Phosphorus. It is prepared as follows: One grain (0.065 gm.) of phosphorus is dissolved in fl. ʒ v. (16 gm.)* of *absolute* alcohol by the aid of heat, and the solution added to a *warmed* mixture of fl. ℥ iss. (56.25 gm.) of glycerin and fl. ʒ ij. (6.68 gm.) of alcohol. When the resulting mixture has cooled ♏ xl. (2.12 gm.) of spirit of peppermint is added. The preparation should be a bright, clear, colorless solution, wherein the odor and taste of phosphorus are almost completely masked by the pungency of the alcohol and peppermint. It is essential that the alcohol used to dissolve the phosphorus be literally *absolute;* and in such case the preparation, if kept in well-filled and well-stoppered bottles out of the light, will keep unaltered long enough for the treatment of an average case. If all the phosphorus be and remain dissolved, the solution contains 0.003 gm. (gr. $\frac{1}{20}$ nearly) in 4 c.c. (fl. ʒ i.)—a scant teaspoonful. The dose, averaging from one-third to one small teaspoonful, is best taken clear, but if too sharp in that condition, may be taken in water, the mixture to be made only at the time of each administration.

Under no circumstances should phosphorus be prescribed as an ingredient of extemporaneous composite medicinal mixtures.

Zinc Phosphide: Zn_3P_2. A peculiar compound of phosphorus, which practically amounts to a medicinal preparation of the element itself, is what is official in the United States Pharmacopœia under the title *Zinci Phosphidum*, Zinc Phosphide. This compound appears as a finely crystalline powder, or as crystalline lumps. It is gray-black in color, with a metallic sheen on broken pieces, and gives faintly the odor and taste of phosphorus. It is insoluble in water or alcohol, but dissolves in sulphuric or hydrochloric acid, with evolution of hydrogen phosphide. Zinc phosphide must be kept in small glass-stoppered vials.

This compound is lacking in the vigorously irritant action of phosphorus, yet even in therapeutic doses may easily upset the stomach and even excite vomiting. From its ready decomposition by acids it yields, in the stomach, some medicinally active condition of phosphorus, and its administration is therefore followed by therapeutic results similar to those attained by the use of the uncombined element. The phosphide is, however, not so certain as preparations of phosphorus itself, and is probably most commonly turned to as a last resort in cases in which phosphorus persistently disagrees. Zinc phosphide contains one-fourth of its weight of phosphorus, and the dose therefore ranges from 0.003 gm. (gr. $\frac{1}{20}$) to 0.016 gm. (gr. $\frac{1}{4}$). It may be given in pill form, and, unlike phosphorus, may be prescribed in combination with other medicines, avoiding only acids, which decompose it. After swallowing, however, the certainty of medicinal action will be enhanced by effecting this same decomposition through the agency of an acid draught, such as lemonade or a little vinegar. The most disagreeable features of the drug are a tendency to eructations of phosphoreted hydrogen and to disturbance of the stomach. With the larger of the doses mentioned above nausea is not at all unlikely. *Edward Curtis.*

[1] Wegner: Virchow's Archiv, June 22d, 1872.
[2] See Phillips' Materia Medica and Therapeutics, Inorganic Substances, p. 51.
[3] Note on the Administration of Phosphorus, E. R. Squibb, M.D., Proceedings of the Am. Pharmaceutical Assn. for 1876, and pamphlet, Philadelphia, 1877.

PHOSPHORUS, POISONING BY.—It is doubtful if there is another substance among the many common poisons which is of so much interest to the toxicologist as is phosphorus—an interest arising from an historical viewpoint, and because of the desire to discover the mysterious causes of its insidious action on living organisms. Moreover, we meet with the anomaly that, unlike most of the other inorganic poisons, and especially arsenic, antimony, and nitrogen, members of the same group in the Periodic System, this element is toxic in its free or elemental state, while its compounds (save the hydrides) are practically non-toxic.

Phosphorus was unknown to the layman as a poison prior to 1840. Shortly after the popularization of matches, about the year 1833, the public became acquainted with its deadly nature, and because of the ease with which the material could be procured, poisonings by phosphorus became alarmingly frequent. In no country have the number of cases been so numerous as in France, where from 1840 to 1880 there were 336 criminal cases of poisoning by this element. The maximum number in a single year was 94 in 1860, or, if we consider the period 1851–70, we find that out of a total of 793 deaths due to poisons 267, or 33.7 per cent., were due to phosphorus, while during this same period 287 are charged to arsenic. France still heads the list in the number of cases of poisoning by this element, which usually equal, or even exceed annually, those due to arsenic. The substitution of "Parlor" and "Safety" or "Swedish" matches (invented by Böttger in 1852) for the yellow phosphorus match was immediately followed by a decrease in the criminal use of phosphorus; the decrease was also due in part to the fact that it became known to criminals that a process had been devised by which the poison could be easily and surely detected (the Mitscherlich method).

Homicidal poisonings are now rare. The majority of cases are due to attempts at suicide or to accidents among children.

Only "yellow" phosphorus, the hydrides of phosphorus, and the phosphides of certain elements, such as calcium and zinc, are of toxicological interest.

