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6

LEAD EXPOSURE AND LEAD POISONING

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The absence of romance in my history will, I fear, detract somewhat from its interest; but if it be judged useful by those inquirers who desire an exact knowledge of the past as an aid to the interpretation of the future, which in the course of human things must resemble if it does not reflect it, I shall be content.

THUCYDIDES 1.22

OCCUPATIONAL EXPOSURE

Lead poisoning may be regarded as one of the earliest occupational diseases contracted by mankind. The suggestion can be made—rather facetiously—that the person who first set his eyes on the birth of metallic lead from its ore was poisoned by the lead fumes from his furnace or kiln. In other words, he was chastised for his impertinence. Generations of artisans throughout antiquity who worked with this dangerous metal received the

same rude treatment without complaint. Polybius (34.9) noted that the 40,000 workers employed in the lead–silver mines near the city of New Carthage produced roughly 36 metric tons of silver per year—equivalent to about 12,000 tons of lead output (see Chapter 4). The figures translate into three occupationally exposed individuals per ton of lead produced. On the basis of the worldwide production figures in Table 4.1, it is estimated that on the average, about 80,000 workers engaged in the mining and smelting of lead were occupationally exposed to lead each year during the time of the Roman Empire. Also, it may be presumed that it took two other craftsmen to fashion 1 ton of the lead into the various commercial items. Thus the total number of workers occupationally exposed to lead during the time of the Roman Empire is estimated to be about 140,000 per year on the average. It needs to be remarked that about 40 industries in the United States employ more than 800,000 workers who are exposed to lead (OSHA, 1978). The figure of one exposed individual per ton of refined lead produced or consumed by the highly mechanized contemporary American society suggests that the estimate of about five exposed persons per ton of lead produced in ancient times may not be very unreasonable. The assumed figure may not exactly be authentic, but it certainly suggests that large numbers of ancient workers were occupationally exposed to lead.

As noted in the preceeding chapters, lead found widespread commercial applications in ancient times. The principal uses for lead are for: nonferrous alloys; pewter and solder; coinage; glass; glazes and enamel; plumbing; stationary; roofs, gutters, and downspouts; burial of the dead; vases, vessels, and kitchenware; statuettes and figurines; ship building and other naval purposes; standard weights; projectiles and in warfare; pigments; medicinal purposes; and food preservatives and colorants. Large segments of ancient industrial ventures thus used lead in one form or another. Since there is nothing to suggest that any deliberate efforts were made to curtail personal exposure to the emissions from the forges and crucibles, it seems likely that many of the ancient artisans who worked the metal experienced acute or chronic "plumbism," or lead poisoning. It is certainly not fortuitous that no occupational disease has had so much written about it, for so long, as plumbism.

From the Bronze Age onward, lead–silver mining remained a major industry that employed large numbers of people in different parts of the world. Using the data in Table 4.1 and assuming an average career in lead mines or metallurgy of 10 years, this gives a figure of about 20 million occupationally exposed persons from the times of remote antiquity to the Fall of the Roman Empire. In primitive lead mines, the incidence of plumbism depended on the type of the ore, and on the personal hygiene of the worker. It is now generally accepted that the low incidence of plumbism in men who work in galena ores is related to the great insolubility of lead sulfide in the tissue fluids of the lungs (Rambousek, 1906; Hamilton, 1925; Waldron and Stofen, 1974). Galena, however, is not exactly nontoxic, and the incidents of plumbism in "dirty" galena mines and in miners with poor hygienic dispositions are not usual (Hamilton, 1925; McCord, 1953). It is easy to see how the ancient slave-miner who crawled and chiseled the lead–silver ores in the deep galleries could have contracted lead poisoning. The slave-miner handled it, inhaled particles of it, and had some of it comingle with his meagre diet. In short, the miner wallowed in it. The literary evidence points to total disregard for the cleanliness of the miners, and worse still, some of the laborers were apparently forced to live in the mine shafts (Davies, 1935, p. 16).

Lead poisoning tends to be prevalent in mines where the finer-grained and more soluble lead-oxide and lead-carbonate ores are exploited. Relatively recent epidemics of lead poisoning associated with the exploitation of the carbonate ores in many parts of the world attest to this fact (Hamilton, 1925; Rickard, 1932; McCord, 1953; Hunter, 1969). As noted previously, lead oxides and lead carbonates made up a substantial fraction of the ores—particularly in the Near East—that were exploited in ancient times. Pliny (35.19), for example, tells us that ceruse was originally obtained as a natural earth on the land of Theodotus and Smyrna, and that it was used by the early masters in painting ships. There is no reason to suggest that the ancient miners did not experience as much plumbism as their counterparts of the last two centuries. The Near Eastern mines certainly would be a lot drier, dustier, and hence more pernicious to the miners.

It would thus appear that a large fraction of the early miners experienced hazardous exposures to lead. Ancient literary sources are totally silent on the incidence of plumbism among this particular occupational group. Why? No concrete answer can be given, but the statement by Julius Pollex (124–192 A.D.) that the miners of his time covered themselves with bags and sacks or employed bladders to cover their mouths suggests that the ancient peoples probably knew that the inhalation of the mineral dust was harmful (Legge, 1934). On a much lighter vein, we are told by Solinus (Quoted by Agricola, 1556) of a species of deadly insects called "lucifuges" that inhabit silver mines principally. These insects resemble spiders, and their bite usually was fatal. Agricola (1556) also alluded to a type of spirit or specter—known as Knauff Kriegn—that inhabits mines and frightens and attacks miners. The victims usually die two or three days after being attacked (Goldwater, 1936). The possibility that the so-called bites or attacks could at times represent fatal plumbism can be raised, albeit rather facetiously.

Subsequently, the lead–silver ores were milled, sorted, and then smelted in furnaces (*fornax, camini*) that were usually located near the mines. In Laurion, Britain, Sardinia, Gaul, and elsewhere, the furnace chimney was generally small (about 2.5 m), but in Spain, it was high. The lead ingot was cupelled to part the lead from the silver, and the separated lead then

molded (in *formae*) into pigs or bullion—the *massae plumbae*. Each of the preceding processes exposed the worker to potentially dangerous levels of lead fumes, dust, and flues.

The greatest potential for high-level exposure to toxic lead fumes is associated with the process of lead smelting and refining. Until fairly recently, the rate of chronic lead poisoning in lead metallurgical plants was very high. Prior to 1895, when risk-control measures were introduced, the cases of lead poisoning among employees of lead smelters in Schemnitz, Hungary, exceeded 70 percent (quoted in Hamiltion, 1914). A survey of a "dirty" lead-smelting factory in India found that many of the workers had chronic lead poisoning (Chakraborty et al., 1964). In 1912, Hamilton found that about 22 percent of the 7500 workers engaged in lead smelting in the United States suffered from the same disease (Hamilton, 1925). These studies pertain to workers in enclosed buildings, and the statistics may not be readily transferable to ancient workers who obtained their lead using "boles" on the hillside (see Chapter 2). Nevertheless, the incidence of plumbism among ancient smelters who attended the furnaces had to be high. In addition, many copper and zinc ores exploited in ancient times contained much lead, and since most of the lead "went into the smoke," the craftsman who processed these ores could have readily contracted plumbism also.

There are cogent reasons for suggesting that a large fraction of the population in the lead–silver mining communities received unhealthy doses of lead. Excavations at Laurion show that the houses and the theater were jumbled together with washeries, cisterns, adits and shafts, and presumed slaves' barracks (Hopper, 1968). The following record in the 367–366 B.C. mine-lease list of the Poletai shows that furnaces and metal workshops were co-mingled with living quarters and were often used in defining property boundaries:

> At Laurion, the same Artemissiakon and the cuttings, of which the boundaries are, on the north the property of Diopeithes of Euonymon and the furnace of Demostratos of Kytheros, on the south the workshop [*ergasterion*] of Diopeithes and the wagon road, and the ravine of the Thorikioi; the lessee Kephisodotos of Aithalidai; the price twenty drachmae. (Hopper, 1979, p. 181)

The smelting and cupellation took place at the higher grounds, and the noxious lead dusts and fumes generated presumably rained on the inhabitants below. Closely spaced cisterns and washing tables lined the small valley at Laurion (Hopper, 1968), spewing lead into the water supply of the communities downstream. The mine tailings and slags were used on roadways and in hydraulic building construction. An aquarium was cemented in the dam, and ore-washing sites at Laurion were made of litharge (Wertime, 1980). Thus the air, water, and soils around the ancient lead–silver mines had the potential of being severely contaminated with lead. Most of the craftsmen apparently lived in the contaminated areas, and it would

seem unlikely, and indeed uneconomical, to transport them daily to their places of work. An analogy may be drawn here between the ancient communities and the modern residents near stationary sources (smelters, lead-processing foundries, etc.) of lead where evidence of severe health impairment has been found even in non–industry-employed persons (EPA, 1977).

In Greco-Roman times, the environments around the lead–silver mining and smelting communities were often considered to be an anathema to health. Xenophon (*Memorabilia* 3.6) tells us that the district of the Laurion silver mines was considered unhealthy and thus unworthy of a visit by Ariston's son Glaucon. According to Pliny (33.31), the exhalations from the silver mines are dangerous to all animals, but especially to dogs. Lucretius (*De rerum natura,* Book VI) provided the following account of the noxious emanations from the precious-metal mines:

> And where there is mining for veins of gold and silver
> Which men will dig for deep down in the earth
> What stenches arise, as at Scaptensula!
> How deadly are the exhalations of gold mines!
> You can see the ill effects in the miners' complexions.
> Have you not heard and seen how short is the life
> Of a miner compelled to remain at this terrible task?
> All these exhalations come from the earth
> And are breathed forth into the open light of day.

Vitruvius (8.3) spoke of water pollution around the mines and the potential adverse health implications:

> But when gold, silver, iron, copper, lead and the like are mined, abundant springs are found, but mostly impure. They have the impurities of hot springs, sulphur, alum, bitumen; and when the water is taken into the body and, flowing through the vessels, reaches the muscles and joints, it hardens them by expansion. Therefore the muscles swelling with expansion are contracted in length. In this way men suffer from cramp or gout, because they have the pores of the vessels saturated with hard, thick and cold particles.

Hippocrates (*On Airs, Waters and Places,* art. 7) also reckoned that waters "having iron, copper, silver, gold, sulfur, alum, bitumen or nitre" (typical of mining effluents) are bad for every purpose, and they are inimical to health.

Del Mar (1880, p. 352) has reviewed the reasons behind the policy of closing lead–silver mines in ancient times. Among the many social (e.g., condemnation of natives to being slave-miners) and economic factors, he emphasized that environmental quality was equally of great concern:

> The physical devastation occasioned by mining for the precious metals must have furnished to all enlightened nations a strong motive to interdict their use

> as money. The mischief done to Lydia, Phrygia, and to the Hedjaz and other parts of Arabia and Asia Minor, once the leading mining countries of the world; to Greece, as attested by the vast heaps of scoriae and ekvolades found near its silver mines; and to ancient Spain through placer and hydraulic mining; the washing down of mountains, the bestrewal of arable valleys with stones and sand, the filling of rivers, the choking of harbours, the destruction of forests and consequent interruption of the rainfall in all these countries—these and many other damages, the evidences of which can be traced upon their surfaces or found in their annals, must have arrested the attention of thoughtful men in ancient times and strongly urged them to the adoption of the only remedy that promised to prove efficacious. This was the entire interdiction of gold and silver money. That this reason was the basis of the ancient Greek laws on the subject there can be little doubt; for most of the Greek States at one time or another resorted to a numerary currency in the place of coins. Among these were Sparta, Athens, Ionia, and Byzantium. When we know that the monopolization of land by the patricians in Upper Italy was sufficient to arouse the Grachhi and lead to the civil wars which desolated Rome for a long period, it is difficult to suppose that the devastation caused by mining was unnoticed, and that no measures were taken to put an end to it.

Such a notion of environmental awareness may also be linked to what was perceived as the unhealthy conditions in such mining districts. Will Durant shared the same sentiments, and in his highly acclaimed work *The Story of Civilization,* he astutely observes that "Laurion pays the price of the wealth is produces, as mining always pays the price for metal industry; plans and men wither and die from the furnace fumes, and the vicinity of the works becomes a scene of desolation" (see McCord, 1953, p. 394). The Roman edict forbidding any mining activities in Italy might have been engendered by the same motive.

