognises the greater incidence of cases during the summer months, and suggests that the greater consumption of liquids at that period of the year may cause more lead to be washed into the stomach. He also suggests that the more actively functioning skin absorbs lead with relative readiness. Since the amount of liquids consumed seems to affect the readiness with which a person is attacked by lead, it is possible that a greater consumption of alcohol in the warmer months may cause the greater incidence of cases at that period of the year.

Duration of Exposure.-

Of those of my cases who were affected for the first time, the shortest period of employment amongst lead workers was 7 weeks. Eight cases occurred within two months of the commencement of work, and 13 within 6 months. At the lead works where the workers were examined, one case had occurred within 42 days, and one case within three months of starting work there. Oliver[10] states that "after a few "weeks' exposure to lead in a white lead factory, I have seen "young healthy women not only lose their ruddy appearance

"and become quickly pale, but die from saturnine "encephalopathy within four months of taking up the work". Tanquerel(11) observed cases that occurred as early as the third day. On the other hand in my series the longest term of employment prior to being attacked was 32 years, and among those examined at the factory visited there were several workers who, although they had been employed there for over 25 years, had never developed any symptoms of plumbism. Tanquerel(12) saw a man who had contracted lead poisoning for the first time after being a lead worker for 52 years.

Many factors may have a bearing on this varying rapidity with which workers are attacked. The eight cases of my series, which occurred within two months of exposure to lead, were equally distributed over the various age periods. Two of the eight were bath chippers and exposed to much dust, no precautions being taken; two were house painters, to most of whom the danger of their trade is known, so they presumably would taken precautions; the others were white lead workers and, being under supervision, precautions were insisted on. Thus, except in the case of the bath chippers who were unconsciously exposed to lead-impregnated dust, there is no reason to suppose that these cases were due to exposure to lead in large quantities, either through ignorance or through negligence. That

general ill-health was not the cause ~~of~~ of the susceptibility is shewn by the fact that some of the workers were under medical supervision during their employment, and would have been rejected had they been considered unfit.

Idiosyncrasy.-

Thus it would seem that there is a personal element which renders some people less liable to be affected by the absorption of lead than others. In this connection Edsall(13) says, "A certain degree of immunity certainly exists "in some persons. Others are certainly especially "susceptible, and intercurrent factors are known to increase "and decrease this susceptibility; but it is difficult to "establish the importance of immunity in considering "industrial cases, because different individuals differ so "largely in their care in advoiding exposure".

In several of my cases symptoms of paralysis were preceeded by gastro-intestinal disturbances, but in one the converse was the case, for although palsy was the result of the first attack the second resulted in gastro-intestinal symptoms. That lead poisoning may thus manifest itself in different ways in the same person is an additional indication that there is some idiosyncrasy, which may vary even in the same individual from time to time.

Influence of Alcoholism.-

That alcoholic intemperance may be a factor of considerable importance in disposing to lead poisoning is generally accepted. Oliver[14] quotes from a report on the white lead industry presented to the French Senate by M.Treille, showing a marked difference in the incidence of lead poisoning in the northern and southern divisions of France: "The intemperate habits of the working classes "of Normandy and Brittany are well known. These two "districts give employment to one-third of the total "number of house painters in France, and yet within their "borders the death rate from plumbism is more than half "that of France. Chronic cases of plumbism are much more "prevalent in the north than in the south. Normandy alone "with its heavy consumption of alcohol has more than one-"half of the total cases of lead paralysis in France. The "influence of alcohol in these cases, as in all, is to "reduce the vital resistance of the nerve cells of the workman, "to render him careless to the necessity for cleanliness, "and thereby render him more prone to plumbism".

Experiments on animals show that alcohol may precipitate an attack of plumbism. Combemale and Francois[15] fed dogs with lead and found they shewed great fear and were subject to fits. Afterwards, animals fed to a point just short of producing those symptoms had

alcohol administered to them with the result that epileptiform fits occurred, which ultimately passed off even though the alcohol was persisted with.

Latent Poisoning.-

All the cases in my series, except one, occurred during employment in lead. The exception was a man who had been working as a plumber for about 12 years, but had ceased work 4 months prior to being attacked with severe colic accompanied by constipation which lasted for several days. This was his second attack; (for) several years before he had had an attack of colic accompanied by double drop-wrist. Oliver(16) describes the case of a female who as a white lead worker had been attacked three times. On her marriage, she did not return to the lead works, and although during the next 17 years she was not knowingly exposed to lead, she was again attacked with plumbism, and lead was found in her urine. Tanquerel(17) also had a case of a painter who had annual attacks of colic for some years after ceasing to work in lead. These cases of latent lead poisoning are rare. The lead seems to lie dormant in the tissues and then suddenly without any known cause gives rise to symptoms of poisoning. It may be that it is present in a harmless insoluble form and that some altered condition of the blood or something dissolved in the blood renders it soluble.