Yellow Phosphorus.—The general properties of this almost colorless, wax-like substance are too well known to require review. A word as to its solubility is, however, necessary. In water pure phosphorus is practically insoluble; in fact, it has been asserted that what is thought to be a solution represents merely exceedingly fine particles in suspension, or else that it is a solution of the vapor. According to Hartmann 1 litre (about ℥ xxxiv.) of water at 38° C. (100.4° F.) will take up 2 mgm. (gr. $\frac{3}{100}$) of phosphorus; while in oils its solubility varies from 1 to 100, to 1 to 10,000 parts, according to the nature of the oil and various conditions, such as temperature, etc. In bile phosphorus is readily soluble, 100 parts of this fluid dissolving 15 to 25 parts.

Because of the low solubility of phosphorus in most of the fluids of the body, only slight action generally follows the ingestion of large fragments of this substance. When taken, however, in a finely divided condition the action is very violent.

Poisoning by phosphorus usually results from matches, phosphorus pastes (vermin killers), or phosphorus oil (Oleum phosphoratum).

Matches.—The modern "parlor" and "safety" matches are usually harmless, so far as poisoning by phosphorus is concerned, owing to the fact that they are made of non-toxic red phosphorus and an oxidizing agent, such as potassium chlorate. The matches of a decade ago, known variously as "friction," "brimstone," "sulphur," "lucifer," "phosphorus," etc., matches, are to be charged with by far the majority of deaths. The heads of these matches contain on an average about five per cent. phosphorus, the limits varying from three to seven per cent. A single head usually contains from $\frac{1}{3}$ to 1.5 mgm. (gr. 0.005 to 0.023). In these matches the sticks after being dipped in sulphur are tipped with a mixture of glue or dextrin containing coloring matter, phosphorus, and an oxidizing substance such as lead nitrate, lead peroxide, nitre, potassium chlorate, or some similar compound. Dissolving these heads in water or a warm liquid yields a liquid in which the phosphorus exists in an emulsion in an exceedingly finely divided condition.

Phosphorus Pastes are now seldom employed, though formerly they were in great demand for destroying rats and other vermin. Here the phosphorus exists very finely divided with flour, lard, and sugar or molasses as a basis.

* In calculating the metric equivalents regard has been paid to the specific gravities of the several fluids.

These pastes vary greatly in composition. They contain, on an average, about two per cent. of phosphorus, but may contain as high as five per cent.

Phosphine.—The hydride H_3P is the only one of importance. One-fourth to one-half per cent. in air causes death in animals in twenty to thirty minutes, while 0.2 per cent. will produce symptoms of asphyxia in a few minutes. In man, when it is breathed in very small amount in air for any length of time, the symptoms closely resemble those produced by phosphorus vapors. Under this head there is another possible source of phosphorus, or rather phosphine, poisoning. It has been suggested that there may be a reduction of phosphates in the intestines by bacteria (a form of auto-intoxication well known in the case of reduction of sulphates to hydrogen sulphide). Some have even gone so far as to claim that acute yellow atrophy of the liver is due to this cause. This action of bacteria is well established for sulphur, arsenic, and antimony compounds; but although it is to be expected for compounds of phosphorus by analogy, all investigations have given thus far negative results with pure cultures of powerfully reducing bacteria, the reduction being carried only to phosphites.

Fatal Dose.—The weight of phosphorus which constitutes a fatal dose is quite uncertain. An examination of the records shows such a variation that it is difficult to make an accurate statement. The fatal dose seems to depend, more than is the case with most inorganic poisons, upon the nature of the material containing the poison, the state of division of the phosphorus, the nature of the material in the alimentary canal, and the idiosyncrasy of the individual. As regards matches, we find that a child has died after sucking the heads of 2 matches. In another case 8 heads caused death. Sixteen match heads have caused the death of an adult; and Tardieu cites a case in which 101 matches were immersed for seven or eight minutes in a cup of hot coffee with a resulting solvent action so low as to permit the matches when dry to be ignited by rubbing in the usual manner, yet the poisonous draught caused very dangerous symptoms. Other records show that where death has resulted from swallowing match heads the number of these taken in each case has varied from 60 to 3,000; and that, on the other hand, recovery has followed prompt medical aid where from 3,000 to 4,000 match heads have been taken.

In the case of Oleum phosphoratum it is probable that a dose of 200–250 mgm. (gr. iij.–iv.) will produce dangerous results, and that 500–600 mgm. (about gr. vij.–ix.) will almost invariably prove fatal.

Phosphorus itself, finely divided in hot water, has in a few instances been employed for homicidal and suicidal purposes. Although the smallest fatal dose recorded is about 8 mgm. (gr. $\frac{1}{8}$), this is abnormally low. It is believed that the toxic dose of well-dissolved or exceedingly finely divided phosphorus is probably about 15 mgm. (gr. 0.23), and that the fatal dose lies in the neighborhood of 150 mgm. (gr. ij.–iij.). Recovery has followed a dose of over 300 mgm. Occasionally cases are met with which seem to indicate that phosphorus may at times have a slight accumulative tendency. With animals the doses may be safely set as follows:

	Fatal dose. Grams.	Therapeutic dose. Grams.
Horses and cattle	0.5 to 2.00	0.010 to 0.050
Sheep and swine	.10 to .30	.002 to .005
Dogs	.05 to .10	.0005 to .002
Fowls and cats	.01 to .03	.0005 to .001

The most susceptible animals per kilogram weight are fowls, the next swine, then dogs. According to Naunyn parrots alone seem to be relatively immune.