Not only the workers engaged in the mining and smelting of lead were liable to suffer from lead poisoning, but those individuals also who used lead in such industries as painting, plumbing, roofing, sculpturing, pewterware making, shipbuilding, enameling, and pottery glazing. A very crude analogy of plumbism among ancient craftsmen may be drawn from the incidence of occupational plumbism in Paris during the early part of the nineteenth century. Of the 1213 patients admitted during the 1830–1838 period in the Hospital of Charity who were suffering from lead colic, about 490 were employed in the manufacture of lead compounds, 390 were painters, 61 were potters, 55 were copper and bronze founders, 35 were lapidaries, 25 were refiners, 14 were plumbers, 11 worked in lead-shot factories, and 6 were glazers, while only 2 worked in glass factories (Tanquerel des Planches, 1848). As noted before, lead was used in these and many other arts and industries in ancient times, and the craftsmen were equally liable to have contracted lead poisoning.

The ancient workshops where the lead was processed were, most often, the backrooms or courtyards of the craftmans' dwellings which was the situation in the industrial district of Athens (Burford, 1972). The numerous literary references, the very large number of independent craftsmen whose names appear on Greco-Roman tombstones, the records of the ancient guilds of professional crafsmen, and the Attic vase paintings of the fifth and sixth centuries B.C. all point to the fact that the workshops where the lead goods were produced remained small—on the whole—throughout antiqiuty (e.g., see Loane, 1938; Forbes, 1971, pp. 55–103; Burford, 1972). As noted previously, even the manufacture of the vast numbers of standardized lead pipes did not entail large factories. During the 15 years of Domitian's rule, there were only 10 slaves and six freedmen in charge of the shops where the lead pipes for imperial structures were made (Loane, 1938). Such home studios present a special hazard to craftsmen that is not found among workers who labor outside the home. First, there is the possibility of 24-hour exposure to the lead that may be contaminating the home. Second, many of craftsmen probably used the kitchen sink and kitchen utensils for their work, thus risking the contamination of their foods. Occasional snacking increases the prospect of hand-to-mouth transfer of the lead. Third, there is the problem of exposing other family members, particularly the highly susceptible women and children, to lead.

Additional factors that would increase the exposure of ancient craftsmen and their dependents to lead was the concentration of workshop communities near the sources of the raw material. Examples include the ancient Ur towns of Sippar ("town of bronze") and Eridu ("town of smiths") that were located near the great metals entrêpot at Drehem or Puzuriš-Dagan (Forbes, 1971). The other well-known examples are the lead–silver metalshops of Attica and the great bronze works of Capua (Loane, 1938). The street names suggest that even in many ancient cities, each craft had its own quarter, street, or alley. In the Athenean agora, the heaviest concentrations of industrial activity found so far are the lead-using bronze foundries and potters' workshops on and around the site of the Temple of Hephaistos, dating from ca. the middle of the fifth century B.C. (Burford, 1972). In ancient Egypt, Mesopotamia, Sumer, Ur, and Assyria, the metalworkers commonly were members of guilds that worked under temple supervision. From the Buddhist texts, we learn that the factories for the working of base metals were supervised by the *lohâdyaksa,* or "the inspector of the base metals" (Forbes, 1971, p. 96). Any such concentration of activities pertaining to the processing of lead and lead products may engender the contamination of the immediate occupational environment with the substance and thus it may represent added risk for the craftsmen and their dependents.

Pending the publication of Needham's forthcoming monograph, the history of occupational lead exposure in ancient China remains virtually a closed book. The classical peoples—certainly the Greeks and Romans—were aware of the dangers invovled in some of the lead-manufacturing processes. Pliny (34.49) tells us that "for medical purposes lead is melted

in earthen vessels, a layer of finely powdered sulfur being put underneath it. On this, thin plates are laid and covered with sulfur and stirred up with an iron spit. While it is being melted, the breathing passages should be protected during the operation, otherwise the noxious and deadly vapor of the lead furnace is inhaled: it is hurtful to dogs with special rapidity." In describing the manufacture of red lead, Dioscorides (5.96) recommended "covering the nostrils, for the vapor is hurtful." And Pliny (33.40) noted that "persons polishing red lead (or cinnabar) in workshops tie on their face loose masks of bladder-skin, to prevent their inhaling the dust in breathing, which is very pernicious, and nevertheless to allow them to see over the bladders." The following excerpt from Vitruvius (6.7) shows that he was well aware of the health risks associated with the plumber's profession:

> We can take as example the workers in lead who have complexions affected by pallor. For when, in casting, the lead receives the current of air, the fumes from it occupy the members of the body, and burning them thereupon, rob the limbs of the virtues of the blood.

Acute and chronic plumbism clearly arrived with trade pursuits and manufacturing processes involving lead. I am not aware of any literary or other evidence to suggest that occupational plumbism was recognized as such by the early (before 1000 B.C.) cultures of India, Mesopotamia, Egypt, and so forth. The record of occupational plumbism left by Hellenistic writers is most inadequate. The epithet *pallidus* was frequently used to describe the pallor of the miner's complexion (e.g., Pliny, 33.11; Lucan *Pharsalia 4*; Statius *Silvae* 4.7). Rosen (1948) attributed this pallor to bad ventilation and ankylostomiasis rather than to metal poisoning. The symptomology in the Hippocratic corpus (*Epidemics* 6.25), which some authorities (e.g., Legge and Goadby, 1912; Aub et al., 1926; Sigerist, 1936; Hunter, 1969) regarded as a description of lead colic, pertained to a miner. The brief reference to the supposed patient with occupational lead poisoning reads (Littré, 1846; Waldron, 1978): "The man from the mines; right hypochondrium strained; enlarged spleen; stomach tense and rather hard; difficulties with breathing; discoloration, in him, the illness went to the left knee, recurrence; he was completely examined." Several people have quite rightly objected to the diagnosis of such a case as lead poisoning (e.g., Stevenson, 1949; Waldron, 1973, 1978). There is nothing in the case history to suggest that the man worked in a lead–silver mine, and as Stevenson (1949) has pointed out, the actual term used—*metallion*—is unqualified, and it can also refer to an employee in the metallurgical works attached to the mine. Thus, the only possible reference to occupational plumbism in antiquity remains extremely dubious.

An awareness of the debilitating effects of metal fumes perhaps is ingrained in the physical attributes of the patron gods of ancient or preliterate craftsmen. In Greek mythology, Hephaistos—a divine smith and patron

of ancient craftsmen—is a pathetic figure, lame and untidy, but he was the most industrious of all the gods. Vulcan, the Roman god of iron, brass, and devouring flame, also was ugly, misshapen, and lame (Hunter, 1969). Both Vulcan and Hephaistos had much in common with the legends of the Teutonic Wieland—a mystical hero of the skilled metalworker—who was lame, the Scandinavian Völunder, and the Finnish smith-god, Ilmarinen (see Forbes, 1971). It is said that the craftsmen of many prehistoric cultures were cripples or pygmies (Forbes, 1971). This occupational calling presumably appealed to those persons incapable of becoming warriors or successful farmers. Rosner (1953) has suggested that the mythological link was forged by the fact that the Anatolian metallurgists of the third millennium B.C. generally experienced chronic arsenic poisoning from the smelting of arsenical copper ores or arsenic–copper alloys, which led to arseneuritis and lameness of the extremities. Such an idea may be farfetched, but the very widespread association of a special deformity with a particular occupation has to be very suggestive. The heavy metal ores are characteristically multimetallic, and the debilitating effects of lead from such ores would certainly not enhance the image of craftsmen in such occupational callings.

Considering the very impressive usage of lead, particularly in Roman times, it is rather strange that the classical literary records are nearly silent regarding the incidence of occupational plumbism in those days. This matter is particularly vexatious, considering that the dangerous nature of some of the saturnine trades was generally recognized. Stevenson (1949) has discussed the question in great detail and has offered three suggestions: (1) the conditions of work reduced the occupational risk; (2) those who were most constantly and dangerously exposed to the hazards of lead (namely slave workers and lowly artisans) did not move in the higher world of the doctors who wrote the books; and (3) the requisite passages in the ancient medical literature have not survived. Stevenson (1949, pp. 84–85) concluded his discussions with the following astute observation:

> It is apparent that a clear-cut social thesis regarding ancient knowledge of plumbism cannot be maintained. Vitruvius is our principal witness and it is difficult to decide the meaning of his testimony, as against the near silence of the medical authors. The latter may have seen and recognized chronic plumbism of occupational origin. At the same time it would be surprising if the physician of antiquity had devoted much of his energy to a disease that was merely occupational. The motive of Christian charity was lacking; the social atmosphere was never democratic in the modern sense; a slave was thought to be less than human; to work for a living was considered degrading. Why should a physician concern himself, except incidentally, with occupational disease? It is perhaps no accident that the majority of the references to occupational disease in general are found in non-medical writers.

It is doubtful, though, that the ancient physicians and technologists were ever able to associate any disease conditions with the lead trade and in-

dustry. If they did, the dietary exposure would certainly have been curtailed and the question as to whether the Roman Empire declined as a result of lead poisoning would never have arisen.

NONOCCUPATIONAL EXPOSURE

Like today, the circumstances under which the ancient peoples were exposed to lead poisoning are legion, often bizarre, and sometimes dramatic. The unusual routes of lead exposure would have included the following:

1. Lead coins and debased bronze or brass coins, when handled excessively, mouthed, or inadvertently swallowed.
2. To ward off evil, the ancient spell-seeker at times wrote the message on "paper" with red lead, which symbolized blood, burned the talisman, and swallowed the ashes. The answer to his imprecation would have come in the form of lead colic.
3. Many yarns were treated with lead salts as makeweight—the hazard here may be more to the workmen than to the wearer.
4. Children's toys, many of which are made of lead (see Chapter 4).
5. Candleholders and wickholders made of lead or pewter could be partially evaporated in burning.
6. Houses were sometimes coated with leaden pigments, and the possibility of childhood pica cannot be completely discounted.
7. The application of lead ointments to the breasts and leaden rouge to the body constituted a hazard to the suckling infants.
8. Lead paintwork in public places.

No attempt will be made to deal with exposure from such adventitious sources; the subsequent discussions will address only the principal exposure routes to lead in ancient times.

Exposure from Cosmetics

As noted in Chapter 5, the use of galena in medicinal or cosmetic preparations can be traced to very ancient times. This mineral, in unprocessed form or as very fine compacted or loose powder (known in Arabic as *kohl*), has been found in ancient graves in Egypt, the lower Indus Valley, pre-Columbian North America, and other places. In ancient Egypt, as in several present-day West African cultures, the *kohl* was used to provide protection against the so-called Egyptian eye disease and as magic to make the eyes larger and brighter. It is not clear to what an extent such saturnine mascara constituted a health hazard; its continuous use over an extended period of time could induce chronic lead poisoning. A recent study observes that "an unusual source of poisoning in the United Kingdom is associated with the use of eye-cosmetics (particularly, *surma,* which contains up to 88% lead sulfide) by Asian families. Between 1966 and 1971, of 38 children in Birmingham with lead poisoning, 15 were Asians" (DOE, 1974). Since the children were not recognized as having pica, it was surmised that they instilled the lead into the conjuctival sac from which the absorption occurred (Snodgrass et al., 1973). Srivastava and Varadi (1968) also reported one case of plumbism in an adult that was caused by the use of saturnine mascara, and another case from the use of lipstick cream containing 67% white lead.

Von Baeyer claimed that the ancient Egyptians prepared their eye ink by using charcoal to calcine the lead sulfate that was made by converting metallic lead into litharge, dissolving the litharge in vinegar, and precipitating the sulfate with an alum solution (*Gmelins,* 1973). Unless strict hygienic conditions were observed, the persons engaged in such a preparation process also ran a high risk of getting lead poisoning.

Lead compounds long have been used for artificial darkening of hair color—the lead reacts with the -SH functional groups in the hair to form black-lead sulfides in the hair shaft. Such saturnine hair dyes might have been quite popular with the women of ancient Italy and the Middle East, who were, in general, dark haired. Pliny (28.191) spoke of a soap ("litharge of silver") "for reddening hair, which was available both in solid and liquid form, and which was used in Germany, more by men than the women." During the Middle Ages, equal parts of litharge, burnt lime, and chalk were used in the form of a thick paste that was left in the hair overnight (Grandjean, 1975). The study by Bagchi (1969) suggests that the use of saturnine hair dyes can be dangerous. He found a common occurrence of chronic lead poisoning among the Hindu women of Bengal, and its neighboring districts, who applied *sindur* (red lead mixed with a red synthetic dye) to the anterior end where they parted their hair. It has been suggested (Bagchi, 1969; Sagarin, 1957) that the use of hair oil helped the lead to be in contact with the skin by forming lipid-soluble lead soap (with the fatty acids of vegetable origin), which thus favors absorption. The hand-to-mouth transfer of the lead cannot be ruled out, however. In an experiment with adult volunteers, Marzulli and associates (1977) found a fourfold to tenfold increase in lead concentrations on auxiliary and pubic hair following the application of 2% lead-acetate hair dyes for 90 days. They concluded that lead-absorption can occur from the scalp. The recent case histories using sophisticated analytical methods thus show that saturnine mascara was an unsafe product. These recent histories point to the ancient *kohls* as being potentially deadly poisons.