III.- SYMPTOMATOLOGY.

Gastro-intestinal symptoms were present in 83 of my cases, but of these 15 also had paretic symptoms in varying degrees, 8 had arthralgia, and one had nephritis. Of another series of 14 who had paralysis, one had arthralgia, and one encephalopathy. Two others suffered from arthralgia and one had gout. Since in lead poisoning different systems may in this way be affected simultaneously, it has not been found possible to classify satisfactorily the cases according to the systems affected. Nor has it been found possible to classify the symptoms as early and late, for symptoms which were early in one case were late or absent in another; and symptoms which were late in many cases were in a few the only symptoms complained of. Thus, although in the majority of cases gastro-intestinal symptoms were first evident, in one case they were the only symptoms present at the seventh attack; and palsy, although usually the result of long exposure and preceded by other symptoms, in one case was present within 18 months

of working in lead and was not preceded by other evidences of poisoning.

A given symptom may also be present at different stages and due to different causes. Thus in most cases headache was an early symptom and preceded or accompanied gastro-intestinal derangement, but in one it accompanied encephalopathy, and in another it was the result of kidney disease.

1. Blue Line.

Burton's line was found to be present in the gums of 75% of the cases. In more than half of these the line existed as a blue line at the margin of the gums, close to the teeth in both the upper and lower jaws. In some it was opposite all the teeth, while in others it was not complete, being present only where the teeth were dirty or decayed. In several cases where teeth were wanting no line was present opposite the vacant spaces. A large blue patch was present in the mucous membrane of the lower lip opposite the incisors in two cases, and a third had a patch in the right cheek. Of the 25 cases in which no blue line was present, it is worthy of note that 50% of these had had palsy, another 10% had definite pareses, while the remaining 40% had other symptoms sufficient to warrant a diagnosis of plumbism. Thirty-two cases (18) among women and young

persons, employed in printing, have been recorded as having symptoms suggestive of lead poisoning with no blue line present. Three of my cases, who had been at work for only two months, developed definite blue lines during that time. According to Osler[19], Oliver stated that a blue line may form after a few days' exposure to lead. In one of my cases, although the lines had been well marked, they disappeared after 14 days non-exposure; while in others they were still quite evident 18 months after exposure had ceased. Osler[20] states that in his experience the blue line may disappear within a few weeks or may persist for months.

A line was present in 77% of those cases in my series who were exposed to dust, and in 65% of the cases not so exposed. This greater frequency among the dust workers my be explained by the theory that the blue line in some cases may be the result, not of deposition from the blood stream, but of absorption by the lymphatics, or by the cells themselves. of chemical action with H_2S in the mouth at the points of deposit

2. Circulatory System.

Anaemia of varying degree was present in 49 of my cases. That lead may interfere considerably with the production of red blood corpuscles is shewn by the fact that in one of the cases in which the blood was

examined there was found to be 3,600,000 red blood corpuscles and 9,600 white blood corpuscles per c.mm.. The haemoglobin was reduced to 70%, a fall which is practically accounted for by the reduction in the number of red blood corpuscles. In Oliver's cases[22] the red corpuscles varied from 2,700,000 to 3,500,000 per c.mm., and the white corpuscles averaged 10,000; and Edsall[23] states that counts rarely show the red blood corpuscles to be below 2,000,000 and that they are usually above 3,000,000 per c.mm. Oliver[24] finds that there is a reduction in the haemoglobin, usually not severe and rather less than in proportion to the decrease of red cells.

Although Oliver[25] found in some cases the degree of anaemia to be in proportion to the extent of exposure to lead; in my cases this was not so. Several cases who had been working in lead, for a few months only, were markedly anaemic, and others who had been lead workers for over 20 years showed no pallor.

In 24 of the cases saturnine cachexia was present. A few of these cases had a peculiar greyish appearance accompanying the pallor, in others the features had become somewhat expressionless.

Arterio-sclerosis was present in eight of the 100 cases, and it is a noteworthy fact that only one of

these was above 50 years of age; three were between 40 and 50, and four between 30 and 40. At the earlier ages there is a much higher proportion with arterial change than would be found in individuals not exposed to lead.

3. Gastro-Intestinal.

The following table shows the frequency with which some of the more prominent symptoms were present in the series of 100 cases:-

Gastro-intestinal derangement	83
Paralysis and Paresis	29
Arthralgia	13
Encephalopathy	1

In the 17 cases in whom there was no gastro-intestinal derangement, there was a history of its having been present at some previous date in eleven cases, so that only six of the 100 cases had never been so affected. Tanquerel (26) classified his 2171 cases according to the symptoms they presented as follows:-

Colic	1217
Arthralgia	755
Paralysis	127
Encephalopathy	72

And these symptoms were present in the 578 cases notified to the Home Office in 1907, with the following frequency:-

Gastric - - - - - - - - - - - 83·6%

Arthralgic - - - - - - - - - 8·1%

Paretic - - - - - - - - - - - 24·8%

Encephalopathy - - - - - - - 4%

At the factory where the workers were personally examined, I found that 49 cases of lead poisoning had occurred during the last 10 years. In 39 of these "colic" was the result of the poisoning. Thus it is seen that Gastro-intestinal symptoms are by far the most common manifestation of lead poisoning.