Fatal Period.—This is quite variable, but there can be no doubt that phosphorus should be classed as a slow poison. The usual period lies between one and four or five days, with most deaths falling on the second or the third day; yet life may sometimes be prolonged until the seventh day, or very rarely until the seventeenth to the twentieth day. Several cases of remarkably rapid death are recorded. Caspar cites the case of a young woman who took 194 mgm. (gr. iij.) of phosphorus in an electuary and died in twelve hours, while Habershon is authority for the statement that death has taken place in thirty minutes.

Symptoms.—The differences in the symptoms between acute and chronic poisoning are chiefly only of degree, and yet at the same time they are quite marked. Even in acute cases it has been shown by Tardieu that it is possible to distinguish three distinct forms, which have been termed common, nervous, and hemorrhagic, according as certain symptoms predominate. The lack of space forbids a consideration of these. Occasionally a patient will show a combination of all these types, the one following tho other.

In what may be called for convenience a typical or normal case of poisoning (generally the result of matches), the victim first complains of pain in the throat. Usually, but not always, this pain extends downward with increasing severity, and is most marked in the epigastrium and abdomen. The tongue is enlarged and coated. Nausea in its most acute form sets in, followed later by vomiting of material of a mucous and bilious character. Very rarely at this stage is the vomit tinged with blood, but the ejected material is generally phosphorescent in the dark. There may be annoying eructations with an alliaceous odor and taste; the exhaled breath may even be luminous in the dark and give rise to a thin white vapor upon striking the air. Colic and diarrhœa set in at this stage, in about thirty per cent. of the cases. The pulse may for a short period be accelerated with an accompanying slight rise in temperature, but soon it becomes small, weak, slow, and often irregular. The temperature may fall as much as 3° or even 4° C. Respiration, which also suffered a slight acceleration, becomes slow, oppressed, and sometimes stertorous. This train of symptoms continues for from twenty-four to forty-eight hours when a remission often takes place; nausea and vomiting ceasing and the abdominal pain disappearing save for a few vague twinges. A period of apparent convalescence supervenes for two or three days; then suddenly, when all seems to be going well, the victim is stricken down with the most violent symptoms. Icterus appears, accompanied by hemorrhages, increasing in number and severity, in which practically all channels are affected. Vomiting and purging having again set in, the ejected matters are bloody in character and may at times consist almost wholly of blood; there is bleeding at the nose and even at the ears, and in women there is almost invariably more or less uterine hemorrhage. Up to the present time, in spite of the reputed aphrodisiac action of phosphorus, no venereal excitation has been observed in either sex in acute poisoning. The blood discharged is very thin and fluid. Hemorrhages have been known to continue for several months, the victim becoming weaker and weaker, and sinking into deeper and deeper apathy, being roused only by recurring nervous disturbances. Accompanying the hemorrhages is seen anæmic cachexia and urticaria, and a blotched skin. The eyes are icteric, blood-shot, and prominent. Owing to paralysis of the sphincter muscles there may be, in the last stages of the disease, involuntary expulsion of urine and fæces. Prior to this, however, the urine is apt to be suppressed, and when discharged or drawn will be found to contain albumin, peptones, hæmoglobin, bile pigments, biliary acids, fibrin and hyaline cylinders, fatty droplets, often leucin and tyrosin, almost invariably sarcolactic acid, subnormal urea, and abnormal ammonium salts, phosphates, and sulphates. It is quite safe to assert that icterus is absent in exceedingly rapid death only. Death takes place in coma or syncope, occasionally in convulsions preceded by delirium.

In addition to the above-mentioned symptoms there is often quite marked paralysis of the voluntary muscles, especially those of the legs, preceded by coldness or numbness and accompanied by formication and twinges of pain. Occasionally there is anæsthesia of the lower extremities, but otherwise there seems to be no loss of sensation.

Recovery from severe acute phosphorus poisoning is rare and takes place only after a long time.

The symptoms seldom appear in less than one to three hours, more often in five to seven hours. There are exceptions, however; for example, Taylor cites a case of a young girl who swallowed a quantity of phosphorus paste, and who at first suffered from symptoms so slight that it was thought that but little poison had been ingested. It was not until the following day that she was taken ill, and on the second day had apparently recovered; on the third day she was stricken with symptoms of poisoning, but these were not violent until the fifth day. Death took place on the sixth day despite the efforts which were made during all this period to save her life.

At one time or another practically all the secretions and excretions have been observed to be luminous in the dark—the exhaled breath, vomited matter, stools, urine, perspiration, etc.

Phosphorus cannot be classed, as is very evident from the above, as a rapid or even moderately rapid poison; and, on the other hand, evidence is lacking which would justify its being credited with any truly latent action.