The use of white lead to enhance the skin tone, to cover pockmarks, freckles, and blemishes, and to enhance one's sex appeal by being used occasionally on breasts was quite widespread in ancient times (see Chapter 1). Red lead also often was an ingredient in concoctions used to impart a

rosy color to cheeks, while lead oxides were often used in yellow pigments for the adornment of the foreheads of ancient Chinese ladies. The common use of such compounds suggests that there was a real danger of transferring the lead from the face, body, or container to the hands, and subsequently to the mouth. Lead absorption can also take place through intact skin, but the extent depends on the lead compound used and the condition of the skin (Mahaffey, 1978). After the cutaneous application of lead-acetate and lead-naphthenate solutions to the back of the rats' necks, Rastogi and Clausen (1976) found highly elevated concentrations of lead in the kidneys, livers, and muscles, which strongly suggests the absorption of the lead compounds through the intact skin of rats. Lipid-soluble lead salts can be absorbed readily through intact skins. Thus, products that contain ointments, oily bases, and surface-active agents that can form lipid-soluble lead soaps will enhance the absorbability of the lead. Even the fatty acids typically found in the sebum and on the skin can react with the inorganic lead to form soaps that can be more readily absorbed (Sagarin, 1957). The fact that lead can be readily absorbed through broken skin and excoriated parts has been known for a long time (see Baker, 1767; Tanquerel des Planches, 1848).

These recent studies thus suggest that *chronic* lead poisoning, stemming from cosmetic use of various lead compounds in ancient times, was probably much more widespread than has hitherto been recognized. The health implications of storing beauty aids in lead vessels are not clear. Martial (6.55) referred to the use of leaden jars for perfumes. Theophrastus (*Enquiry into Plants, and Minor Works,* art. 41) observed that the worst that can happen to perfume "is that they should be deprived of their proper heat. This is why men put them into vessels of lead . . . for lead is cold and of closed texture, (and thus) neither lets the odor pass away through them, nor do they take in anything." As noted in several sections before, lead lids were frequently used where the vessels needed to be hermetically sealed.

Exposure from Drinking Water

The contamination of ancient drinking water comes principally from the use of lead pipes, lead-based solders, lead–pewter vats, lead-lined cisterns, as well as pewter and leaded bronze kettles (see Chapter 4). As discussed previously, the Romans were the first to make an impressive use of lead pipes in their water-distribution systems. The level of their exposure to lead that can be attributed to their plumbing systems has been a matter of long-standing debate and interest (e.g., Girolamo Mercuriale, 1588; Baker, 1767; Kobert, 1909; Stevenson, 1949; Gilfillan, 1965; Hodge, 1981). The question has remained fairly intractable because the available evidence

yields conflicting clues on the plumbosolvency of the water supplies in Rome.

What, then, are the factors influencing the lead concentrations in the water supplies of ancient Rome?

Alkalinity and pH

Soft waters (alkalinity of 0–25 mg/liter $CaCO_3$) with moderately low pH (below 6.5) are particularly corrosive to lead pipes, and the numerous incidents of acute plumbism from drinking such lead-piped waters attest to this (Moore, 1977). The alkalinity and pH of the water supplies in Rome cannot now be determined unambiguously. *Rome relied almost exclusively on springs as the source of her water.* These are now lost in the mists of time (see Table 6.1). Learned discussions on the possible sources of the waters delivered to ancient Rome have been presented by Lanciani (1888, 1897), Asby (1935), and Van Deman (1973). Stated briefly, few—if any—of these source springs have been identified unambiguously.

Rome itself is situated on calcareous rocks and the present-day municipal water is quite hard, averaging about 300 mg/liter $CaCO_3$ (Amulree, 1973). The thick limestone encrustations on the remains of many ancient aqueducts (Asby, 1935; Van Deman, 1973) and the fact that the systems were cleaned frequently by the *circuitores* suggest that the aqueducts suffered from serious calcareous deposits. Using this line of reasoning, Forbes (1964, p. 177) has concluded that "the manifold cases of rather intense incrustations of calcium carbonate on the interior of ancient lead pipes suggest that this complaint (of possible lead poisoning) is grossly overrated."

The area around Rome, however, contains other geological rock formations (see Lanciani, 1897). The principal ones include: (1) argillaceous beds that are conspicuous in the Vatican and Janiculum ridges and are used widely as an essential element of Roman masonry; (2) the volcanic rocks exemplified in the Alban hills and the Sabatine volcanic range. The tufa, pozzolana, and selce were extensively employed in Roman buildings and in making cement (67% pozzolana and 33% lime); and (3) alluvial deposits that abound on each side of the Tiber River (Lanciani, 1897, pp. 5–6). Volcanic rocks generally made good aquifers, and in fact, the head springs of Aqua Appia, Aqua Virgo, Aqua Trajana, and Aqua Alexandrina are believed to be from possibly noncalcareous rocks (Lanciani, 1897; Ashby, 1935; Van Deman, 1973). Waters in contact with noncalcareous volcanic rocks are noted for being soft and relatively acidic, that is, corrosive to the lead pipe. In this respect, it is significant that the four above-mentioned aqueducts accounted for about 25% of the water consumed daily in ancient Rome. (This conclusion is taken from the supply figures given by Frontinus).

Table 6.1 Sources of Water for the Aqueducts of Rome

Aqueduct	Year Built	Number of Taps in Use	Source of Water or Intake Location[a]
Aqua Appia	312 B.C.	704	The source of the original aqueduct lay within the bounds of the vast estate of Lucullus (ager Lucullanus), between seven and eight miles from the city, 780 paces (1,153.62 m) along a crossroad to the left of the Via Praenestina (Frontinus, *1*:5), or probably, as Lanciani (1878) suggests, of the Via Colatina. The exact site of the springs, which were selected doubtless for their proximity to the city as well as for the excellent quality of their water, cannot now be determined, though their general location is clear. They lie, as in the time of Appius Claudius, in a level stretch of marsh-land rich in springs fed from the slopes of the Alban hills. The source of the later branch of the conduit, the Ramus Augustae, which was located more than a mile nearer the city than that of the older branch, was to be found, according to Frontinus (*1*:5), on a crossroad 980 paces (1,450.5 m.) to the left of the Via Praenestina. Its site has not so far been identified.
Anio Vetus	272 B.C.	1610	Concerning the site of the intake, no information has been handed down to us by ancient writers, apart from the statement of Frontinus (*1*:6) that it lay above Tibur at the twentieth milestone from the . . . Gate, where it gave a portion of its water to supply the people of the town. The exact point to which the words of Frontinus refer has been, from the time of Canina, the subject of much, though fruitless, discussion.
Anio Novus	52 B.C.	5625	The main source of the aqueduct was, as is indicated by its name, also the Anio river. Its intake lay, in the time of Claudius, somewhat higher up than that of the Anio Vetus, at the forty-second milestone of the Via Sublacensis (Frontinus *1*.15). When, however, despite the insertion of a settling tank below the intake, the water brought to the city remained dirty and unpalatable, the intake was removed, by the orders of Trajan, farther up the river beyond Subiaco, where the waters were drawn from Nero's lakes, which served as a vast storage and clearing tank. In order to render still more wholesome the waters of the aqueduct, the Rivus Herculaneus was added as a supplementary source, near the thirty-eighth milestone on the road to Subiaco.
Aqua Marcia	140 B.C.	1935	The original source, or fons, of the Marcia was situated, as stated by Frontinus (*1*.7), beside a crossroad three miles to the right of the thirty-sixth milestone of Via Valeria as one comes from Rome, where its waters lay like a quiet pool of a deep green hue. While the general location of the source of the conduit is certain, the changes wrought in the floor of the valley by nature during the two milleniums which have passed have buried springs themselves far below the modern level. Augustus added to the original conduit a second source bearing his name, the Aqua Augusta, a fitting rival of the older source, not only in the excellence of its water but in its abundance (Frontinus *1*:12). For not only was the volume of the earlier aqueduct doubled by it, but out of its surplus water, the Claudia also was filled to overflowing (Frontinus *1*:14; *2*:72). The exact site of the springs of the Augusta is unknown. According to Frontinus (*1*:12), however, they lay above those of the Marcia, 800 paces (1,187 m.), from the junction of the two channels. In accordance with the Roman custom, Caracalla added to the Marcia, in 212 A.D., in compensation for the water drawn from it for his baths, a new fountain-head, the Fons Antoninianus, which was regarded later as an independent conduit and called the Aqua Antoniniana, or Jovia (Lanciani, 1878). In addition to its more regular sources, the Marcia, in times of crisis, drew also a supplementary supply of water from the nearby spring of the Claudia, the Fons Albudinus, the excellence of which equaled that of the older aqueduct itself (Frontinus, *1*:14).
Aqua Julia	33 B.C.	809	The source of the conduit, according to Frontinus (*1*:9), is "on a crossroad two miles to the right of the Latin Way as one comes from Rome, at the twelfth milestone from the city." The general site as indicated by Frontinus was located by Lanciani in 1878, according to whom it lay in the region already famous for its springs, the *Ager Lucullanus,* in the valley in

Table 6.1 *(continued)*

			which the source of the Tepula had been discovered almost a century earlier. The individual springs, several in number (*ex pluribus adquisitionibus*), the union of which formed the *caput,* or fountain-head, of the conduit (Frontinus, *7*:69) cannot, however, be identified with certainty, though those pointed out by Lanciani seem open to little doubt. To these legitimate sources, the watermen (aquarii) of the following century fraudulently added a considerable part of the brook called the Crabra, belonging by rights to the people of Tusculum, the line of which passed close by the springs of the aqueduct—an abuse corrected by Frontinus in accordance with the orders of the Emperor Trajan (Frontinus, *7*:9). The supply of water furnished by the conduit was later increased by the addition of 162 *quinariae* (6,723 cubic meters in twenty-four hours), which it received from the Cubia behind the Gardens of Pallas in the city (Frontinus, *2*:69).
Aqua Alsietina	2 B.C.	392	The original source of the conduit, the tiny lake of Martignano, lies a little to the northeast of the larger lake of Bracciano (*lacus Sabatinus*), on a crossroad six and a half miles to the right of the Via Claudia at the fourteenth milestone from Rome (Frontinus, *1*:11). A supplementary supply of water was added, when the water inspectors (aquarii) considered it necessary, from lake Bracciano or from its outlet, the Arrone, by a branch channel which joined the main conduit at Careiae (Frontinus, *2*:71).
Aqua Claudia	52 A.D.	(5625)	In the part of the valley of the Anio river below Arsoli where the noted springs of the Marcia were located, the engineers of Claudius found two other springs a short distance higher up which vied with if they did not surpass the earlier ones in the rich abundance of their waters (Frontinus, *2*:72), while but a little inferior to them in quality. The site of these springs, which bore the names of *fons Caeruleus,* from the celestial blue of its water, and *fons Curtius,* was located, according to Frontinus (Frontinus, *1*:14), at the thirtyeighth milestone of the Sublacensian Way. Owing, however, to the varied vicissitudes through which the bed of the valley has passed, the actual site of the springs as well as of the collecting basin *(caput aquarum)* cannot now be determined. To these two fountain-heads was added, a little later, a third, called the *fons Albudinus,* the water of which was so excellent that, when united with the Marcia as a supplementary source, the latter suffered no deterioration in quality from the admixture. The precise location of the Albudinus is not known, though it is clear that it lay at no great distance from the other sources of the aqueduct. Abundant as were the three earlier sources, the public and private demands on the Claudia made a still further supply of water necessary. The waters of the Augusta, which had been designed by Augustus as a supplementary source for the Marcia only, were in part, therefore, turned into the channel of the Claudia, with the understanding, however, that the latter should receive only the surplus water which the Marcia could not carry. Though the site of the springs of the Augusta is not known, ancient references make it clear that it lay well above those of the Marcia not far from the Claudia.
Aqua Trajana	109 A.D.		The system of the Trajana, apart from its multiplicity of sources, is simple. The groups of fountain-heads, each consisting of several distinct springs, from which it drew its water lay in the hilly regions to the north between the shores of the lake of Bracciano and the villages of Oriolo and Bassano. They were, according to Cassio, five in number: the springs of (1) the Fosso di Fiora, (2) Grugnale near Oriolo, (3) Ceresaro near Bassano, (4) the Fosso della Spina, and (5) the Ferriera. The head-reservoir, or collecting basin, the *caput aquae* of the Romans, lay somewhat farther down between Vicorelle and Trevignano.