In all of the 100 cases that had occurred within three years of commencing work in lead, gastro-intestinal derangement was the chief result of the absorption of lead. On the other hand, in one case which occurred after 32 years working in lead, and in another who had had six previous attacks in the course of 30 years, the only symptoms complained of were colic and constipation. Thus, the series of cases indicates that although gastro-intestinal derangement is usually the result of more or less short exposures to lead, it may also arise after long and repeated exposures

In one of my cases, paralysis had preceded gastro-intestinal symptoms. At the first attack there had been drop-wrist, which had passed off before work was resumed;

but at the second attack colic and constipation were complained of.

Although colic was present in 75 of the 83 cases who had gastro-intestinal derangement, in the cases of other observers it has not always been present with such frequency. For instance, in an outbreak of lead poisoning among 150 men in the army at Southern Tyrol, although the chief symptoms were pallor, blue line in gums, metallic taste in mouth, obstinate constipation, pains in limbs and chest, muscular tremor, etc., in no case was colic present.

The colic in my cases varied considerably in degree. In most it was more or less severe while it lasted; one case when admitted to hospital yelled so much with the pain that he had to be kept in a room by himself. The pain in all the cases was paroxysmal in character, and the different attacks varied in severity. In 10 cases only was the pain referred to the umbilicus. Seven obtained relief by pressure on the abdomen, while four complained of marked tenderness on pressure. In one case, besides the attacks of acute pain, a constant dull aching was described, and for some time after the colic had ceased tenderness on pressure was complained of on the left side of the abdomen. Oliver[27] states that when there have been

repeated attacks of colic, a degree of tenderness results limited to one half of the abdomen, usually that which was the seat of the pain; and on the whole he is of the opinion that this occurs more frequently on the left than on the right side of the body. In 10 of my cases, observed during attacks of colic, the abdomen was rigid, and in eight of these was retracted. The rigidity in one case was more marked on the left side, and persisted for two days after the disappearance of the colic. During the attacks of colic in four cases, it was noted that the pulse was retarded, in one of these there were only 45 pulsations to the minute. In all four the pulse was hard and incompressible. Oliver[28] has also noted in some cases an inequality in the two radial pulses. The amount of urine excreted during the attacks of colic was scanty in three cases, and in two there was a rise in temperature. In one of these the rise was slight, 99·5° F. being recorded on two successive days, but in the other the temperature rose to 100° F., 101° F. and 100·5° F: on the three days after admission to hospital. In this latter case, the gastro-intestinal symptoms were accompanied by double drop-wrist and weakness in one ankle. According to Oliver[29], acute lead colic is usually accompanied by a rise of temperature, but Osler[30] states that slight fever may be present.

Of the 100 cases constipation was present in 74, and in 69 of these colic was also present. The degree of constipation varied considerably. In one case there was absolute constipation for 15 days, and it was with some difficulty in many cases that the condition was rectified. In others relief was obtained in a few days by appropriate treatment. Diarrhoea was present in two cases, in one of whom it had been preceeded by constipation for eight days. In both constipation followed the diarrhoea.

Vomiting was present in 29 of the 100 cases. Only two of these had no other gastro-intestinal symptoms, but more than half of all the cases had suffered from nausea and anorexia, particularly in the mornings, for a varying length of time prior to cessation of work.

In several cases the tongue was coated and the breath was foul, and a few complained of having had a metallic taste in the mouth.

4. Urinary.

The urine was examined in 68 cases. In 56 of these (82·2%) it was found to be normal, the other 12 (17·8%) having albuminuria. Eleven of these latter were suffering from gastro-intestinal derangement and were

more or less slightly affected. Albumen was only present in these cases for a few days and was small in amount, being in most instances little more than a trace. In the other case, however, albuminuria was more marked and more permanently established. This man was 33 years old, and had been engaged in enamelling and painting for 14 years. His previous history was good, there having been no illnesses of any consequence, nor had he suffered previously from symptoms due to lead absorption. He complained of headache, of pains in the loins, and of severe pains in the abdomen of a colicky nature, accompanied by marked constipation. A blue line was present in both gums, and there was marked anaemia. There was also tremor of the tongue, and firm pressure over the calf of both legs revealed marked tenderness. Under the eyes some puffiness was noticed. The urine excreted was small in amount, and it contained blood and albumen in considerable quantities. The blood disappeared after a few weeks' treatment, but the albumen was still present at the end of eight weeks.

