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PHOSPHORUS AND SOME OF ITS COMPOUNDS.

Phosphorus.—*Phosphore*, Fr.; *Phosphor*, Ger. A translucent, nearly colorless solid, resembling wax, without taste, but having a peculiar smell. Its specific gravity is 1·8.

Oleum Phosphoratum.—Phosphorated oil. Prepared by dissolving phosphorus in ether and almond-oil. One part of phosphorus to 100 parts of the menstruum. Dose, ℥i—℥v.

Pilulæ Phosphori.—Phosphorus pills. Each pill contains about $\frac{1}{100}$ grain. Phosphorus is dissolved in chloroform, and then mixed with powdered althea and acacia, glycerin, and water. The pills are coated with balsam of tolu.

Tinctura Phosphori (not official).—Phosphorus, one grain; absolute alcohol, five drachms; glycerin, one ounce and a half; spirit of wine, two drachms; spirit of peppermint, two scruples. "Dissolve the phosphorus in the alcohol with a little heat; at the same time warm the spirit and glycerin together. Mix the two solutions while hot, and add the spirit of peppermint on cooling. Dose, one half to one drachm."

Tinctura Phosphori Ætherealis (not official).—Solution of phosphorus in ether. Dose, five to ten drops in sirup. A solution of phosphorus in chloroform, or bisulphide of carbon, may also be prepared for internal administration. Pills of phosphorus may be extemporaneously made by mixing the bisulphide of carbon solution with some inert powder. The evaporation of the bisulphide leaves the phosphorus in a finely-divided state intimately incorporated with the powder.

Zinci Phosphidum.—Phosphide of zinc. Dose, one twentieth to one tenth of a grain. It is best administered in pill-form made with conserve of roses.

Synergists.—Oils and fats favor the absorption of phosphorus, and should never, therefore, be employed in cases of poisoning by this agent. Arsenic, and in a feeble degree sulphur, are synergistic.

Antagonists.—The chief chemical antidotes to phosphorus are hydrated magnesia, lime-water, powdered charcoal, and sulphate of copper. To this list must be added turpentine of a certain kind. Phosphorus is now frequently taken in the form of matches, the particles of which do not readily dissolve in the stomach and intestinal juices. When pure phosphorus, in the sticks or cylinders in which it occurs in commerce, is swallowed, large masses may remain imbedded in the folds of mucous membrane, or, escaping solution, descend with the other contents of the canal. Considerable time may thus elapse from the ingestion of the poison until its action begins. Emetics, therefore, assume a high degree of importance, and the most serviceable emetic is sulphate of copper, which is at the same time a chemical antidote (Eulenburg and Guttmann). Bamberger has shown that phosphorus reduces sulphate of copper to the metallic state, the first step in the process being the formation of phosphide of copper, and that the masses of phosphorus are surrounded by a layer of copper, preventing its evaporation. He therefore advises that an emetic dose of sulphate of copper be first administered. Emesis may be facilitated by giving hydrated magnesia, diffused in a quantity of tepid water. As catharsis is next in importance, the bowels should be thoroughly evacuated. After the emetic dose of sulphate of copper has acted efficiently, this antidote should be given in small doses as frequently as possible—about one twelfth of a grain every twenty minutes. As the irritability of the stomach may prevent sufficient retention of the sulphate, the carbonate of copper has been proposed as a substitute, although Eulenburg and Landois, in their experiments on animals, have been unable, by the exhibition of the latter, to prevent death in cases of phosphorus-poisoning.

Unquestionably the most important chemical antidote is *turpentine*, the French acid turpentine, especially. Letheby was the first to note that the vapor of turpentine prevented the toxic action of the vapor of phosphorus, and that workmen employed in the match-factory at Stafford, who were protected by vials of turpentine worn about the neck, escaped necrosis of the maxillary bones and other deleterious effects. Dr. P. C. Andant next published cases indicating the antidotal power of turpentine, and M. Personne submitted the subject to experimental demonstration and confirmed the observations of Andant. As turpentine destroys the luminosity in the dark and arrests the escape of the vapor of phosphorus, M. Personne infers that it acts similarly as an antidote, that is, prevents the combustion of phosphorus in the blood and the consequent consumption of the oxygen. The author has collected forty-six cases of poisoning by phosphorus, in which turpentine was employed as the antidote, and of this number but four were unsuccessful (Köhler, Sorbets, Laboulbene, Schimpff, Lichtenstein, Rommeleare, Berthold, etc.). Rectified oil of turpentine is not antidotal. The acid French oil is the preparation which has been used with success. The experiments of Vetter on animals fully confirm the results of clinical experience, for he found that, while the rectified oil of turpentine had no effect, the crude, acid, French turpentine was very efficient as an antidote. The action of the crude turpentine is a process of oxidation and combination by which phos-