Table 6.1 *(continued)*

Aqua Alexandriana	ca. 226 A.D.		The fountain-head of the Alexandrina lay on the eastern edge of the basin of the Pantono to the south of the Via Praenestina. Here, at the foot of the hill called Sasso Bello to the east of Monte Falcone, several groups of springs are still to be seen. A second group of springs is also visible a little above those of the Felice, which formed the source in ancient times, seemingly, of a small aqueduct supplying the town of Gabii, which was built or possibly restored by Hadrian, according to an inscription (Lanciani, 1878) found in 1795. A little farther down the slope, however, a third and larger group of springs has been disclosed in more recent times, which, from its character, and proximity to the remains of the channel, may be the source of the Alexandrina. The individual springs have not been positively identified, nor have any traces of the collecting basin or reservoir been found.
Aqua Virgo	19 B.C.	2504	The springs of the aqueduct, according to the ancient authorities (Fontinus, *1*:10) lay two miles to the left of the Via Praenestina near the eighth milestone of the Via Collatina, in the lower part of the vast estate of Lucullus *(ager Lucullanus)*. In this locality, in the marshy plain rising gradually to the Alban hills, the birthplace already of three aqueducts, the engineers of Agrippa found a fourth group of springs so remarkable in the abundance and excellence of their waters that a shrine was erected near by to the young girl who discovered them. The number of individual springs united in the ancient collecting basin is unknown. In addition to these abundant sources, the supply of water was still further augmented, as has been said above, by a number of tributaries *(adquisitiones)*, which were united to the original stream along its course (Fontinus, *1*:10).

[a]Summaries are from Van Deman, 1973.

The literary evidence generally suggests that a large fraction of the water supply to the city of ancient Rome was relatively soft. Ancient Romans believed strongly in Hippocrates' adjudication that "water contributes much towards health." Thus they eschewed all sources of water that Hippocrates (*On Airs, Water and Places,* arts. 7–8) claimed to be bad, notably "waters that are marshy, stagnant and belong to lakes; waters which have their fountains in rocks or from a soil which produces ephemeral thermal waters 'which must necessarily be hard'; and waters from snow and ice 'the worst of any for all purposes whatsoever.' " As is evident from Table 6.1, they sought for the best potable waters, "which are those that flow from elevated grounds, and hills of earth; these are sweet, clear and can bear a little wine; they are hot in summer and cold in winter, for such necessarily must be waters from deep wells." Whether the springs tapped by the Romans originated from deep-seated, noncalcareous aquifers can only be guessed at. Many later Roman authors noted that good potable waters "can bear a little wine," and it would seem that the Romans were able to estimate roughly the alkalinity of their water by dosing it with a strongly colored wine (*vitis faecenia*) of the Algerian type (see Forbes, 1964, and references cited therein). Such a test can be expected to work only in soft to moderately alkaline waters.

The Romans believed that the potable water should be properly tested and Vitruvius (8.4) recommended the following: "The water, being sprinkled over a vessel of Corinthian or any other good bronze, should leave no trace. Or if the water is boiled in a copper vessel and is allowed to stand and then poured off, it will also pass the test, if no sand or mud is found in the bottom of the copper vessel." There is little doubt that very hard waters are unlikely to pass such tests. Furthermore, both Hippocrates and Vitruvius stress that boiled vegetables should not be "hardened" by water. Vitruvius (8.6) and Palladius also recommended the addition of mineral salts to purify waters that contained too much lime.

An additional hint on the relative softness of the water supply in ancient Rome can be derived from the classification by Celsus (2.18):

> Rain water is the lightest, then the spring water, next water from the river, then from a well, after that from snow ice; heavier still is water from a lake, the heaviest from a marsh. The recognition of the quality of water is as easy as it is necessary for those who want to know its nature. For by weighing, the lightness of water becomes evident, and of water of equal weight, that is better which most quickly heats or cools, also in which pulse is most quickly cooked.

It is thus not surprising that by the time the aqueducts were fully developed, those systems that derived their waters from surface sources and ephemeral springs (e.g., Aqua Aliestina, Aqua, Anio Vetus, and the original Anio Novus [see table 6.1] were generally considered unpalatable and were used primarily for water mills, water shows (*naumachia*), and sewer flushing (Leake, 1930; Forbes, 1964; Amulree, 1973). Such waters—from

lakes, rivers, and ephemeral springs—are the most likely to be hard. On the other hand, the favorite drinking waters of Aqua Marcia and Aqua Virgo were so pure that they did not even need any *piscinae* or settling tanks where the calcareous scales and precipitates were collected and removed (Pliny 31.41; Statius *Silvae* 1.5). The exact source of the waters of Aqua Marcia has remained problematic, and the possibility that this aqueduct drew some—if not most—of its waters from noncalcareous and perhaps deep-seated aquifers cannot be completely ruled out. Although there were numerous springs around Rome, what, then, was so special about the few that were tapped for the aqueducts, some of them at considerable distances from Rome? Did the Romans seek out the springs with soft waters in order to obviate the problem of calcareous deposits? There is also the question of the widespread use of the water supplies in the *thermopolia* where the hot water was prepared for the baths and for sale. Was any deliberate attempt made to ameliorate the scaling problem by relying on the supply of relatively soft water? Perhaps there was.

Temperature

The solubility of calcite decreases with temperature (see Garrels and Christ, 1965). Thus, heating tends to reduce the carbonate alkalinity of the waters. The winter temperatures of the source springs for Aqua Marcia, Aqua Julia, and Aqua Tepula have been estimated to be 45°F, 50–52°F, and 61–63°F, respectively (Lanciani, 1888; Ashby, 1935). Such spring waters, when they are cooled to ambient temperatures, may be expected to have lower alkalinity than surface waters. Furthermore, a reduction in carbonate alkalinity often entails a reduction in pH. Hot waters with pH values below neutral are known to be particularly corrosive to lead pipes (Pocock, 1980). The high plumbosolvency of such hot and acidic waters has been known for a very long time. Pausanias (4.35) noted that in his time "a hot spring has been found at Dicaearchia Puteolis so acid that in a few years it dissolved the lead through which its water passed."

Duration in Pipe and First-Draw Water

The channels of the Roman aqueducts were lined with rough-cut stone, tufa, sand, or concrete. The claim by Pirro Ligorio in the sixteenth century that the channel of Aqua Virgo was lined with lead sheet in marshy places has been disputed (see Ashby, 1935, p. 171). The water in the aqueduct arrived at the *castellae* (tanks) from which it was conveyed, often in lead pipes, to the consumer. Since the Roman water supply worked on the principle of constant offtake, the castellae had little storage capacity, thus implying constant flow of water through the pipes to the withdrawal points. Frontinus (2.111) tells us that "there must necessarily be some overflow from reservoirs, this being proper not only for the health of our city, but also for use in the flushing of sewers." Water, however, was piped into the villas and ground floors of the tenement blocks (*insulae*) where the aristocrats usually lived. Tenants of the upper floors of the insulae obtained their water from the nearest fountains or the water carriers (*aquarii*) (Carcopino, 1940). Thus the high concentrations of lead that characterize first-draw water (e.g., see Wong and Berrang, 1976) would have been a problem only to the affluent to whom the emperor had granted supplies (*sub nomine Caesaris*). During the time of Frontius (ca. 35–103 A.D.), there were over 14,000 taps affixed directly to the castellae, and there were many other unregistered ones connected to the supply lines in Rome. These outlets, usually made of bronze, fed the lead pipes that then conducted the water to the aediles, which were often located at considerable distance from the castellae.

It would thus appear that a certain fraction of the water supply to the ancient city of Rome was relatively soft. The plumbosolvency of such waters, however, could have been mitigated by several factors. The water supply worked on the principle of constant offtake, implying a comparatively short contact time with the lead in the distribution system. The affluent households supplied with piped-in water were probably large, required a lot of water, and conceivably reduced the build-up of lead in the tap water.

To put things further into perspective, it needs to be noted, that out of the 95 larger aqueducts in service during the Roman Empire, only 9 or so were located in the capital city of Rome itself (Leger, 1875; Forbes, 1964). In Asia Minor, there were major aqueducts in Sardis, Ephesos, Pergamon, Miletus, Nysa, and Smyrna, and Spain had large aqueducts at Merida and Segovia. In Gaul there were famous ones at Nimes, Arles, and Lyons, while Germany and Britian were served by the aqueducts of Cologne, Bonn, Mainz, Trier, Lincoln, Dorchester, Sulis, and so forth (see Chapter 4 for references). Most of these aqueducts were equipped with lead plumbing that at times carried highly corrosive soft waters. The universality of lead plumbing during the Roman Empire suggests that the urban populations of the provinces with soft waters were probably exposed to much higher levels of lead in their drinking waters compared to those who lived in the city of Rome. The city of Pompeii is another interesting example. Because of the great head of the ancient aqueduct, the water could be forced to the castellae located in the highest parts of the city. The city had only a few mains, and private citizens were forced to tap their water directly from the castellae and convey it over long distances. Lead pipes were used everywhere to pipe the water to all but the poorest homes. Some of the private houses had as many as 30 taps (Mau, 1902).

Leaden Water Tanks

It has already been noted (Chapter 4) that lead vats and cisterns were extensively used in ancient times for storing water. Petrie (1920) maintains that large water tanks lined with lead were in use in Egypt since ca. 600 B.C. Such lead containers, which were particularly common in Roman

times, represented a health hazard, especially if the corrosive types of water were stored in them. Many ancient examples are also known (see Chapter 4) where lead sheets were used in roofing, in flashings, and to line the drains to the water tanks. Such usage would have contributed some lead to the drinking water. Indeed, as early as the sixth century A.D., Aetiös (4.1.78) implicated the rainwater from a lead roof as a cause of dysentery.

If the ancient peoples recognized the inherent dangers of lead pipes, they made no attempts to discourage their use. The references to lead pipes in Pliny, Frontinius, and Vitruvius show clear matter-of-fact tones. Vitruvius (8.6) certainly made an important observation when he stated:

> Water supply by earthenware pipes has these advantages. First, if any fault occurs in the work, anybody can repair it. Again, water is much more wholesome from earthenware pipes than from lead pipes. For it seems to be made injurious by lead, because white lead is produced by it; and this is said to be harmful to the human body. Thus if what is produced by anything is injurious, it is not doubtful but that the thing is not wholesome in itself.
>
> We can take example by the workers in lead who have complexions affected by pallor. For when, in casting, the lead receives the current of air, the fumes from it occupy the members of the body, and burning them thereupon, rob the limbs of the virtues of the blood. Therefore it seems that water should not be brought in lead pipes if we desire to have it wholesome. Our daily table may show that the flavour from earthenware pipes is better, because everybody even when they pile up their tables with silver vessels, for all that, uses earthenware to preserve the flavour of water.

The repetitious use of "it seems" suggests that he was only guessing about the possible danger of lead pipes, based on his familiarity with the incidence of palsy among the lead workers and his understanding of the toxicity of white lead. He referred to the earthenware pipes as "cheap," and the rest of his text leaves no doubt as to his preference for lead pipes in major water-supply systems. Much later, Palladius (*De re rustica* 9.11) also noted that lead pipes make the water injurious because "ceruse, which is harmful to the human body, is a product of the attrition of the lead." He was probably quoting from Vitruvius.

In his letter to Fuscus ("lover of the city"), Horace ("lover of the country") asked: "Is the water purer, which in city streets struggles to burst its leaden pipes, than that which dances and purls down the slobing brook?" (*Epistles* 1.10). As Stevenson (1949) has pointed out, this statement represents more a poetic fancy than a condemnation of lead pipes per se. Galen (8.45) seems to be the only ancient medical authority to have expressed any reservation against the use of lead pipes. After recommending pure rainwater as the most proper for the preparation of his *confectio ex capitibus papaveris,* he particularly directs that water flowing through leaden pipes is to be avoided "for a certain slime from the lead is present in it. And for this reason those who drink the sediment of such water are subject to disorders in the intestines." Galen, however, forgot to stress that the rainwater should not be collected from roofs weathered with lead sheets, or that the concoction itself should not be boiled in leaden kettles or pots. Athenaus actually alluded to possible colic from drinking water boiled in bronze or lead kettles: "A small cup of boiled water, if he drank it raw, it sits heavily and causes pain" (*Deipnosophistae* 3.122). Or again: "Let me not see anyone boiling water in a kettle for me. There's nothing the matter with me. Heaven forbid! But if I get a twist in my belly or navel, I've got a charm which I bought of Phertatus. . . ." (*Deipnosophistae* 3.122). Pliny's (14.29) assertion "man is so skillful in flattering his vices, that he has even found means to render water poisonous" rings so true, but it was not aimed at lead pipes.