In six cases of the 100 the urine was examined for the presence of lead, but in only two was a positive result obtained. In both of these albuminuria was also present; but Oliver[31] has frequently found traces of lead in non-albuminous urines. Ralfe[32] was of the opinion

that excretion of lead by the kidneys was the chief means of elimination, but Dixon Mann[33] as the result of observations on cases being treated with lead medicinally, came to the conclusion that "lead is slowly and continuously "eliminated by the bowels and to a lesser degree by the "kidneys". That the amount excreted by the kidneys is small is shown by the experiments of Thudicum[34] on animals which were suffering from lead poisoning. Of the 14 cases in which he examined the urine, in two only did he obtain a weighable quantity of lead; but he demonstrated its presence in all the others.

Gout.- One of my cases suffered from gout. He was 43 years old, and had been employed as a painter for over 20 years. This was his fourth attack, all the others having taken place during his exposure to lead. No tendency to gout was indicated in his family history. There was a marked blue line in both gums, and a considerable degree of anaemia and cachexia was present. No gastro-intestinal symptoms were complained of. The urine was normal, and there was no arterio-sclerosis. No paralysis was present, but there was marked wasting of the interossei muscles of both hands. The right wrist was swollen and was acutely tender, and there was marked thickening with some tenderness and limited movement at the left ankle,

this having been the seat of previous attacks. The small joints of the right hand had also been previously involved, there being some enlargement of the proximal end of the three outer distal phalanges, and also some deviation of the fingers ulnar side. That the absorption of lead may be a factor in the causation of gout has been doubted by many, for among lead workers gout has only been found with any frequency in those districts where gout is prevalent. Lead workers accounted for 33% of Garrod's[35] cases of gout at King's College Hospital, and for 18% of Sir Dyce Duckworth's[36] cases at St Bartholomew's Hospital, percentages far in excess of that representing the number of lead workers in the population. Garrod[37] also observed cases where small doses of lead given medicinally brought on attacks of gout.

5. Neuro-Muscular.

Headache was complained of in 20 of my cases, in 17 of whom there were gastro-intestinal symptoms present. It is evidently an early symptom, because 19 of the 20 had suffered from headache for a varying period prior to ceasing work owing to other symptoms. Headache was present associated with paralysis in two cases, and with nephritis in one.

Vertigo was complained of in three cases, two

of whom had paralysis, and one arthralgia; and the two cases who had paretic symptoms complained of insomina.

Pains of various kinds were present in 34 cases, in 11 of whom they were situated in the joints. Of those 11 who had arthralgia 8 had also gastro-intestinal symptoms, one had paralysis while only two had no other complication. The pains were most frequently situated in the joints of the legs, the knees being most commonly affected. In one case the pains were present in the ankles and wrists, and in another in the finger joints. Muscular pains were present in 23 cases. Four of these complained of general pains, while three had pains in the arms and legs, six in the arms alone, seven in the legs, and three in the back.

Muscular tenderness was present in four cases, in two of whom it was revealed by pressure over the calves of the legs. In one case marked tenderness on pressure existed along the nerves of the right arm.

Several of those who had paralysis or paresis complained of numbness. In most of these the hands were affected, but in a few the feet also. In only one case was there definite anaesthesia. In this case sensation was completely lost in certain areas in both legs, more

especially below the knees.

Tremor was a fairly frequent symptom being present in 20 of the cases. In 19 of these the tremor was present in the hands; three also had it in the legs and two in the tongue. In one case tremor was confined to the tongue. Ten of the 20 cases who showed tremor were suffering from palsy, and in none of the remaining 10 cases was the exposure to lead less than 8 years. This would seem to indicate that tremor is a comparatively late symptom of lead poisoning, but that it may occur early is shewn by the fact that, among the workers I examined at the white lead factory, two had marked tremor of the hands and one had tremor of the hands and tongue.

The knee jerks were absent in one of my cases, but were exaggerated in six, all of whom were suffering from gastro-intestinal symptoms but had no paralysis.

General weakness was complained of in 16 cases, in most of whom gastro-intestinal disturbance was the chief symptom. Two had weakness in the knees and one in the arms and legs without any wasting.

Paralysis.- The average period of exposure to lead in 29 cases of my series suffering from paralysis was 15·1 years, while the general average of the 100 cases

was 12·1 years. Besides the longer exposure that is thus suggested as being necessary to produce paralysis, there would seem to be either a greater absorption of lead or some idiosyncrasy to its action in those cases who become the subject of lead paralysis. For in my series of cases 19 (63·6%) of those with paralysis had had one or more previous attacks of lead poisoning, while only 33 of the 100 cases had previously suffered.