phorus is converted into phosphoro-terebinthinic acid—a spermaceti-like substance, without poisonous or irritating qualities, which is eliminated by the kidneys, the urine having a camphoraceous instead of the violet odor due to turpentine itself. Although the crude French oil is to be preferred, it is probable that our common oil of turpentine, exposed to the air, will develop antidotal power, by absorbing and ozonizing oxygen. The vapor of turpentine acts in the same manner on the vapor of phosphorus. The change in the effects of phosphorus acted on by turpentine has been thoroughly worked out. Administered to dogs, from one to fifteen grains, this substance excited no nausea, did not impair the appetite, caused no change in the tissues, and was eliminated harmlessly by the kidneys.

To sum up: In the treatment of poisoning by phosphorus, in any of the forms in which it is introduced into the stomach, an emetic of sulphate of copper should be promptly employed, and the bowels should be moved by hydrated magnesia. When the stomach is emptied, small doses of sulphate of copper may be administered, but preferably turpentine, which should be given as rapidly as possible in an emulsion of gum, carefully avoiding oil. To counteract the cardiac and general systemic depression, opium will become necessary. If phosphorus has entered the blood despite the use of the appropriate antidotes, and much injury to its corpuscular elements has resulted, transfusion can be employed with considerable confidence, since Jürgensen has succeeded in several instances in saving life by this expedient. Direct transfusion of human blood, with or without previous withdrawal of some portion of the damaged blood, is the proper procedure.

Physiological Actions.—The vapor of phosphorus is highly irritating to the conjunctiva and to the broncho-pulmonary mucous membrane. If caries of the teeth exist, necrosis of the maxillary bones may be induced by the vapor; but it is doubtful whether, as has been affirmed, such necrosis may occur when the teeth are perfectly sound. There is an obvious distinction between the local effects of the vapor of phosphorus and the disease of the osseous system, the result of the constitutional impression of this agent.

In ordinary medicinal doses, phosphorus gives rise to a sense of warmth at the epigastrium, but, if the dose be large, decided heat and even burning are experienced, and tenderness of the epigastrium remains. Prolonged administration of full doses will excite considerable gastric disturbance, and a catarrhal state of the mucous membrane. In the process of the oxidation of phosphorus, hydrogen is evolved, which in its nascent state readily combines with a portion of phosphorus, forming phosphide of hydrogen, eructations of which constitute one of the disagreeable features in the administration of this remedy. The action of the heart becomes more frequent, and the cutaneous circulation, especially, more rapid; the body temperature rises somewhat; the mental activity and the muscular power increase; the menstrual flow grows more abundant, and in males aphrodisiac effects are experienced, and the urine and sweat are more abundantly excreted. Phosphorus promotes the constructive metamorphosis; it increases the activity of the organs of vegetative life, and is a natural excitant of the functions of animal life; it enters largely into the formation of tissues, and is a necessary element in the phosphorized fat which holds an important position in the composition of the cerebral matter. The administration of phosphorus increases the excretion of urinary phosphates.

The effects of phosphorus in toxic doses have been elaborately studied, both in fatal cases of poisoning, occurring in man, and by experiments on animals. The form in which it is swallowed affects the rate at which the action occurs. If taken in solution in oil, in ether, or in the paste used as a vermin-destroyer, the toxic symptoms appear more promptly than if match-heads or ordinary phosphorus has been swallowed. An interval of varying duration elapses from the ingestion of the poison until disturbance of the stomach ensues. This interval—one to three hours—is occupied by the solution and oxidation of the phosphorus. Then epigastric uneasiness, nausea, and vomiting, come on; first, the contents of the stomach, and then mucus and bilious matters being ejected. The vomiting, accompanied by considerable epigastric pain and tenderness, persists usually for several days, when it assumes a special character, owing to the presence of the so-called "coffee-grounds," or "black-vomit." At first the vomited matters have a distinct odor of phosphorus, and appear phosphorescent in the dark. After several days of vomiting these symptoms disappear, and there may then be more or less hæmatemesis, as well as coffee-grounds, due to erosions of the mucous membrane (Wolfe). The condition of the intestines varies with the presence or absence of phosphorus in their contents. The stools may be simply pasty and grayish from the absence of bile, or they may contain mucus and blood, and appear phosphorescent in the dark. Accordingly, as they may or may not be irritated, will the symptoms be those of constipation, diarrhœa, or dysentery. The very characteristic but not invariable symptom—jaundice—appears on the second to the fifth day after the reception of the poison. It is absent in one fourth of the cases, and may be absent, also, when there is considerable fatty degeneration of the liver (Wolfe, Alter). It presents the usual appearance of jaundice as it occurs in acute yellow atrophy. It does not attain the maximum at once, but it appears first as some yellowness of the conjunctiva, the urine also becoming dark and loaded with urates, at the same time.