Exposure from Foods

Elevation of lead concentration may occur in foods that are grown near ancient base-metal mining communities. Exposure from such a source, however, would have been a local problem for a population presumably overburdened with lead from other exposure sources.

The principal sources of lead in ancient foods included the contamination and adulteration of the food during processing, leaching from lead, pewter, or bronze utensils, improperly glazed pottery used in storing or cooking the foods, use of lead-containing preservatives and colorants, and from condiments and seasonings adulterated with lead. Lead in cooking water and dining utensils may also be transferred to the diet. The exposure from lead-contaminated beverages will be discussed later.

Lead vessels, as well as pewter and leaded bronze vessels and utensils, were in use in the Old World since remote antiquity (see Chapter 4). As noted previously, the peculiarity of ancient Chinese bronzes was their consistent high percentage of lead. The cooking vessels used in ancient China, such as *ting, li,* and *hu* (probably for boiling and simmering-stewing), and *hsien, tseng,* and *fu* (for steaming), were made of pottery, lead, and leaded bronze (Chang, 1973; Linduff, 1977; Schafer, 1977; Yu, 1977). For example, seven bronze *fu* vessels with a lot of fish bones were discovered in Han tombs in Canton (Mai, 1958), and from Han tombs at Li-Chu and Shao-hsing in Chekiang a number of bronze, pottery, and iron *fu* were unearthed in 1955 (Yu, 1977). The lead and bronze cooking vessels certainly would have contributed lead to the foods—especially when they were employed in preparing acidic foods—or if the pots were scraped occasionally to prevent burning, as is usually the case with thick liquids. A suggestion of the magnitude of leached-out lead comes from an eighteenth-century English bronze plate containing 3% lead that emitted 0.15 mg lead/dm^2 in an acetic acid test (Grandjean, 1975). By comparison, it is not rare for ancient Chinese bronze vessels to contain over 30% lead. Old Chinese

sources, however, are remarkably silent on lead poisoning from cooking vessels.

There was a marked dichotomy in the composition of pre-Han serving utensils and vessels. Vessels for grain, such as *kui, hsu, fu,* and *tui,* were pewter–bronze, lead, pottery, and basketry, while those for dishes, such as *tou, pien,* and *tsu,* were mostly made of wood or baskets (Chang, 1977). *Tou* and *pien,* the two most important vessels for serving meat dishes, are not known to be made of bronze or lead during the Shang and Early Chou periods. *Tou* vessels appeared in the latter half of the Chou era in bronze, but from the beginning of the Han epoch onward, they were again almost exclusively wooden or lacquered. Chang (1977) speculates that food and drinks were cognitively classified during the Shang and Chou periods into different categories similar to the five elements (see Chapter 1), and different vessel materials could only come into contact with certain kinds of foods and drinks, according to specific rules. Irrespective of its exact significance, such a dualistic principle would have curtailed the dietary intake of lead by the rich, who could afford meat and rich vegetable dishes.

Lead, pewter, leaded bronze, and lead-repaired vessels have also been found in the remains of the ancient cultures of India, Mesopotamia, the Levant, Persia, Egypt, among others (see Chapter 4). In addition, lead was frequently used in antiquity for mending broken pottery. The Romans, however, were the first to popularize the use of lead, pewter, and leaded bronze utensils on a grand scale. "The remarkable thing about lead vessels," writes Pliny (34.49) is that "they will not melt if they have water put in them, but a hole is burnt in the same vessels if filled with pebbles or copper coins instead of water." The bronze of Campania, "which is most esteemed for utensils," contained 8–10 lb of lead per 100 lb of copper (Pliny 34.20). Pot-bronze was a blend of 3–4 lb of lead and 100 lb of copper (Pliny 34.20). Furthermore, it was common practice for the Greeks and Romans to coat their copper or bronze cooking pots with lead or lead alloys. Pliny (34.48) says that "when copper vessels are coated with stagnum (a lead–silver or lead–tin–copper alloy) the contents have a more agreeable taste and the formation of destructive verdigris is prevented, and, what is remarkable, the weight is not increased."

Large hoards of Roman utensils are extant, particularly from the excavations of Pompeii, where several kitchens have been found that were apparently in use at the time of the eruption of Vesuvius in 79 A.D. For example, a set of bronze saucepans *(caccabus?,* or *abenum),* presumably coated originally with stagnum, has been found in situ on the hearth in the kitchen of the House of Vettii at Pompeii (Liversidge, 1957). Roman bronze (often leaded) and pewter frying pans *(fretale, sartago, patellae,* or *patinae),* bowls for *bain-marie* cooking, cooking pots *(ollas),* and strainers *(colae)* are widespread, and exemplary hoards have been found at several sites in Pompeii, and at Gneisenau, Germany, Pannonia, Newstead, Scotland, several locations in Britain (Liversidge, 1957), and at Olynthus (Robinson, 1941). Such utensils would have been relatively important sources of dietary lead intake, and recent cases of lead poisoning from such sources are indeed recorded in the medical literature (e.g., see Mahaffey, 1978 for a review).

The Romans typically served their food on dishes and plates *(discus* or *conchiclar)* made of silver, bronze, pewter, and pottery, hoards of which are frequently found. Knives and spoons of all shapes and sizes as well as ladles and dippers *(trullae* and *simpula)* were made of bronze (often leaded), iron, silver, wood, or bone. The lead scraped off and leached from the dinnerware would have contributed to the dietary lead intake.

The adulteration of foods, particularly condiments, with lead, no doubt, is as old as gourmet cooking and specialized food processing. Intentional addition of lead to food items would have been rare, although the use of lead compounds as a colorant for, and to add weight to spices is not inconceivable (see Schmidt, 1924). The sweet taste that lead salts bring out in organic acids was certainly familiar to the ancient peoples—particularly to the Romans. Since the Romans did not have sugar, they extensively used boiled-down grape juice *(mustum curari)* to impart sweet flavor to their dishes. According to the degree of boiling down, the sweet syrup was called *sapa* or *defrutum* or *defritum,* or sometimes by its Greek names *car(o)enum, hepsema,* or *siraeum (sireion).* The definitions given in the various classical texts do not always agree with each other. Demokritos (extracts in the *Geoponica* 90.7.4) has told us that "some who upgrade wine boil the must until 1/20 has evaporated. . . . The Lacedaemonians on the other hand boil it until 1/5 has evaporated." According to Columella (12.21) and Varro (1.60), *defrutum* is must reduced to one third of its volume by boiling, and Pliny (14.11) declared: "*Siraeum,* by some called *hepsema* and in our country *sapa,* is a product of art, not of nature, made by boiling down must to a third of its quality; must boiled down to only one-half is called *defrutum.*" Palladius (11.18) furnished the following definitions:

> Now about the prepartion of *defrutum, caroenum,* and *sapa.* Although all three are made from the same substance, namely from must, the method of their preparation modifies both their names and their properties. For *defrutum* has its name from "boiling down," and it is ready when it is reduced to a thick consistency. *Caroenum* is ready when it has lost one-third of its volume with two-thirds remaining, *sapa,* when it has been reduced to one-third. The latter is improved when quinces are cooked with it and fig wood is added to the fire.

All the classical authors agree on one point, namely, that lead vessels are to be preferred for boiling the must because they make the concentrate sweeter and more durable. For must that should be boiled "lead and not copper jars should be used," declared Pliny (14.27). Cato (*On Agriculture,* art. 105) and Palladius (11.18) also recommended lead vessels. Columella

(12.20) explained his choice of lead vessels as follows: "The vessels themselves in which the thickened and boiled-down must is boiled should be of lead rather than brass; for, in the boiling, brazen vessels throw off copper-rust and spoil the flavor of the perservatives." Columella (12.19) recommended gentle heating and constant stirring of the must—treatments that would have exacerbated the leaching of lead from the vessels:

> We shall carry from the vat to the boiling vessels as much as we require of the must which has flowed from them before the pedicles of the grapes are removed from the wine-press and we shall heat the furnace at first with a gentle fire and with only very small pieces of wood, which the country people call *cremia* (brushwood), so that the must may boil in a leisurely manner. The man in charge of this boiling should have ready prepared strainers made of rushes or broom, but the latter should be in a raw state, that is to say, not beaten with a hammer. He should also have bundles of fennel attached to the ends of sticks which he can let down right to the bottom of the vessels, so that he can stir up any dregs which have settled at the bottom and bring them up to the top; he should then clear away with the strainers any scum which remains on the surface, and he should go on doing this until the must seems cleared of all lees. Then he should add either some quinces, which he will remove when they are thoroughly boiled, or any other suitable scents which he likes, continuing nonetheless to stir the liquid from time to time with the fennel to prevent anything from sinking to the bottom which might perforate the leaden vessel. Next, when the vessel can stand a fiercer fire, that is, when the must, being partly boiled away, is in a state of internal seething, stems of trees and larger pieces of wood should be put underneath, without, however, actually touching the bottom; for unless this contact is avoided, the vessel itself will not infrequently be pierced, or, if this does not happen, the must will certainly be burnt, and having acquired a bitter taste will be rendered useless as a preservative.

There can be no doubt that the Roman sapa was highly contaminated with lead. Hofmann (1885) showed that freshly pressed Styrian must of white grapes, when reduced in volume by 50%, acquired no less than 237 mg of lead per liter of must from a lead sheet with a surface area of 348 cm^2 placed in the boiling liquid. Eisinger (1977) prepared sapa according to the classical recipe, and he found that it indeed had a pleasing taste and aroma, and that the lead content was about 1000 mg/liter. The two studies clearly suggest that one teaspoonful of sapa per day could cause chronic lead poisoning, and countless Romans would have consumed more than this dosage from their foods and drinks. Such a syrup also would have extracted additional amounts of lead from lead-lined copper pots, pewter, and leaded bronze vessels and utensils used in food preparation.

The Roman fondness for sweet and sour flavors is well known, and the cooks made common use of the cheap (in relation to honey and other ancient sweetners) sapa in their sauces and seasonings to assuage the appetites of their patrons. Pliny (14.11) said that sapa was one of the cheap mixtures devised for adulterating honey. Out of the 450 or more recipes in

Apicius' cookbook (compiled in the fourth or fifth century A.D.),* roughly 20% (85 dishes) called for *defrutum* or *caroenum*. Examples of Apicius' recipes featuring boiled-down must include: stuffed and chicken rissoles; broth to be used as a laxative; marrows—as hors d'oeuvres, Alexandrian fashion, and with fowl; seasoning of mallows, turnips, peas, beans, lentils, mussels, and mushrooms; patinae of fish, fruit, and green vegetables; fricasse of fish or forcemeat; barley soup or broth; lentils with mussels; sauces for all types of birds, such as crane, duck, chicken, and flamingo; sauce for roasted, boiled, or sliced meats; truffles; sauce or seasoning for boar, hare, venison, fried veal, and roast lamb; suckling pig cooked in a metal casserole; as well as sauces and seasonings for all kinds of seafood—crayfish and large prawns, squid, sea urchins, bonito, salt fish, grilled conger eel, tunny fish, perch, murena, and scorpion fish (Apicius, *The Art of Cooking*. 1–10). It should come as no surprise that defrutum was featured widely in ancient pastries (see Soyer, 1853). Curiously enough, sapa was mixed with flour to fatten the snails reared by skillful speculators who reserved them (the heavy ones!) for the Roman sybarites (Varro 3.14; Pliny 9.57).

The leaching of utensils used in preparing the sweetened dishes probably added more lead to the meals. A large majority (well over 50%) of Apicius' recipes use wine, and thus this raises the possibility that such dishes were also contaminated with lead from cooking vessels, or in the wine.

Any lead in the water would have been transferred to the foodstuffs during cooking. Recent studies using the radioactive tracer technique, in fact, show that during cooking, vegetables and rice absorb up to 80 percent of the water borne lead (Moore et al., 1979; Little et al., 1981). The preparation of several ancient sauces such as *passum* (Columella 12:39) called for soft and corrosive rainwater that had been boiled down, probably in lead or lead-lined vessels. The lead intake by foodstuffs cooked in water from the plumbing system would have contributed significantly to the dietary exposure of the Roman population to that metal.