Of the 29 cases with paretic symptoms, 19 had definite paralysis; in the others there was paresis only. In 4 of the latter there was impaired power of extension of both wrists, in 3 of the right wrist, in 2 of the left wrist, and in one there was weakness of both legs. The loss of power had extended to the arms in two of the cases in which the right wrist was affected. Wasting accompanied the paresis in one case only.

Table showing the relative frequency with which paralysis affected the various regions in my cases.

Paralysis of both wrists			3
,,	,,	and fingers	6
,,	,,	shoulder and fingers	1
,,	,,	fingers and ankle	1
,,	,,	with paresis of legs	1
,,	right wrist		1
,,	,,	and fingers	3
,,	,,	arm and fingers	1
,,	fingers		1
,,	,,	and weakness of wrist	1

The right hand only was affected in both the cases in which the paralysis was confined to the fingers. In one there was loss of power of extension of the second and third fingers, and in the other of the three outer fingers, only portions of the extensor communis digitorum being affected. The whole of this muscle was paralysed in those cases where paralysis of the fingers was accompanied by wrist drop, and in 6 of the 10 so affected there was also wasting of the interossei muscles. In all those with wrist drop the extensors of the carpus were wasted, but in no case was the supinator longus involved. A few, however, had marked weakness of flexion shown by the grip being impaired. In 4 of those in whom both wrists were affected, paralysis of the right wrist was more marked, in the others it was equally developed. Wasting and loss of power of the right deltoid was marked in the case in which the shoulder was involved. There was slight ankle drop of the left leg in one case with some wasting of the peronei muscles.

It will be seen then that the muscles of the wrist were most frequently involved, and that the right wrist was more often and more severely affected than the left. According to Oliver(38) "overwork is the determining "factor in the part of the muscular system involved in "paralysis".

Encephalopathy.- Cerebral symptoms were present in one case of the 100. In Tanquerel's[39] series of 2171 cases of lead poisoning, 72 had encephalopathy of which 16 ended fatally. The case in my series had been exposed to lead for 15 years as a white lead worker, but Tanquerel[40] found in his cases that encephalopathy occurred most often after short exposures. Ten of his cases occurred within 30 days, and 34 within 9 months of exposure to lead. In my case there had been two attacks of lead poisoning within the previous two years, in which he had suffered from "lead colic". A blue line was present in the gums and anaemia was marked. Constipation was complained of and colic was severe at times. Besides arthralgia and arterio-sclerosis, double drop wrist was present. The temperature varied between 99°F. and 101·4°F. for a few days, and returned to normal as the patient improved. Delusions were present. At night he was much worse, having then delirium of a most active type. This continued for a week, when cerebral symptoms gradually abated and disappeared altogether, and the patient appeared to recover completely.

Eyes.- Blindness was present in one of the 100 cases. This man had been a painter for four years and was suffering from colic and constipation. The dimness

of vision, for sight was not completely lost, only existed for two days. The urine was normal, and examination of the eyes with the ophthalmoscope was negative. Berry[41] writing of this temporary amblyopia says, "It is one of the rarest symptoms of lead poisoning", but Oliver[42] does not find it to be altogether infrequent, for he states, "In not a few cases is blindness complained of", and again[43] "Temporary loss of vision is occasionally "complained of by patients during attacks of colic".

Albuminuric retinitis was present in the case suffering from nephritis. In no case, however, was found the neuro-retinitis which Oliver[44] has described as being present mostly in acute cases. He ascribes its presence to the direct toxic action of lead.

IV.- DIAGNOSIS.

The difficulties in Diagnosis.- The symptoms described as being present in my cases bear out the fact that the manifestations of lead poisoning may be many and varied. Although in many cases the diagnosis was beyond doubt, in a few the symptoms were not characteristic. In such cases, where, after exposure to lead, symptoms arise similar to those of lead poisoning, there may be considerable difficulty in determining whether lead is a causative factor or not. This difficulty is greatly increased where the period of exposure to lead has been very short, or where it has been so slight that it is questionable whether during such an exposure, lead sufficient in quantity to give rise to poisoning could be absorbed; e.g., Oliver (45) quotes the case of a woman who developed drop-wrist subsequent to washing the overalls of a painter, and also two cases who developed lead poisoning as the result of living in freshly-painted rooms.

Difficulty of diagnosis may also arise in cases with symptoms suggestive of lead poisoning but in whom, until it has been sought for, exposure to lead had been unrecognised; and where exposure to lead has terminated some time before, in the case of a subsequent illness it may be difficult to determine the part played by lead as a causal factor.

Since the Workmen's Compensation Act, 1906, provides compensation for those suffering from lead poisoning, there may arise cases where it is important to determine when the patient has ceased to be the subject of lead poisoning.