The chemical changes which phosphorus undergoes in the stomach, and the combinations by which it enters the blood, are as yet not fully

explicable. That some phosphoric acid and phosphide of hydrogen are formed is certain. That the oil or fat in the stomach will dissolve some portion of the phosphorus, and thus facilitate its diffusion as phosphorus into the blood, is highly probable (Husemann and Marmé). Phosphorus is also slightly soluble in water at about 100° Fahr., and in organic fluids, as the bile, to a greater extent (Hartmann). As in the oxidation of phosphorus, phosphorous and phosphoric acids, and phosphide of hydrogen, are products, it is certain that these exert a poisonous influence to a greater or less extent in the stomach (Lecorché). A portion of the agent taken undoubtedly enters the blood as phosphorus, and the subsequent changes in tissue-metamorphosis are due to its presence in the blood, where it has been detected by Bamberger and others. With the entrance of the poison into the blood the action of the heart increases, and the temperature rises, the fever having a remittent type (Mannkopff). Toward the end, however, the function of hæmatosis and of tissue-metamorphosis are so depressed that the body-heat declines below normal. In other cases there is no fever at all, or it appears near the end. Very great weakness of the heart's action has usually been observed, and the pulse has been much accelerated, although in some instances it became very slow, descending as low as 40. The damage done to the blood is shown in the hæmorrhages which take place from the various mucous surfaces—from the nose, stomach, intestines, kidneys, uterus (menorrhagia and metrorrhagia)—and into the areolar tissue, in the form of petechiæ and ecchymoses. A hæmorrhagic diathesis develops, so that the bleeding from a simple wound, a leech-bite, etc., may become uncontrollable.

The intellect may remain unimpaired, but usually there are restlessness, with coma, sometimes noisy delirium, anæsthesia of the extremities, paresis of the members, and, near the end, convulsions (Hermann).

The poison entering the blood is eliminated chiefly by the kidneys. The changes occurring in the urine are of especial interest. No departure from the normal occurs until the alterations in the composition of the blood, and the general steatosis, prepare the way. The urine is diminished in amount, contains albumen, blood, and sometimes fibrinous casts. When jaundice comes on, its appearance is first announced by the presence of bile-pigments and acids. Urea almost entirely disappears toward the fatal termination ; leucin and tyrosin are occasionally present, and a peptone-like substance ; but the peculiarity most distinctive is the large quantity of paralactic acid, especially in the fatal cases (Schultzen and Riess).

The duration of the cases of phosphorus-poisoning is by no means uniform. Although the rule is that symptoms do not follow immediately on the entrance of the poison into the stomach, there are cases in which pain, nausea, and vomiting do occur almost immediately, and the most formidable symptoms come on promptly. One case is reported in which death occurred within nine hours, and numerous cases have terminated in death at the expiration of forty-eight to seventy-two hours. But usually the cases are less acute, and death does not occur before the end of the first, second, or third week. It is important to bear in mind that death may take place unexpectedly, before the most severe symptoms manifest themselves (Naunyn) ; and that the absence of decided gastric disturbance does not necessarily indicate a mild case. When recovery takes place, the improvement is slow, and the duration more or less protracted. In cases observed by Schultzen, the swelling of the liver could be distinguished at the expiration of four weeks, although the jaundice and the hæmorrhages had disappeared.

The changes induced by phosphorus are eminently characteristic. In the stomach are found erosions of variable extent, often absent ; fatty degeneration of the epithelium ; and a gastro-adenitis, first described by Virchow, and confirmed by subsequent observers, notably by Bernhardt, whence the membrane has a swollen, grayish, or yellowish color. The same state of the mucous membrane may exist in the intestine as well. The liver is much enlarged as a rule, but may be atrophied. In five of the sixteen cases studied by Wolfe the liver was atrophied, but this is probably a more advanced change, and is, therefore, encountered in the most protracted cases. The color of the liver is usually a pale yellow, or it may present a deep yellow, the acini appearing enlarged and distinct. The increased size of the organ, and the change in its appearance, are due to fatty degeneration of the hepatic cells and epithelium (Mannkopff) ; but, according to some other authorities, an interstitial hepatitis is also set up, which is especially well marked in chronic phosphorus-poisoning. The jaundice, it is agreed generally, is due to resorption of the bile, swelling of the bile-ducts and of the orifice of the ductus communis preventing the entrance of the bile into the intestine. The presence of bile-pigments and acids in the urine supports this view, but it has also been maintained that the jaundice is hæmatogenic from dissolution of the blood.