One characteristic feature of Roman cooking was the pervasive use of *garum*, or *liquamen*, which seems to have been a Greek invention of the fourth century B.C. and which was later introduced to Rome (Brothwell and Brothwell, 1969). This sauce was prepared not only at home but also in large quantities in *liquamen* factories, some of which attained commercial fame. Basically, it was made from salted-down entrails of fish from

*Whereas Apicius wrote his cookbook in the first century A.D., the book *De Re Coquinaria*, as we now know it, was compiled toward the end of the fourth century, or beginning of the fifth century A.D. (Flower and Rosenbaum, 1958). The compiler probably added the various recipes for the average middle- and lower-class households to Apicius' original recipes for the more luxurious table. The collection of recipes from several sources gives us a picture of Roman eating throughout a 300–400-year period.

which the liquor was strained and stored in jars. There were few Roman dishes that were not improved with a dash of this sauce. Two eggs with a dash of good garum made a simple and delicious meal (Martial 13.40). The sauce was prepared in several ways (see *Geoponica* 20.46), including the following, for a quick process:

> If you wish to use the garum at once—i.e., not expose it to the sun, but boil it—make it in the following manner: Take brine and test its strength by throwing an egg into it to try if it floats; if it sinks the brine does not contain enough salt. Put the fish into the brine in a new earthenware pot, add origan, put it on a good fire until it boils—i.e., until it begins to reduce. Some people also add *defrutum*. Let it cool and strain it two and three times, until it is clear. Seal and store away.

The contamination of liquamen with lead from the addition of defrutum is significant. We cannot tell exactly what liquamen tasted like, but from the recipe for its preparation, it must have been sharp and acidic, and thus was corrosive to the leaden utensils. The basic liquamen was mixed with water, wine, and vinegar, and it was then called *hydrogarum, denogarum, oxygarum,* and *muria*. Sometimes other spices and boiled-down must were also added to the mixture. The conclusion thus seems inescapable that the fish sauces, condiments, and wine preparations constituted a source of lead contamination for a large number of Roman dishes.

Xenophon (*Hieron* 1.22) could not have been more perspective in his condemnation of such foods: "How now?" said Hieron, "have you noticed these many contraptions which are set before tyrants—acid, pungent, astringent, and their brothers?" "Indeed I have," replied Simonides, "and in my humble opinion they are very much opposed to man's nature." "Do you not think," said Hieron, "that such viands are due to the appetites of a soul debased and sick? For they who really like to, as you doubtless know, require none of these fancy contraptions." By the fourth and fifth centuries A.D., such entrées were dished up not only to the tyrants, but to a large segment of the Roman population as well.

Then as now, apple, cherry, pear, plum, peach, quince, and other preserves were made at home by heating or boiling down the appropriate ingredients; the use of pewter or lead-lined utensils would have insured the contamination of such food items with lead. Furthermore, sapa was sometimes added as a sweetener or preservative. Often, the fruits were immersed in a liquor (brine, vinegar, honey, rainwater, etc.) and then stored in a vessel, presumably made of lead or one that was lead lined. Such manifold contamination of fruits and vegetables is exemplified by the following entries in Apicius' (1.12) cookbook:

> *To keep grapes fresh.* Take undamaged grapes from the vine, and reduce rain-water to one-third and put it in a receptacle in which you also put the grapes. Treat the receptacle with pitch and seal with gypsum, and store it in a cool place where the sun does not enter, and you will find fresh grapes when required. The water can be given to the sick as honey-water.
>
> *To keep quinces fresh.* Choose faultless quinces with their twigs and leaves, and put them in a receptacle, and pour over honey and *defrutum:* you will keep them for a long time.
>
> *To preserve blackberries.* Make juice of blackberries, and mix with thickened must (i.e., *sapa*), put in a glass vessel together with whole blackberries; you will keep them for a long time.
>
> *To preserve turnips.* First clean and arrange them in a vessel, and then pour on myrtle-berries mixed with honey and vinegar.

Marcus Cato (ch. 7) also has the following to say about the preservation of various farm products:

> grapes are preserved in grape-pulp in jars; also they keep well in boiled wine, or must, or after-wine. Plant or ingraft all kinds of fruit—sparrow-apples, Scantian and Quirinian quinces, also other varieties for preserving, must-apples and pomegranates; of pears, the volema, the Anician frost-pears (these are excellent when preserved in boiled wine), the Tarentine, the must-pear, the gourd-pear, and as many other varieties as possible; of olives, the orcite and posea, which are excellent when preserved green in brine or bruised in mastic oil. When the orcites are black and dry, powder them with salt for five days; then shake off the salt, and spread them in the sun for two days, or pack them in boiled must without salt. Preserve sorbs in boiled must; or you may dry them; make them quite free from moisture. Preserve pears in the same way.

The preceding suffices to suggest that foods were one of the principal sources of lead ingested, particularly by well-to-do Romans. Livy (39.6, 9) tells us that, aside from being a chore which the cheapest slave could do, cooking turned into an art during the second century B.C. As these "artisans" became more and more sophisticated, they resorted increasingly to lead-contaminated condiments to assuage the "sweet teeth" of their patrons. The men who reportedly "lived for their palate alone" (Seneca *De beneficiis* 1.10, 2) presumably died by their palates as well. The classical satirists and moralists certainly handled the gourmand of their time without mercy (e.g. Horace *Satires* 2.2; Lucan *Nigr* 31.72 ff.; Seneca *De beneficiis* 1.10.2; *Epistles* 47.1–8, 89.22, 90.7).

There is no literary evidence, however, to suggest an apprehension of the dangers associated with lead contamination of the dishes. One is therefore surprised to find the following astute observation by Musonius (ca. 20–90 A.D.): "That masters are less strong, less healthy, less able to endure labour than servants; countrymen more strong than those who are

bred in the city, those that feed meanly than those who feed daintily; and that, generally, the latter live longer than the former. Nor are there any other persons more troubled with gouts, dropsies, colics, and the like, than those who, condemning simple diet, live upon prepared dainties." (Excerpt from Humelbergius Secundus, 1829) The published works of Musonius are not now known to be extant (Charlesworth, 1936), and it is difficult to establish whether the preceding remarks were his exact words. In a sense, he does seem to be alone among the classical authors in associating symptoms of lead poisoning with dainty food consumption.

Lead Contamination of Beverages

The contamination of fermented beverages with lead was fairly widespread in ancient times, but it became rather prevalent in the Greco-Roman world. Gilfillan (1965) listed 14 different ways in which the Romans contaminated their wine with lead. Only the major sources of lead contamination of ancient drinks will be considered in this section.

Since the earliest times, drinking *chiu* (fermented beverages or "wine") was a basic part of Chinese living, whether during the most sacred rituals or in any casual moment of relaxation from work or worry (Schafer, 1977). These beverages were at times served—and presumably stored—in lead or highly leaded bronze flagons and cups (Chang, 1977; Linduff, 1977). Indeed, a ranking official called Thang Tsun, who lived near the end of the Early Han Dynasty, was accused of hypocrisy because he used earthenware vessels for his food and drink (Chang, 1977, p. 79; Ying-shih Yu, 1977, p. 79). Similarly, some court officials with ministerial positions under the reign of the emperor Kuang-wu (Han Dynasty, 206 B.C.–220 A.D.) were berated for seeking to achieve reputations of frugality by using plain wooden cups for eating and drinking (Yen, 1958, p. 536). The suggestion is thus made that the aristocracy of ancient China was inclined to drink from metallic cups. The habit certainly raises the question of chronic plumbism among users of the lead and bronze wine containers.

Linduff (1977) has considered the problem of lead in the Late Shang and Early Chou ritual vessels, and she has emphasized the fact that the wine-drinking lead and bronze vessels were eliminated almost entirely from Chou inventories at the end of the tenth century B.C. Linduff presented some documentary evidence that alleges intemperance with respect to alcoholic-beverage drinking in Shang China. She expressed the opinion that "the downfall of the Shang was at least in part attributed to overindulgence in drink. But the symptoms could have been due to lead present in even small portions of liquid taken from bronze ritual vessels." Linduff, however, did make the valid point that the use of lead or bronze *chueh* and *chia* receptacles for libation liquids or oblutions did not necessarily mean that all the contaminated "wines" were actually consumed. A good measure of the liquids would have been sprinkled or poured as offerings to the ancestors (1977). Whether the Chou realized the dangers of drinking from their lead or bronze vessels remains a vexing question; the elimination of such ritualistic drinking vessels was probably aimed at curtailing excessive drinking rather than at preventing plumbism.

The ancient Chinese were not the only people to use drinking vessels (*kylix, kantharos, kotyle, oinochoe, kyathos,* etc.) made of lead alloys (see chapter 4). Lead tumblers have been found in graves predating 3000 B.C. at Ur (Partington, 1935, p. 253), in prehistoric graves at al-'Ubaid (Woolley, 1934), and in a cave at Trapeza, Crete, which dates to the Early Minoan period (Branigan, 1968). From these very early examples, cups and flagons made of lead and its alloys became progressively more abundant, and by Roman times they were regularly used by the common freedmen—while the aristocrats were accustomed to use gold or silver goblets. Numerous finds of these vessels are known. It is germane also to mention a very familar scriptural passage from Matthew (26:27–28): "And He took the cup, and gave thanks, and gave it to them saying, Drink ye all of it; For this is my blood of the new testament, which shall be shed for many for the remission of sins." In the early Christian days, the "cup" that held the wine would often have been made of lead or leaded bronze (Pulsifer, 1888), and only a few of the missionaries could afford the gold and silver goblets. We can only speculate on the possible health risks posed by the leaden vessels. It is of heuristic interest to note that Leonardo da Vinci's *The Last Supper* surprisingly showed the dinner plates to be made of pewter (*Hamilton Spectator,* Dec. 2, 1981, p. 33).

The ancient wine vases, casks, or jars (*amphora, hydria,* and *krater)* were generally made of pottery, leather, or skin, and wood (Seltman, 1957; Forbes, 1965). Occasionally, metal flogons and glass amphorae were used domestically for special wines. Forbes (1965, p. 112) has noted the important contribution of the wine trade to the development of Celtic art:

> The typical wine-vessels or "amphorae" and bronze flagons with beaked spouts are found in excavations in prehistoric Europe. They prove how wine penetrated into central France by way of rivers Rhône and Saone and by crossing the Belfort gap in the mountains reached the upper Rhine region. Along with the wine went the drinking ritual and all the vessels connected with carrying, storing, mixing and drinking it. These beautiful pottery or bronze vessels had a profound influence on the art of the European barbarians and a famous archaeologist has truly said that la Tène (Celtic) art may have largely owed its existence to Celtic thirst.

Bronzes of the La Tène period tend to be notoriously high in lead (Chapter 4), and it would not have been propitious for anyone to drink the wines stored in some of the flagons.

Lead was frequently used in antiquity for repairing the amphorae as well

as the *pithoi,* or *dolia* (wine vats). Numerous examples of pottery so mended have come from Bronze Age sites in the Aegean and the Greek mainland, from Hallstatt-culture sites of prehistoric Europe, and from Roman-age sites, such as at Olynthus (see Chapter 4). Cato (art. 39) remarked that rainy-day jobs on the farm included mending wine jars with lead. Also, wooden casks used in storing wines were sometimes provided with lead hoops. Additional contamination of the wine in amphorae could also have come from the lead plugs used to "stopper" the vessels and from the red-lead and white-lead pigments used in the proprietary labeling of the containers.

The ancient peoples paid close attention to whether the must was fermenting properly in the *dolia*. One of the tests for the so-called acetic fermentation entailed square plates of lead, tin, and copper, measuring three finger lengths in size, which were glued to the inner surface of the vat lid. After the vat had remained sealed for 40 days and the plates were still clean, then the wine was passed as good. Otherwise, a black, sour-tasting bloom would be deposited on the tin plate, the copper plate would be covered with foul-smelling bubbles, and the lead plate would be turned "whitish with scales resembling ceruse" (*Geoponica* 7.15; Hofmann, 1883). Pliny (14.25) referred only to the lead-plate test rather superficially: "It is a proof that wine is beginning to go bad if a sheet of lead when dipped in it turns a different color." From such a test grew the habit—among some vintners, at any rate—of having lead strips permanently in the wine vats as a form of quality control. This practice continued well into the Middle Ages with disastrous consequences (see Baker, 1767).