It has been seen that many of the symptoms of lead poisoning are subjective and, as in other conditions where compensation is provided, there is a tendency for workmen, most of whom soon become acquainted with the results of absorption of lead, to exaggerate those symptoms either intentionally or unintentionally. It is only natural for a lead worker, knowing the dangers of his trade, to ascribe to it all those illnesses which he cannot otherwise account for; especially as he knows that by so doing he may be provided for during absence from work. Oliver(46), speaking of the effect of the Compensation Act, says "Lead workers seek medical advice for the most

"trivial aches in their limbs and chest, to an extent which "was not done a few years ago, and they invite reassurance "that they are suffering from lead poisoning in order to "obtain the benefits under the Act".

Factors on which a Diagnosis may be based.- Those symptoms which appeared early in my cases included early morning nausea, sometimes accompanied by loss of appetite, headache, and a metallic taste in the mouth. Anaemia, although it did not vary directly with the length of exposure, was markedly present in several cases after working in lead for a comparatively short time. Among males anaemia is rare, and its presente in a male lead-worker must be of considerable significance. Arthralgia was present alone only in one case. It usually accompanied gastro-intestinal disturbance; consequently pains in the joints, particularly those of the legs unaccompanied by no swelling or rise in temperature, in early cases where other symptoms may not be pronounced, would be a valuable diagnostic factor. Although tremor in some cases accompanied definite paralysis, in others it was unconnected with palsy; being therefore a more or less early symptom.

With one exception, all my cases which showed

albuminuria, were more or less slight examples of plumbism, hence the demonstration of albumen in the urine in somewhat indefinite cases would aid in arriving at a positive diagnosis. Colic was the most frequent symptom in my cases, and in the majority it was severe and accompanied by constipation. The diagnosis of lead colic may be strengthened by finding that the pain is referred to the umbilicus, or that a dull aching pain is present in the left side, as were shown in some of my cases. The slowing of the pulse and the suppression of urine in lead colic were well marked features in several instances. Although lead colic is usually accompanied by a rise in temperature, it is noteworthy that two patients had pyrexia. This would indicate that, although the absence of a temperature might aid in arriving at a diagnosis in some cases, the presence of fever is not to be taken as an absolute negative sign. Should colic be accompanied by constipation of a marked degree it is more likely to be lead colic, but the two cases in which diarrhoea was present indicate that absence of constipation must not be taken to exclude lead poisoning.

My cases showed the usual distribution of paralysis, viz. that there is a tendency for the paralysis to begin in the right arm, to affect the left arm later

and then the legs; that the extensors of the fingers or of the wrists (the supinator longus escaping) are the first to be affected; that it spreads to the arm and to the extensors of the ankle. Implication of the flexors is unusual except in very marked cases. The paralysis of lead poisoning is easy to diagnose when marked in degree and characteristic in distribution; but when there is slight weakness only, the presence of other symptoms would assist in arriving at a conclusion; and conversely the presence of extensor weakness, however slight, would cause a positive diagnosis to be made where the other symptoms were somewhat indefinite.

If will be seen then, that although some of the individual symotoms of lead poisoning may be very characteristic, at times they may not be so; but in these cases a positive diagnosis may be arrived at by finding the history of others and the occurrence of two or more symptoms together.

In making clear the dependence of certain symptoms upon the action of lead, it must be of importance to show that besides exposure to lead there has been absorption, and further, that when absorbed the lead has been present in a soluble form.

A blue line in the gums due to the local deposit

of lead sulphide is a certain indication that lead has been absorbed. It was seen that a blue line was present in 75 of my cases of poisoning, but I also found it to be present in 79% of the white lead workers whom I examined at the lead factory. Paddock Bate[47] also found the presence of a blue line frequent among lead workers. He states that it was present in 70% of 520 examinations of workers in paints and colours, in 53·5% of 106 examinations of electric accumulator makers, and in 84% of 1034 white lead workers. But since the presence of a blue line, not due to other causes, proves that the patient has absorbed lead, it is only fair to assume that he may be absorbing it if there is still exposure. Should exposure have ceased, the possibility of latent lead poisoning must be kept in mind.

On the other hand, 25 of my cases of poisoning showed no blue line, therefore its absence must not be taken as a conclusive negative sign. In these cases, although no lead was deposited in the tissues in an insoluble form, there must obviously have been sufficient in solution in the blood to give rise to poisoning. It would seem, too, that the formation of a blue line depends on other factors besides the absorption of lead, for it was noticed that most of the white lead workers who shewed no line had taken

more care to keep the teeth in a cleanly state.

It does not follow, therefore, that because lead is present in the tissues in an insoluble form it is also circulating in the blood, nor on the other hand is it the case that because none is in the tissues none can be in the blood. Still, it is easier to conceive that poisoning is taking place in those cases where it is known from the presence of a blue line that there is lead in the system, than it is in those cases where on account of the absence of a blue line it is not known whether lead is present or not.