The changes in the composition of the blood are numerous and important : it is fluid, non-coagulable, its corpuscles altered in form, and it contains much fat (Méhu). There are numerous ecchymoses, especially under the peri- and endo-cardium (noted in thirteen out of sixteen cases by Wolfe), under the capsule of the liver, and in other situations. Besides the alterations in the blood, the occurrence of ecchymoses is favored by fatty degeneration of the small blood-vessels and capillaries (Klebs). The heart is also the seat of an acute fatty degeneration, and its tissue is soft and easily torn. The spleen is enlarged, and the kidneys are also enlarged and fatty, the renal epithelium being crowded with oil-drops.

Not every case exhibits the wide-spread changes above described. If death occur in a short time, within nine hours, as has been noted, not sufficient time will have elapsed to allow of universal steatosis. There may, indeed, be no characteristic morbid appearances under such circumstances. In other cases, the changes may be limited to the liver.

Chronic poisoning by phosphorus presents some interesting features. It occurs in those who are exposed to the vapor, in workmen engaged in phosphorus-factories, and especially in the workers in match-factories. Irritation of the bronchial mucous membrane, and to a less extent of the gastro-intestinal, takes place, with the attendant symptoms of cough, loss of appetite, indigestion, constipation, failure of nutrition, etc. The most important change is that occurring in the maxilla, more especially in the inferior maxilla, which is both more severely and more frequently diseased. The lower jaw has been repeatedly removed for this phosphorus necrosis, which begins in carious teeth, develops into a periostitis, and ends in death of the bone. The alveolar process only, or a part or the whole of the bone, may be cast off. Phosphorus increases the production of osseous tissue ; the spongy tissue is thickened, and the compact is rendered more dense. Extensive osteophytic formations take place in animals fed on it, and the marrow cavity of long bones may be much encroached on, even closed, by the deposit of new osseous material (Wegner).

THERAPY.—The author enjoins on his readers the necessity for caution in the use of phosphorus. As this agent so readily induces an acute fatty degeneration, when taken in poisonous quantity, the propriety of its administration in large doses for long periods may well be questioned.

Phosphorus, occupying an important position as an agent utilized in the constructive metamorphosis, may properly be prescribed when the nutritive functions are deficient in activity. It is especially in nutritive failure of the osseous and nervous tissue that phosphorus is required. The original suggestion by Wegner of its probable utility in *osteomalacia*, or softening of bones, has been acted on by Friese, who found it remarkably beneficial in some obstinate cases. It will prove useful, also, when this condition exists in *rickets*. That hitherto incurable malady—*progressive pernicious anæmia*—has in some instances been apparently arrested by the administration of phosphorus ; but it has failed in others. Further investigations are needed.

The physiological action of phosphorus in small doses in increasing mental activity finds a therapeutical expression in the use of its preparations in cerebral disorders. It is indicated in pathological states dependent on anæmia, and contraindicated in vascular congestion and excitement. Cases of *wakefulness*, dependent on cerebral anæmia and exhaustion, are often remarkably benefited by phosphorus in the form of the pill or tincture. It does not procure sleep in the way that

chloral and bromide of potassium do. By the use of it in suitable states we supply to the cerebral substance a material which it requires for the healthy performance of its functions. It acts most beneficially in the cases of wakefulness in which the nutritive functions of the body are wanting in activity. The *wakefulness of the aged*, accompanied with muscular cramps, feebleness of memory, giddiness, and trembling of the voluntary muscles on exertion, is improved by the preparations of phosphorus. *Early decay of the mental powers*, associated with atheromatous changes of the cerebral vessels, and consequent impaired nutrition of the brain, is benefited by minute doses of this agent. In these states, occurring in the aged, it is better to combine with the phosphorus, or to administer simultaneously, cod-liver oil. The author has seen good results from such a combination in *paralysis agitans*. Large doses of the medicine in these disorders of advanced life are improper and unsafe. The best results are obtained from the persistent use of minute doses. M. Delpech has obtained excellent results from the use of phosphorus in *paralysis*. It is obviously adapted to cases of chronic character in which all acute symptoms have subsided. The paralytic symptoms which accompany *white softening of the brain* (local and circumscribed anæmia) have appeared to the author to be improved by the use of the phosphates, hypophosphites, and lacto-phosphate of lime.