Acute Poisoning in Animals.—Typical symptoms, similar to those seen in man, are observed in dogs and swine. Horned cattle behave somewhat similarly, but horses and fowls are affected in an entirely different manner. Fowls are exceedingly sensitive to this poison, suffering chiefly from severe thirst, diarrhœa, and chorea. They die without having shown any characteristic symptoms save that they are apt to move with a peculiar hopping gait. Horses die suddenly in a few days, having shown practically no symptoms of poisoning. In cows a cessation of milk secretion is almost invariably observed. In animals, especially ruminants, the first symptoms appear after several hours. The shortest period of illness can be set at about ten to fifteen hours. Most animals die on the second or third day, or on the third to the fifth day. Sometimes death comes on very suddenly through paralysis of the heart following an apparent improvement.

Chronic Poisoning is almost invariably the result of breathing air containing vapors of phosphorus, and is therefore seen in workmen engaged in industries using phosphorus, such as the manufacture of "sulphur" matches, phosphor bronze, etc. In the manufacture of phosphorus chronic poisoning is very rare. Up to 1900, in the great Coignet factory in France, there had been only one case of maxillary necrosis in fifteen years. In the days of the extensive manufacture of sulphur matches chronic poisoning was so alarmingly frequent, especially among workmen in the "drying rooms," that several governments passed laws forbidding the manufacture of this kind of match. Since the introduction of parlor and safety matches chronic poisoning has become very rare.

This remarkable disease is characterized by bronchial catarrh, chronic gastro-enteritis, loss of appetite, constipation often followed by diarrhœa, exquisite toothache, chronic periostitis passing into necrosis of the maxillary bones, cachexia, and fever. In general, we have all the symptoms of acute poisoning, but in much less violent form and coming on slowly and insidiously.

The gums swell; there may be salivation; the teeth ache, decay, loosen, their dentine becomes exposed; there is persistent gingivitis; dental abscesses increase in number and the fistulæ discharge sequestra and fetid pus. The breath is horribly fetid. The victim suffers from pains in the joints and legs, rapidly weakens and wastes away. Hectic fever sets in, and death may occur in convulsions, more often in coma or syncope.

Usually it is the lower maxillary which is first attacked; less frequently and less seriously, at the outset, the upper jaw is affected. As the disease progresses both jaws become diseased. Sometimes the necrosis extends to the nasal bones and even to the base of the skull, when death from meningitis results. In the case of severe necrosis the mortality seems to range in the neighborhood of forty-five per cent. This disease has been incorrectly termed by some European physicians progressive necrosic osteoperiostitis. Following the necrosis there is marked thickening of the affected bones, and the cartilage becomes ossified. Workmen having carious teeth suffer most from maxillary necrosis. In fact, there is reason to believe that, in the absence of penetrating caries, necrosis of the jaw bones is rarely if ever met with. It has, therefore, become an established custom in all well-conducted phosphorus industries to employ only men and women having sound teeth. Necrosis of the jaw develops after about six months' exposure to the vapors of phosphorus. Occasionally it may appear in a shorter period, or may fail to appear until after several years. This is only another instance of the remarkable variation in the action of this element.

Contrary to the facts observed with most other substances giving rise to chronic poisoning there are no records showing that the domestic animals frequenting the industries are afflicted with phosphorism.

Antidotes.—The most satisfactory chemical antidotes are copper sulphate, and oxidizing substances such as *old* turpentine, hydrogen peroxide, potassium permanganate, etc. In the case of acute poisoning administer copper sulphate, three grains every five minutes until the stomach has been sufficiently cleared. Follow this by one of the oxidizing agents, as, for example, old turpentine in emulsion in mucilage, one drachm every half-hour combined with the inhalation of turpentine vapor, or wash out the stomach with 0.2- or 0.3-per-cent. solution of potassium permanganate, or with a one- to three-per-cent. solution of peroxide of hydrogen. Magnesium sulphate may also be given to clear the bowels. The efficacy of copper sulphate depends upon its action as an emetic, and upon its property of reacting with phosphorus to form an insoluble copper phosphide and in part to oxidize the phosphorus, metallic copper and phosphoric acid resulting. With old (oxidized) turpentine a turpentine-phosphoric acid of low toxicity results, while with permanganate and peroxide the phosphorus is oxidized to non-poisonous phosphoric acid. Besides the administration of antidotes the patient must receive such treatment as the symptoms require. Administer ice and cold demulcent drinks. The paralysis and the sinking of blood pressure must be counteracted by excitants. All substances and foods containing fats or oils must be forbidden. Some practitioners bar the use of alkaline drinks on the ground that there is danger of the formation of phosphine; others insist upon their use as essential to maintain the alkalinity of the blood.

Prophylaxis.—In all industries using phosphorus, exceptionally good ventilation is imperative. There should be a constant circulation of fresh air in all the rooms. Exceedingly great care should be exercised under the supervision of a competent and conscientious foreman. Every workman should be required to wash and bathe frequently and thoroughly, and especially always to wash the hands before eating. Medical examinations should be made compulsory at stated intervals, and all cases of sore mouth, toothache, etc., should be at once excluded from the workrooms. Only men and women with sound teeth should be employed. A mouth wash containing boric acid, beta-naphthol, and eucalyptol has been found useful as a preventive against necrosis.