The presence of anaemia would seem to indicate that lead is present in the system in a soluble form. Although anaemia was present in 49 of my cases, I also found it to be present in 45% of the white lead workers I examined. Paddock Bate(48) found anaemia with varying frequency in lead workers. It was present in 15·5% of those working in paints and colours, in 9% of electric accumulator makers, and in 53% of white lead workers that he examined. Thus it is seen that anaemia may be present with as great frequency in some trades as it was in my cases of poisoning, but that that frequency is not so great as in the case of the blue line. The presence of anaemia, although not signifying that poisoning is taking place,

demonstrates that lead has been absorbed into the system, and that there is a possibility of toxic symptoms arising; but the absence of anaemia does not prove that there is no lead in the system. Since anaemia when produced tends to persist, its continuance cannot indicate that more lead is being absorbed.

Microscopic appearance of the Red Blood Corpuscles.

Since Grawitz drew attention to the presence of basophil granules in the erythrocytes as evidence of lead poisoning and as an aid to its early diagnosis, many observers have carried on experiments to find out the diagnostic value of this observation. Carozzi[49], assistant to the Clinic for Industrial Diseases at Milan, examined the blood of 230 painters. Most of these men had worked for some years at this employment. Many had previously had attacks of colic, and six had been treated in hospital for nephritis. At the time of inquiry 44 were suffering from muscular pains and 70 from digestive troubles; 15 showed tremor; 17 paralysis of the right arm, one of the left and 3 of both arms. In 3 there was parasthesia, and in one paralysis of the facial nerve. A blue line was present in more than half of the total number (122 out of 230).

Basophial granules were found to be present in

the erythrocytes of 189 of those painters, but they could not be demonstrated in 41.

It is well known that Basophilia may appear in the other pathological conditions of the blood, especially in pernicious anaemia, tuberculosis, malaria, and cancer. According to Glibert[50], Dr O.Galet has shown that great numbers of basophil granules are present in animals who have suffered from prolonged pyrexia, and Trautmann[52] found 33 basophil granular erythrocytes per million in a perfectly healthy individual.

Schmidt[51] examined the blood of 110 persons who had never been exposed to lead, and in 1·8% there were over 100 basophil granular erythrocytes per million, in 12·7% they were present up to 100, and in 85·5% were entirely absent. Trautmann[52] examined the blood of 100 anaemic patients, and found in 86 no basophil granular red blood corpuscles. The other 14 had an average of 61 per million, two having over 100 per million. He also examined the blood of 233 lead workers, 43·8% of these showed no basophil granular erythrocytes, 35·6% showed under 100 per million and 20·6% showed over 100. Of these workers 195 complained of various pains, and in 12 unmistakable signs of lead poisoning were present. According to Hofmann[53], numerous examinations of healthy

persons and of those slightly ill from various diseases, show that never more than 100 - 200 basophil granular cells per million are found. Only severe cases of malaria and cachexia are exceptions, and these of course cannot be confused with lead poisoning. He also states that, as a rule, the number of basophil granular cells in normal persons is much below 100 per million, but on the contrary in lead workers he has found up to 300, 500, 1000 or even 5000; and in one fatal case of suicidal lead poisoning, as many as 27,000 basophil granular cells per million were counted.

Those who maintain that the presence of these basophil granules is of diagnostic value, are of opinion that in no condition are they to be found with such frequency or in such great numbers as in lead poisoning. Trautmann (52) is of the opinion that where there are more than 100 basophil granular erythrocytes per million, it is to be regarded of diagnostic value; and when this number is present he would report workers as unfit for duty.. In those cases where litigation is pending he suggests a standard of 300 per million.

At no place has so much diagnostic importance been attached to the presence of basophil granulation as

at the Lead Department in the Hygienic Institute of the University of Leipzig. The standards that I have mentioned as having been suggested by Trautmann are in use there. The blood of about 400 - 500 lead workers is examined yearly, and Hofmann[53] states that by the early recognition of the dangerous action of lead, and the prompt exclusion of those showing excessive blood changes, the number of cases of lead poisoning in the factories and workshops of Leipzig has diminished very notably. According to Legge[54], Hofmann has also stated that the number of nervous workers, some of whom became the subjects of plumbophobia, has been reduced to a minimum by the assurance that he has been able to give to a large number as to the absence of any injurious effect of lead on their blood.