Lead glazes and enamels have been discussed in a preceding section (see Chapter 4). In general, pottery and other artifacts garnished with lead glazes were extensively used in Egypt and the Near East in the Ptolemaic period (ca. 330–30 B.C.) and in China during the Han and possibly the Chou periods. If the medieval glazes are any indication (see Grandjean, 1975), the ancient glazed vessels must have given off large doses of lead if they were used in storing or serving wines and other acidic beverages. We know, for example, that salt meat stored in a lead-glazed bowl sometimes takes the color and taste of lead chloride (Taylor, 1863, p. 433), and that the Romans routinely boiled seawater and brine solutions (which they added to their wines) in leaden vessels (Pliny 14.120; Cato 23.1–4; Columella 12.20–25). Lead contamination of wines and beverages stored or served in lead-glazed vessels certainly would have been high enough to cause plumbism among ancient consumers. A number of cases of both fatal and nonfatal lead poisoning from this source have been reported in recent years (Beritic and Stahedljak, 1961; Harris and Elsea, 1967; Lewin and Lundin, 1968; Klien et al., 1970; Browder, 1972; DuFour et al., 1972; Williams, 1972). The contamination of wines from glazed pottery conceivably was not widespread. Most of the ancient authors who dealt with wines recommended the coating of wine skins and wine jars with pitch in particular,

and with resins, wax, varnish, or oil (Pliny 14.24–25; Columella 12.18–19. Indeed, Columella (12.19) tells us that "it will be well that those (boiling vessels) which are made of lead should be coated inside with good oil and be well rubbed, and that then the must should be put in. This prevents the boiled-down must from being burnt."

Some contamination of ancient wines with lead may also be expected from the cement used to seal the plugs or covers of the amphorae. "To coat the brim of wine jars so as to give a good odor and keep any blemish from the wine," Cato (art. 107) made the following recommendation: "Put 6 *corgu* of the best boiled must in a copper or lead vessel; take a *hemina* of dried crushed iris and 5 pounds of fragrant Campanian melilot, grind very fine with the iris, and pass through a sieve into the must. Boil the whole over a slow fire of faggots, stirring constantly to prevent scorching; continue the boiling, until you have boiled off half. When it has cooled, pour into a sweet smelling jar covered with pitch, seal, and use for the brims of wine jars." Pliny, (14.27) recommended basically the same toxic sealant for wine vessels: "The jars must never be filled quite full, and the space above the surface of the wine must be smeared with raisin-wine or boiled-down must mixed with saffron or iris pounded up with boiled must. The lids of the jars should be treated in the same way, with the addition of mastich or Bruttian pitch."

Perhaps the most spectacular and probably the most damaging contamination of ancient drinks with lead stemmed from the use of sapa, defrutum, etc., as sweetners, adulterants, or preservatives. A modern vinter owes a deep though unromantic debt to sulfur. Wine barrels are sterilized by having sulfur burnt inside them, and sulfur is used to control fermentation as well as to preserve the health of a wine once it is made. It imparts no disagreeable flavor to the wine and, more importantly, it is harmless to the enophic consumer (Younger, 1966). Sulfur as such was hardly ever used in viticulture in ancient times, and in its stead boiled-down must was widely used. Lead and its salts—dissolved in the acid that spoils wine—give it a pleasant saccharine taste without any perceptible tint, and they arrest the progress of the acid fermentation as well (Beckmann, 1846). In the process, however, the wine is rendered quite toxic.

The contamination of grape juice *(mustum curari)* often began even as the grapes were being pressed. Cato (art. 20) specified the use of lead in the construction of the wine press: "The iron pivot which stands on the post must stand straight upright in the centre; it should be fastened firmly on all sides with willow wedges, and lead should be poured over it to prevent it from shaking; if it moves, take it out and fasten again in the same way, so that it will not move. Make the sockets for the stones of orcite olive wood, and fasten them with lead, being careful to keep them tight. Fix them on the axle."

In bad years when the must was of low grade, it became quite customary for the winegrowers in Greco-Roman times to boil the must down (to

increase its sugar content) before fermentation. The author of the *Geoponica* (7.4) noted that "some who upgrade wine boil it until 1/20 has evaporated and then add 1/10 gypsum. The Lacedaemonians on the other hand boil it until 1/5 has evaporated." People also attempted to improve the sugar content of must from unripe grapes in the same manner. According to the *Geoponica* (5.47), one estimates roughly how much must one can expect the grape to yield, adds one third of this estimated volume in the form of water, presses the grapes, and then reevaporates the juice to one third of the volume. From what has been said about the preparation of sapa and defrutum, there is little doubt that the concentration of must took place in lead containers. At times, the fermentation was aided by simply spiking the must with an older boiled-down must. Columella (12.20) recommended either spiking or boiling down musts from wet vintages.

The must not used for making wines had to be preserved until consumed or sold. Columella (20.19) tells us how this was done: "Some people put the must in leaden vessels and by boiling reduce it by a quarter, others by a third. There is no doubt that anyone who boiled it down to one-half would be likely to make a better, thick form of must and therefore more profitable for use, so much so that it can actually be used, instead of must boiled down to one-third, to preserve the must produced from old vineyards." The culinary uses of defrutum have already been discussed.

The principal difficulties confronting ancient winegrowers included the acidity and instability of their wines, and Pliny (14.26) tells us that in his time "whole volumes of instructions on how to remedy these have been published." To help their wine live until it was "old," the ancient peoples sometimes used wine lees and such additives as pitch, resin, gypsum, turpentine, chalk, marble dust, wood ashes, potash, crushed shells, fennel seeds, sweet almonds, and burnt spruce shavings (see Beckmann, 1846, and Hofmann, 1883, for excellent reviews). The statement by Demokritos (*Geoponica* 6.19) that the acidity of excessively sour wines was blunted using minium (sandix) is disconcerting. The usual "aid" to indifferent Greek and Roman wines, however, was boiled-down must (e.g., *Geoponica* 7.13; Cato, art. 23; Pliny 14.25; Columella 12.21). Columella (12.21) recommended year-old defrutum rather than fresh products because it had by then already proved itself, whereas with even well-preserved freshly boiled must, one could never tell whether or not it would turn sour and thus spoil the wine it was supposed to aid:

> Must of the sweetest possible flavour will be boiled down to a third of its original volume and when boiled down, as I have said above, is called *defrutum*. When it is cooled down, it is transferred to vessels and put in store that use may be made of it after a year. But it can also be added to wine nine days after it has cooled; but it is better if it has remained undisturbed for a year. A *sextarius* of this boiled-down must is added to two *urnae* of must if the latter comes from vineyards in the hills; but if it comes from vineyards in the plains, three *heminae* are added. When the must has been removed from the vat, we allow it to cool off for two days and to become clear. On the third day we add the boiled-down must; then, after an interval of two days, when the must together with the boiled-down must has finished fermenting, it is purified, and a heaped spoonful or a half-ounce measure generously filled with roasted and pounded salt should be added to each two *urnae* of must.

In like manner, Cato (art. 23) recommends; "If necessary, add to the new wine a fortieth part of must boiled down from untrod grapes. . . . When you use boiled must or marble dust or resin, stir frequently for twenty days and press down daily."

Several ancient authors also talked of preserving must or wines using boiled-down seawater or a boiled-down solution of common salt in rainwater (Athenaeus 1.31; Dioscorides 5.27; Palladius 11.14; Pliny 14.25; *Geoponica* 8.24, 7.4). Columella (12.25) furnished the following details on how to preserve must and wine with salt water:

> Since some people—and indeed almost all the Greeks—preserve must with salt or sea-water, I thought that part of the process ought not to be passed over in silence. In an inland district, to which sea-water is not easily conveyed, brine for preserving purposes will have to be made as follows. Rainwater is most suitable for this process, or, failing that, water flowing from a very clear spring. Therefore you will take care to place as much as possible of one or the other of these in the best vessels available for five years beforehand in the sun; then, when it has putrefied, you must leave it alone till it has returned to its former condition. When it has done so, you must have other vessels ready; and gradually strain the water into them, until you reach the dregs; for some sediment is always found in water which has been allowed to stand. When the water has been thus treated, it must be boiled down to a third of its original volume, in the same way as must which is boiled down. Then a *sextarius* of white salt and a *sextarius* of the best honey are added to fifty *sextarii* of fresh water, which must be likewise boiled down and all impurities removed. Then, when the mixture has cooled down, whatever liquid there is, that amount must be added to an amphora of must.
>
> If, however, your property is near the sea, water should be taken from the open sea when the winds are silent and the sea is as quiet as possible, and should be boiled down to a third of its original volume, some of the spices detailed above having been added, if it shall be thought fit, so that the wine may have more flavour after it has been treated.

Columella (12.21) also tells us that his paternal uncle of the same name, an "illustrious agricola," employed (and presumably devised) such a preservation technique. In order not to oversalt the wines, he (12.21) counsels any careful proprietor interested in wine making to try three or four samples of his very first vintage with varying amounts of preservatives in order to ascertain just how much brine the wine can stand without its taste being harmed.

The point that should be emphasized here is that lead forms highly soluble complexes with the chloride ions (Nriagu, 1971). Thus, boiling a brine

solution in a leaden vessel would certainly result in high-level contamination of the liquor with lead. The preservative action of the "treated" brine solutions most likely can be attributed to the lead acquired from the boiling vessels. An analogy can be drawn here with the observations by Celsus (2.30) and Pliny that raw honey was a good dietary laxative, but that when boiled it was turned into a constipating agent. The only way the effect could be reversed simply by boiling is to presume that enough lead was leached out of the boiling kettles to serve as the antidiarrheal agent (Kobert, 1909).

The Greek admiration for *oinos thalassikos* (salted or seawater wine) is well known. "Wine is sweet when seawater is poured into it," says Athenaeus (1.26b). The salting of ancient wines is thus subject to a double interpretation. In the first place, it was used to preserve the life of the wine, and in the second place, it was used either to give "bite" or piquancy to the wine, or to disguise a deficient wine. The latter motive is of little concern here.

Dryness in ancient wines was not always a desirable quality (Younger, 1966, p. 146). According to Athenaeus (1.30b–c, 32c–d), "the Athenians liked not the hard stiff poets any more than they liked Pramnian wines, which contract the eyebrows as well as the bowels; rather they want wines with delicate bouquet and nectar-distilling ripeness . . . for sweet wine is the most nutritious; it smooths the tract through which it passes and by thickening the humors more, tends to incommode the head less." Although a degree of sweetness of the ancient drinks was obtained by blending (Athenaeus 1.32a–b), a common and widely used process involved boiling the wine down in lead kettles until it became sweet, or else "doctoring" the wine with boiled-down must. To make sharp wine mild and sweet, Cato (art. 109) advised: "Make 4 pounds of flour from vetch, and mix 4 cyathi of wine with boiled must; make into small bricks and let them soak for a night and a day; then dissolve with wine in the jar, and seal sixty days later. The wine will be mild and sweet, of good colour and of good odour." On the other hand, Pliny (14.24) suggested a less complicated method: "In some places they boil the must down into what is called sapa and pour this into their wines to overcome their harshness." Columella's (12.20) detailed prescriptions will be given later.

Ancient literary sources leave us with a compelling impression that a large number of Greek and Roman wines were hopelessly "fiddled." Athenaeus (1.32c) remarked slyly that it "was a true saying, that wine must have not only its portion of water but also a bit of a jest." The popularity of wine adulteration is better exemplified in the following indignant passages from Pliny: "We know that for the sake of colouring the wine, colours are added as a sort of pigment and that this gives the wine more body. So many poisons are employed to force wine to suit our taste—and we are surprised that it is not wholesome" (Pliny 14.25). And then in a sweeping condemnation, Pliny says: "Today indeed not even our nobility ever enjoys wines that are genuine. So low has our commercial honesty sunk that only the names of the vintages are sold, the wines being adulterated as soon as they are poured into the vats" (Pliny 23.20). Also, equally noteworthy is the following (Pliny 14.8): "And about the rest of the wines grown in the Province of Narbonne (Gaul south of Lyon), no positive statement can be made inasmuch as the dealers have set up a regular factory for the purpose and color them by means of smoke, and I regret to say also employing noxious herbs and drugs. . . ." It is not outside the realm of possibility that the noxious drugs included lead salts (Baker, 1767, p. 261).