Post-mortem Appearances.—In typical cases the appearances after death are very striking and characteristic. Acute yellow atrophy and cirrhosis of the liver are practically the only diseases which yield lesions that can be confused with poisoning by phosphorus. The appearances are almost identical in each of these diseases, yet the symptoms and progress of the diseases are so different that there is little danger of error when the practitioner is in possession of the history of the case.

There is often corrosion and ulceration of the stomach and duodenum. The mucosa of the stomach is soft, swollen, mammillated, and degenerated.

The most characteristic feature, however, is the remarkable icteric condition and fatty degeneration of the liver and kidneys in particular, but also of the heart, of the glands of the stomach and intestines, and even of the muscles. The alimentary canal as a whole is usually contracted. Multiple hemorrhages are found in the lungs, heart, and throughout the alimentary canal. Occasionally there is no corrosion nor ulceration of the mucosa of the œsophagus and stomach, but in such cases a hemorrhagic or ecchymosed condition is rarely absent. A similar condition obtains in the mesentery and the peritoneum.

The pleural and pericardial cavities contain bloody serum and the serous membranes are ecchymosed.

The liver will generally be found enormously enlarged, fatty, soft, pasty, and light or dark yellow in color, with the acini enlarged and prominent, while here and there are hemorrhagic spots. When the period of illness has been very prolonged, the liver may be found to be not only no longer enlarged, but even subnormal in size. It may be luminous in the dark.

Although slow poisoning by ammonia, alcohol, arsenic, antimony, cyanides, sulphocyanates, etc., also gives rise to fatty degeneration, the steatosis is seldom so extensive, so marked, nor of so rapid formation as in poisoning by phosphorus. Cases are recorded in which death from phosphorus took place in forty-eight hours, yet in this short period there was marked steatosis of the liver, kidneys, heart, and glands of the stomach.

Rarely death may take place and the autopsy will fail to reveal any noteworthy lesion or marked inflammation of the mucosa.

Mechanism of Action.—As regards this phase of the action of phosphorus, it is to be stated that at the present time no satisfactory theories have been formulated. Because of the lesions and remarkable effects of phosphorus, this substance has long been a most interesting and fruitful field of research for toxicologists and pharmacologists, yet in spite of the many investigations the mechanism of its action is still an *ignis fatuus.*

Phosphorus seems to be resorbed without change, and is carried by the blood either in colloidal solution, in the state of excessively fine emulsion, or the element is vaporized by the heat of the body and the vapor dissolved by the blood. It suffers, because of the high partial pressure of the oxygen in the blood, little or no immediate oxidation. The effects produced upon the tissues cannot be due to the action of hypophosphorous, phosphorous, or phosphoric acids, nor to any alkaline salts of these acids. The hypothesis that hydrides of phosphorus are formed and carried by the blood and are the primary cause of illness seems to be no more tenable than the oxidation theory.

It has been shown repeatedly that while from a chemical viewpoint phosphorus should not be able to exist as such for any length of time in arterial blood, not only is such the fact, but, as already stated, it suffers but little change.

All experiments go to show that phosphorus is to be classed as one of a group of poisons chiefly affecting the metabolism, of which group hydrocyanic acid, oxalic acid, and carbon monoxide are the other best-known types. Bauer has pointed out that the oxygen taken up and the carbon dioxide given off in acute poisoning is always abnormally low (eight to eleven per cent. CO_2 instead of twenty-four to twenty-seven per cent.), and that the respiration curve indicates a powerful disturbance of the metabolism. Moreover, this is further borne out by the fact that peptone-like digestion products are usually eliminated in the urine, that the urea is subnormal, and that the albumin of the food, and also to a certain extent of the organism, is decomposed, and goes to form fat, leucin, tyrosin, and probably sarcolactic acid. The decrease in the amount of urea has been explained on the theory that owing to the formation of acids (lactic acid?) a great part of the nitrogen, which would otherwise be converted into urea, goes to form ammonia to neutralize the acids. Because of this neutralizing action the alkalinity of the blood falls and probably countless blood corpuscles are destroyed; for this latter reason phosphorus is also classed, by some authorities, in the group of so-called "blood poisons." This whole question of action on the blood is very little understood. Cases are reported in which no destruction of blood corpuscles has been observed. In man there seems to be a transitory increase of erythrocytes and a decrease of leucocytes. In dogs the erythrocytes and hæmoglobin are not affected, but the leucocytes seem to be increased. In fowls there is undoubted dissolution of red corpuscles and an increase of leucocytes. Following the destruction of the red blood corpuscles—which, it is assumed, takes place at some stage in poisoning by phosphorus—an abnormal secretion of bile pigments takes place; at the same time the bile becomes thick and viscid and moves through the ducts slowly. To account for the direct cause of icterus several theories have been advanced: one ascribing it to catarrh of the duodenum and cutting off of the ductus choledochus; another to the compression of the tiny bile ducts by the swelling of the liver; still another that the mucosa of the biliary passages becomes diseased, and that there is finally a clogging of these passages through fatty degeneration and rupture of the walls of the vessels. It is likely that all these causes contribute to the retardation of the flow of the bile, and that this fluid overflows into the lymphatics. The cause of the polycholia is, however, not yet understood, but its results are apparent in cerebral disturbances, as shown by coma, etc.