But, on the other hand, some observers do not find the presence of basophil granular erythrocytes so constant, nor do they attach much importance to their presence. As the result of his earlier work, Goadby[55] states that he would not confirm the finding of basophil granules in a large percentage of the cases which showed definite anaemia. He was not then satisfied that the presence of basophil granules in the red blood corpuscles was of such importance as to render them of diagnostic

value in lead poisoning. The results of his more recent researches have not been published yet, but according to Legge(56), prolonged investigation has confirmed ~~the~~ his earlier findings. Oliver(57), in discussing the value of the presence of basophil granules in the erythrocytes, says "I have made scores of examinations of the blood in the "late, as well as in the early, stages of plumbism; but only "in a very few instances have I found basophilia. This "alteration in the composition of erythrocytes has therefore "been of no assistance to me from a diagnostic point of "view. At present I have a rabbit under observation. It "has taken 300 grains of lead nitrate in solution during "the last 18 months. It has on two occasions been slightly "paralysed, but has recovered. Lead has been found in the "faeces and urine and yet ..... on no occasion have I "found even one basophil red corpuscle".

Those negative results of Goadby and Oliver go far to minimise the diagnostic value of the presence of a certain number of basophil granular red blood corpuscles in the blood in cases of suspected plumbism. It is also to be remembered that in Trautmann's painters 43·8% showed no basophil granular erythrocytes, and that in Schmidt's cases, who had never been exposed to lead, 1·8% had over 100 basophil granular red corpuscles per million, and 12·7% had

up to 100 per million.

Lead in the Urine.- The presence of lead in the excreta would indicate that lead is circulating in the blood. Mann has been quoted as pointing out that lead is excreted in the faeces, and to a less extent in the urine. Examination of the faeces would not be practicable in many instances; even some of the tests for lead in the urine are tedious and most objectionable unless carried out in suitable premises. It would be difficult, too, in many instances to exclude the possibility of lead ingested by the mouth passing in the faeces without having been absorbed. More importance may be attached to the presence of lead in the urine, for it is not open to this objection. The diagnostic value, however, depends to a large extent on the frequency with which it may be found in the urine of those who, although exposed to lead, do not show any symptoms. According to Osler(58), Putman found traces of lead in the urine of 25% of 150 lead workers presenting no symptoms of lead poisoning; and Bedson, according to Oliver(59), examined the urine of 23 white lead workers who had not made the slightest complaint as to the state of their health. In all he found lead to be present in quantities from ·64 - 2·75 parts per million.

On the other hand, the presence of lead in the urine of those suffering from lead poisoning does not seem to be constant, for in two only out of six of my cases in which it was tested for, was it found; and Oliver[60] states that "the best proof that a patient is suffering from plumbism is the detection of lead in the urine on chemical analysis, but its absence is no proof to the contrary".

Although lead, then, may be present in considerable quantities in the urine of lead workers with no symptoms of poisoning, and ~~it~~ may be absent in cases where there is evidence of poisoning, the demonstration of its presence, in cases presenting symptoms possibly due to the action of lead, must be of considerable importance, in that the presence of lead in the blood is thus demonstrated. It must be easier to satisfy oneself that certain symptoms are the result of the action of lead if it is known that lead is circulating in the blood, than if such is not known to be so.

It will be seen, then, that the diagnosis of lead poisoning depends on the presence of characteristic symptoms, or the presence together of several symptoms which may or may not be characteristic singly, and that the diagnosis may be considerably strengthened by the

demonstration of lead in the system and particularly so if that lead is in solution in the blood.

Determination of Recovery.- In cases where there has been lead palsy, no difficulty should arise in determining whether the results of the action of lead have passed off; but in those cases where the symptoms have not been so severe and obvious, there may be the utmost difficulty in deciding when the toxic action of lead has ceased. The longest period of abstention from work in those of my cases who suffered from colic was six weeks. Of the painters suffering from colic, whose blood Carozzi examined, the duration of incapacity in hospital was as follows:-

18	for a period of	2 to 30	days.
10	,,	,, 35 to 75	,,
2	,,	,, 80 to 110	,,
4	,,	,, 150 to 300	,,
3	,,	,, 400 to 600	,,

Thus, in 37 persons there was a mean of 93·2 days incapacity. Oliver[61] writes that he is unable to give any definite opinion as to when colic and constipation may cease after exposure to lead has been terminated. As a rule he finds that both have disappeared within two months, but in some cases constipation may never quite disappear.

The presence of a blue line and anaemia are not of great prognostic value, for once they are present they often tend to persist indefinitely. In one of my cases, examined two years after exposure had ceased, both the blue line and the anaemia were marked, although the patient had then evidently recovered from the effects of lead poisoning. Nor would it appear that the presence of lead in the urine is of much assistance. Large quantities have been found by Oliver in the urine 16 months, and even 11 years, after work in lead had ceased. But if it could be proved that lead had been absent from the urine for some time and had reappeared again, there would be strong presumption that poisoning by lead was taking place should symptoms be complained of.

Careful consideration of the facts outlined above render it apparent that the weight of ~~endemic~~ evidence tends to indicate that in some cases of lead poisoning, it is quite impossible, by any of the diagnostic methods at present at our disposal, to form a definite opinion as to whether the toxic action of lead has ceased, i.e., whether any given patient is or is not suffering from the effects of lead poisoning.

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