The preparations of phosphorus are very serviceable in *neuralgia*. It is true Dr. Anstie, in his recent able work on neuralgia, expresses the opinion that "its utility is not very extensive or reliable." Radcliffe, Bradley, Broadbent, Mr. J. Ashburton Thompson, on the other hand, report cures in some obstinate cases. Mr. Thompson's experience indicates that large doses are necessary to effect a cure. In his own words : "I now invariably begin by giving $\frac{1}{12}$ of a grain every four hours, and this I conclude to be an average dose." The formula given under the title "Tinctura Phosphori" is Mr. Thompson's ; each drachm of it contains $\frac{1}{12}$ of a grain of phosphorus. With this solution he has treated successfully thirteen cases of neuralgia. Dr. Broadbent has given phosphorus with advantage in "epileptiform vertigo," neuralgia, and "nervous breakdown from overwork."

We have no remedy at present more efficient in the treatment of *impotence* than phosphorus. In the physiological state, *priapism* is one of the results of its toxic action. It is, of course, adapted only to cases functional in character, and not to impotence from organic defect.

According to Dujardin-Beaumetz, phosphorus is useful in that very protracted and troublesome disease, *progressive locomotor ataxia*, or posterior spinal sclerosis. Although the author has not observed any instances of cure of this affection by phosphorus, he has witnessed in a few instances decided amelioration.

Phosphorus has lately been employed as a substitute for arsenic in the skin-diseases for which the latter is used—notably *acne, psoriasis, lupus.* The author has seen excellent results from the use of the compound sirup of the hypophosphites in *acne indurata.*

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PHOSPHITES AND PHOSPHATES.

Preparations.—*Syrupus Calcii Lacto-phosphatis.*—Sirup of the lacto-phosphate of lime. Dose, a teaspoonful. Lactic acid has the property of dissolving freshly-precipitated phosphate of lime.

Compound Sirup of the Phosphates (not official).—Parrish's chemical food. Each drachm contains two and a half grains of phosphate of iron and one grain of phosphate of lime.

Syrupus Hypophosphitum.—Sirup of the hypophosphites. Composed of hypophosphites of calcium, sodium, and potassium. Dose, a teaspoonful three times a day.

Syrupus Hypophosphitum cum Ferro.—Sirup of the hypophosphites with lactate of iron. Dose, a teaspoonful three times a day.

Sodii Phosphas.—Phosphate of sodium. "Large, colorless, transparent, monoclinic prisms, speedily efflorescing on exposure to air, odorless, having a cooling, saline, and feebly alkaline taste, and a slightly alkaline reaction. Soluble in six parts of water at 60° Fahr., and in two parts of boiling water." Dose, one drachm to one ounce.

Sodii Pyrophosphas.—Pyrophosphate of sodium. "Colorless, translucent, monoclinic prisms, permanent in the air, odorless, having a cooling, saline taste, and a slightly alkaline reaction. Soluble in 12 parts of water at 60° Fahr., and in 1·1 boiling water; insoluble in alcohol." Dose, half a drachm to half an ounce.

Calcii Hypophosphis.—Hypophosphite of calcium. "Colorless or white six-sided prisms, or thin, flexible scales, of a pearly luster, permanent in dry air, odorless, having a nauseous, bitter taste and a neutral reaction. Soluble in 6·8 parts of water at 60° Fahr., and in six parts of boiling water." Dose, gr. ij—gr. x.

Calcii Phosphas Præcipitatus.—Precipitated phosphate of lime. "A light, white, amorphous powder, permanent in the air, odorless, tasteless, and insoluble in water or alcohol." Dose, gr. ij—gr. v.

Sodii Hypophosphis.—Hypophosphite of sodium. Small, colorless or white, rectangular prisms, or a white granular powder, having a sweetish, saline taste and a neutral reaction. Soluble in one part of water. Dose, gr. v—gr. x.

Physiological Actions.—In the first edition of this work the *phosphates* were included in the same section with *phosphorus.* There is a strong argument in favor of this arrangement, based on the chemical reactions which ensue when phosphorus is introduced into the stomach. Phosphorus has a strong affinity for oxygen, and compounds are quickly formed in the stomach. It is probable, however, that some phosphorus enters the blood uncombined. It is certain that the effects