As to what happens to the phosphorus in its long sojourn in the blood we know but little. Only one point is clear. Part unites with many as yet wholly unknown basic products of the metabolism to form toxic compounds. Selmi has succeeded in isolating some of these compounds from the urine, and has given them the name phosphoptomaïns, while Van den Corput has called them toxicomaïns. According to this latter investigator most of the ill-effects of phosphorus are due to the formation of these retention toxicoses. Besides these phosphorus bases in the urine and blood, Kunkel advances the hypothesis that part of the phosphorus is oxidized by the blood, and that the phosphoric acid thus produced is eliminated in the form of esters.

In the matter of the fatty degeneration of the liver the weight of evidence seems to be that we must regard it as the result of two causes: one, the formation of fat in the organ itself, and the other the transportation of preformed fat to this organ. Experiments on animals have shown that the microscope will demonstrate the beginning of fatty degeneration in the liver in as short a time as six to eight hours after the administration of the poison, and in about twelve hours in the kidneys and heart (Kobert).

No satisfactory explanation of the cause of the corrosion and ulceration of the mucosa of the alimentary canal has yet been found. It has been suggested that this may be the result of the nascent action of oxygen acids of phosphorus at the moment of their formation; but since the early formation of these acids is uncertain a better explanation is wanted.

As to phosphorus necrosis, little can be said save that it follows periostitis. It is not the mineral stroma which is attacked, but the cells of osseous tissue. Necrosis often follows an injury to the bones or periosteum, in illustration of which an interesting case, recorded by Wegner, may be cited. A boy working in a match factory rapidly developed periostitis and necrosis of the bone following the breaking of his leg. Wegner's investigations on the action of phosphorus on the bones are of great interest, although they shed but little light upon the mechanism of the action. He found that the administration of very small amounts of phosphorus daily, either internally by the mouth or as vapor, to young animals, caused an abnormally rapid development of osseous tissue, that the bones formed were more compact than usual, that the medullary cavities were much reduced in size, and that the abnormally developed bones did not differ in chemical composition from bones normally grown.

Investigations upon the action on the heart show that the beating is arrested in diastole in both warm- and cold-blooded animals, that the action is probably directly upon the heart muscles, that the automatic centres are first affected and then the muscles are greatly weakened, although they still respond to artificial stimuli.

Clinical Tests for Phosphorus.—Expose to the vapors given off from the warmed material to be tested two strips of filter paper, one of which has been moistened with silver-nitrate solution, the other with lead-acetate solution. If phosphorus is present, the silver paper blackens while the lead paper should remain unchanged. If both papers blacken, hydrogen sulphide is present and must first be removed before testing. In such an event add to the material to be tested sufficient lead acetate solution to precipitate all the hydrogen sulphide as lead sulphide, and test with the two papers as before. The blackening of the silver-nitrate paper is due to the formation of silver phosphide and metallic silver.

A less satisfactory test consists in boiling the material to be tested with a small piece of roll sulphur. After a few minutes the piece of sulphur, which has taken up most of the free phosphorus present, is removed, washed, and examined in a darkened room. On being gently warmed and rubbed with the finger the sulphur will shine with the peculiar glow of phosphorus, if this latter element is present.

If possible the suspected material should always be tested in the laboratory by the Mitscherlich distillation method.

There are reasons for believing that phosphorus can exist in the body in the free state for about eight weeks. After twelve weeks it can still be detected in the form of phosphorous acid, but after about fifteen weeks it is probable that all the elemental phosphorus has been eliminated or oxidized to phosphoric acid. As regards the detection of free phosphorus after death, it is safe to say that chemical tests usually fail after four weeks; but there are instances in which it has been possible to obtain undoubted proof fifteen weeks after burial.

Emile Monnin Chamot.

PHOTOMICROGRAPHY.—DEFINITION.—The process of obtaining a macroscopic photograph of a microscopic object. It is sometimes incorrectly termed microphotography, which is the reduction by photography of landscapes, portraits, or other gross photographs to collodion positives of minute size, which are subsequently mounted beneath a small convex lens, in watch charms, paper knives, pencil handles, and the like. It is to be noted that this distinction is not universal on the continent of Europe. The above title in German is Mikrophotographie; in French, Photomicrographie.

HISTORY.—The first photomicrographs and probably also the first photographs were taken by Wedgewood and Davy. The record of their experiments, published in 1802, some time after the death of Wedgewood, show that they used a solar microscope and obtained images upon paper and leather which had been washed with a silver solution. They were, however, unable to fix the images so obtained and, when exposed to daylight, the entire surface became uniformly dark.

The Rev. J. B. Reade, of England, in 1837, with a solar microscope photographed entomological specimens and sections of vegetable tissues upon paper coated with nitrate of silver solution and fixed the images with an infusion of galls. In 1839, at a soirée given by the Mar-

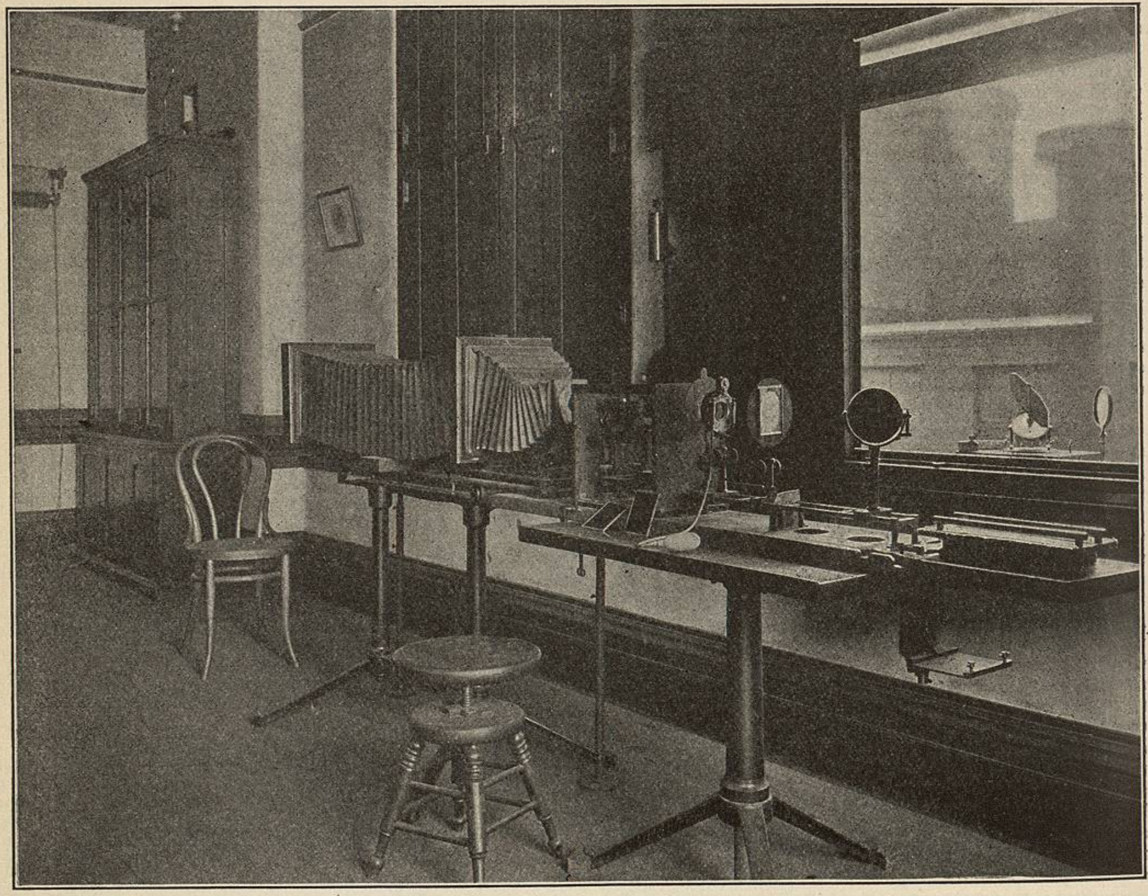

FIG. 3805.—Installation for Photomicrography with Heliostat. The objects are arranged, from left to right, in the following order: camera, microscope, screens, shutter, and mirror; outside the window, on a levelling stand: heliostat and a second mirror.

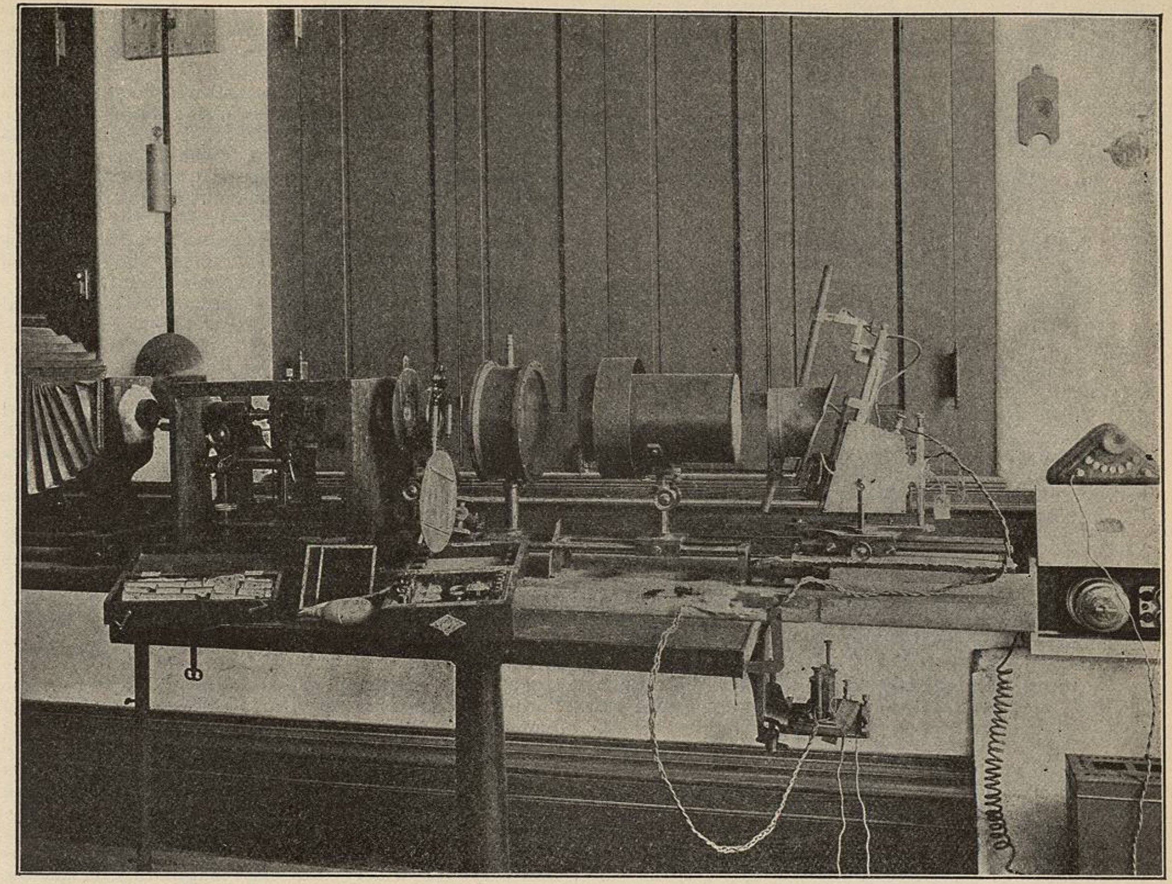

FIG. 3806.—The Optical Bench, Arranged for Photomicrography with the Electric Arc Lamp. The objects are arranged, from left to right, in the following order: end of camera, microscope, screens, shutter, water-bath, condenser system, arc lamp; on the table: battery of oculars and objectives, color screens and bulb of pneumatic release of shutter; under arc lamp—the adjustable shunt coil; at the extreme right, against the wall: switches and rheostat.

In practice a cloth is thrown over the frame which encloses the microscope, for the purpose of shutting out the rays of light from the eyes of the operator, while permitting at the same time all necessary manipulation. The screens, water-bath, condensers, and arc lamp are all enclosed in such a manner as to reduce to a minimum the escape of light into the room.

quis of Northampton, then president of the Royal Society, Mr. Reade exhibited more perfect results, and some of his photomicrographs were on sale at a bazaar in Leeds the same year. It was not until after Daguerre had announced his discovery before the Academy at Paris on the 19th of August, 1839, that attempts to use photography to obtain pictures through the microscope were generally undertaken. In 1840 Mr. Dancer, of England, photographed through a gas microscope upon silvered plates; he also by means of the solar microscope photographed wood sections and fossils on paper and glass plates. Dr. Donné, of Paris, in 1840, presented to the Academy of Sciences photomicrographs on daguerrotype plates; and in collaboration with M. Léon Foucault, in 1845, published an atlas on the study of the fluids of the body, illustrated by cuts from daguerrotypes. One of the first publications in England to use photomicrographs as illustrations was the *Quarterly Journal of the Microscopical Society*, which in 1852 contained prints from negatives by Mr. Joseph Delves. Since these early attempts the practice of photomicrography and its use for illustration have steadily grown. The list of those who have done notable work is a long one, and contains many well-known names.

The Apparatus.—The several parts comprising the apparatus for making photomicrographs are collectively called an installation. In its simplest form it may be a long bellows camera with a photographic lens on the front or on the front of a conical extension, as ordinarily used by photographers for making enlarged copies; such an arrangement is useful when the original object is of comparatively large size and the magnification slight, as the limit of a few diameters is very quickly reached by this method. For most photomicrographic work a microscope is a necessity, as are also the accessory apparatus on the optical bench and, in the present day of rapid dry plates, the camera. Sometimes, in the days when the slow, comparatively non-sensitive wet plates were in use, the room in which the optical bench and microscope were placed formed the camera; the source of illumination was outside the room, and enough diffuse light was admitted through yellow glass to enable the operator to work. Such an arrangement was used by Surgeon-General J. J. Woodward in making his now classical photomicrographs of difficult test diatoms, etc. At the present time, however, the rapid color-sensitive plate demands much greater care in the exclusion of all light not used in taking the picture, and many forms of photomicrographic apparatus have been devised. Some operators, in Europe especially, prefer to work with the vertical apparatus, subsequently enlarging the pictures so obtained; but most of the English and American photomicrographers use the horizontal apparatus, and with the long camera bellows obtain the desired magnification directly. The installation, then, may be described as consisting of the source of light, the optical bench with its accessories, the microscope, and the camera.

The Source of Light.—This may be an oil lamp of one