It serves no purpose to describe here the wide assortment of additives used by the ancient peoples to give their wine a most peculiar flavor and fragrance or to enhance its bouquet (see Hofmann, 1883, for example). The practice relevant to this discussion is the general concoction of essences from defrutum and herbs, pitch, *odoramenta,* and berries. Columella (12.20) provides a detailed description of the ancient art of "condire"—the doctoring of wines with herbs and sweetening ingredients—in his case, boiled-down must:

> The odours boiled with the must which are generally speaking suitable for wine are iris, fenugreek and sweet rush; a pound of each of them ought to be put in the boiling-cauldron, which has received ninety amphorae of must, when it has just gone off the boil and has been cleared of scum, Then if the must is naturally thin, when it has been boiled down to a third of its original quantity, the fire must be removed from below it and the furnace immediately cooled with water: even if we have done this, the boiled-down must nevertheless sinks to a level lower than the third of the vessel. But, although this is some disadvantage, it is nevertheless beneficial; for the more the must is boiled-down,—provided it be not burnt—the better and the thicker it becomes. Of this boiled-down must, when it has been thus treated, it is enough if one sextarius is mixed with one amphora of wine. When you have boiled ninety amphorae of must in the boiling cauldron to such an extent that only a little of the whole remains (which means that it has been boiled-down to a third), then and not before, add the preservatives which are either liquid or resinous, namely ten sextarii of liquid Nemeturican pitch, after you have carefully washed it with boiled seawater, and also a pound and a half of turpentine resin. When you will add these things, you will stir the leaden vessel thoroughly, so that they may not be burnt. Then when the boiling liquid has sunk to a third of its original quantity, withdraw the fire and stir the leaden vessel from time to time, so that the boiled-down must and the preservatives may mingle together. Then when the boiled-down must seems to be moderately hot, you will gradually sprinkle into it the rest of the spices after they have been bruised and sifted, and you will give orders that what you have boiled down is to be stirred with a wooden ladle until it begins to cool. If you do not mix them as we have directed, the spices will sink to the bottom and be burnt. To the aforesaid quantity of must the following spices ought to be added: the leaf of spikenard, the illyrian sword-lily, the Gallic spikenard, the costus, the date, the angular rush and the sweet-rush, of every one of which

> half-a-pound will suffice; also a quincunx of myrrh, a pound of sweet reed, half-a-pound of cinnamon, a quadrans of balsam, a quincunx of saffron, and a pound of vine-leafed cripa. These, as I have said, ought to be added after having been pounded when dry and sifted, and rasis, a kind of crude pitch should be mixed with them, which is considered to be better the older it is; for in the course of time it grows harder and, when it is pounded, it is reduced to powder and mixes with these preservatives. But it is enough for six pounds of it to be mixed with the quantities already mentioned. It's uncertain how much of this preparation ought to be added to forty-eight sextarii of must, because the calculation of the right amount must be based on the quality of the wine. I personally, if the vintage is wet, usually mix a triens of the preservative in two amphorae; if it is dry, a quadrans, so that the quantity of must is four urnae, an urna being twenty-four sextarii. I am aware that some husbandmen have put a quadrans of the preservative in each amphora, but that they were obliged to do so owing to the excessive weakness of the wine, which scarcely kept sound for thirty days.

Columella (12.20) ended his instructions with the injunction to the perpetrator to make sure "that the flavour of the adulterants is not noticeable, for that drives away the purchaser."

An indictment of these Greek and Roman *confusum* (mixed or blended) wines as highly toxic poisons comes from the experiment by Hofmann (1883). Following the instructions of Columella (12.11), to each of two urns (26.6 *L*) of must of grapes from (1) mountain vineyards, (2) field vines, and (3) slightly acidified must, he added roughly ⅙ congius (0.55 *L*), 3 heminae (0.82 *L*), and as much as 2 sextarii (1.1 *L*) of defrutum, respectively. He also added 13.6 g of table salt, an equal amount of gypsum, and roughly 11 cc of the powder of *foenum Graecum*. He found that in the process, each liter of the mountain wine acquired 15 mg of lead, while the lead concentrations in the valley wine and poorest must were about 22 and 30 mg/l, respectively.

Kobert's (1909) valiant attempt—to confirm that the Roman wines were highly contaminated with lead by actually measuring the lead contents of desiccated wine residues in the *ampullae* from the catacombs or the amphorae from Pompeii, Herculanum, and elsewhere—never materialized. Such a study may still yield interesting results.

Boiled-down must was also widely used in the effort to imitate certain popular brands of ancient wines. The recipe containing defrutum is given, for instance, in the *Geoponica* (8.22), for imitating the Aminaean wine that was valued for its delicate bouquet. Cato (art. 24) recommends that "if you wish to make a straw-colored wine, take equal parts of yellow and Apician wine and add a thirtieth of old boiled wine. Add a thirtieth of concentrated must to any kind of blended wine."

In terms of lead contamination, the least radical adulteration procedure was the improvement of wines by blending together two or more wine brands (Martial 1.18; Athenaeus 1.326; Pliny 14.9; Palladius 11.14; Proverbs 33.29–30; *Talmud-B*, Pesahim, 456; etc.). Another way of giving new wine the appearance of the old consisted in triturating fragments of earthen vessels in which quality old wines had been stored with the lees of old wine. Damogeron claimed that when a *modius* (about 4.4 liters) of this mixture was added to one amphora of fresh new wine and left standing for two weeks in sealed vessels, you would think that the wine was 10 years old (*Geoponica* 7.24).

There was also the habit of mulling wines, usually in leaden vessels, before they were served during the cold season (Galen 7.6; Athenaeus 1.31d). In his *Satires* (art. 5, line 145), Persius mocked a spendthrift: "You take your dinner on a bench while a dumpy pot exhales for you the fumes of some reddish Veientine wine that has been spoilt." Archaeological finds actually confirm such a practice. About 120 bars and restaurant bars have been identified in Pompeii, and nearly every block of houses excavated has its own bar, in much the same way that cafes are located in modern continental cities (Younger, 1965). One of the distinctive types of bars found at Pompeii and also at Herculaneum was the *thermopolium*, which featured mulled hot drinks. Excavations of such a tavern in Pompeii have yielded a lead kettle enclosed in a stove, provided with an outlet pipe leading into the alley premises, and presumably used to heat mulled wine and some other drinks (*Gmelins*, 1973). Gilfillan (1965) believed that since the houses were almost unheated, there must have been many cold days when mulled wines were in demand. Very often though, the Greeks, in particular, and the Romans also mixed their wines with water (Seneca *Epist.* 73; Martial 6.86; Hippocrates *Aphorisms* 16.5; Athenaeus 2.36a–c; Aristophanes *The Frogs* 211). The mixing bowl or cauldron, which was at times warmed over a charcoal brazier (Athenaeus 2.37–39), typically was made of leaded bronze, leaded brass, or pewter.

In addition to table wines, there were also afterwines (*vinum faecatum*), which Pliny (14.11) does not even include among the wines; the "artificial" (herbal, aromatic, and medicinal) wines; and the sweet *(dulcia* or *bellaria)* wines, including those that contained honey. Pliny (14.29) estimates that there were at least 185 kinds of beverages in his time, and even double that number if one included the varieties. A number of these beverages apparently were contaminated with lead simply because they contained the tainted boiled-down must, or else their preparation called for boiling down, presumably in a leaden kettle. The following are representative of common Greek and Roman drinks that are believed to have been severely contaminated with lead:

1. *"Decocta," "karynon," "yayin mebushal," "adynamon."* These drinks contained grape juice or must boiled down to the required consistency (Dioscorides 5.13; Mishnah 2.6; Talmud-B, p. 525; Pliny 14.12, 14.19). "Thereupon Cynulcus asked for a drink of *decocta* saying that he

needed to wash away salty words with fountains of sweetness" (Athenaeus 3.121f.).

2. *"Oxmel," or sour-honey.* A mixture of honey, vinegar, sea salt, and rainwater boiled 10 times (Pliny 14.20; Dioscorides 5.22). If lead vessels were used, the lead concentration would have increased with each heating, and the final product would have been a deadly poison.

3. *"Aqua mulsa," "melicrat," or "hydromel."* A blend of honey with rainwater boiled down to a third of its original volume (Pliny 14.20; *Geoponica* 8.28; Columella 12.12). It acted as an antidiarrheal agent (Pliny 14.20).

4. *"Thalassomeli."* A mixture of equal parts of brine, fresh honey, and rainwater and evaporated in a lead kettle until it acquired the consistency of defrutum and used in the same way as *mella,* or *aqua mulsa,* and defrutum (Columella 12.11; Pliny 31.36).

5. *Fruit syrup.* Columella (12.42) furnished the following instructions:

> The preparation of a remedy against colic called "fruit-syrup" is made as follows. An urna of must made from Aminean grapes grown on trees is boiled in a new earthenware or lead cooking-pot with twenty large quinces which have been well cleaned and are sound, sweet pomegranates, which are called Carthaginian apples, and service apples which are not very soft and have been split and had their seeds removed, a quantity weighing about three sextarii. These are boiled so that all the fruit dissolves in the must, and there should be a boy to stir the fruit with a wooden slice or a reed, so that it cannot burn. Then when they have been boiled down so that not much juice remains, they are allowed to cool and are strained, and what is left at the bottom of the strainer is carefully crushed and pulverized and then boiled again a second time in its own juice upon a slow charcoal fire, so that it may not burn, until a thick sediment, resembling lees, is formed. But before the preparation is removed from the fire, three heminae of Syrian rosemary, crushed and sifted, are added on the top of all and mixed in with a spatula, so that it may unite with the other ingredients.

6. *"Myrtites," "mursinites," or myrtle wine.* Basically a mixture of the juice of myrtle berries and honey that was thickened by boiling (Cato, art. 125; Columella 12.38; Pliny 15.37, 14.19; Palladius 2.18, 3.27; Dioscorides 5.37). To this group may be assigned *kydonites* or *melites*—a mixture of quince juice, honey, and vinegar, which was boiled (in a lead vessel probably) until it acquired the consistency of honey (Palladius 11.20; *Geoponica* 8.27; Dioscorides 5.28).

7. *Herb wines and wines from shrubs.* The preparation of sapa-like concentrates to be used in the adulteration of wines has been described previously (from Columella 12.20). Such concentrates often were used also in the preparation of the herb or shrub wines. In addition, we find several other instructions, such as: "Among the plants grown in gardens, wine is made from the root of asparagus, and from cunila, wildmarjoram, parsley-

seed, southern-wood, wild mint, rue, catmint, wild thyme and horehound; they put two handfuls of herb into a jar of must, together with a pint of boiled-down grape-juice and half a pint of sea-water" (Pliny 14.19; Geoponica 8.2–15; Dioscorides 5.64). "The following is the way to make up wines flavoured with wormwood, hyssop, southern-wood, thyme fennel and pennyroyal. Take a pound of Pontic wormwood and four sextarii of must and boil down to a quarter of the original quantity and put what remains when it is cold into an urna of Aminean must. Do the same with the other things mentioned above. Three pounds of dry fleabane in a congius of must is removed, can be added to an urna of must" (Columella 12.35; Pliny 14.19). These beverages were initially used solely for therapeutic purposes but gradually became adopted as the drinks for women.

8. *"Circumsicium," or "circumcidaneum" (afterwines) for the field hands.* "Pour into a jar 10 quadrantals of must, 2 quadrantals of sharp vinegar, 2 quadrantals of boiled must, 50 quadrantals of fresh water. Stir with a stick thrice a day for five consecutive days. Then add 64 sextarii of old sea-water, cover the jar, and seal ten days later. This wine will last you until the summer solstice; whatever is left over after the solstice will be a very sharp and excellent vinegar" (Cato, art. 104; Columella 12.40).

9. *"Spiced-wine surprise."* It is made as follows (Apicius 1.1):

> 15 lb. of honey are put in a metal vessel into which you have previously put 2 pints of wine, so as to boil down the wine while cooking the honey. It is heated over a slow fire of dry wood, stirring all the while with a stick; when it begins to boil over it is checked by adding [cold] wine; it also sinks when removed from the fire. When cool it is heated once more. This must be done a second and third time, and only then is it removed from the fire, and skimmed on the following day. Then take 4 oz. pepper, 3 scruples of pounded mastic, a handful each of aromatic leaf and saffron, 5 roasted date-stones, the dates softened in wine, having previously been soaked in wine of the right kind and quality, so as to produce a soft mash. These preparations completed, pour over 18 pints of sweet wine. In the end add coals, if it is too bitter.

In spite of the widespread use of preservatives and the widespread adulteration and aromatization of wines, the Roman connoisseurs still appreciated a pure wine. Columella (12.19) firmly states: "We regard as the best wine any kind which can keep without any preservative, nor should anything at all be mixed with it by which its natural savour would be obscured; for that wine is most excellent which has given pleasure by its own natural quality." There is, however, no doubt that by the Empire period, the palate of the upper-class Romans had become habituated to the confused and adulterated wines. The confusion in taste could have been conditioned by the Roman fondness for pungency and richness in their cooking. Juvenal (*Satires,* 11) satirizes, in this regard: "But nowadays a rich man takes no pleasure in his dinner—his turbot and his venison have no taste, his un-

guents and his roses seem to smell rotten." Their widespread use of sapa and defrutum to disguise the imperfections of their wine and to satiate their "sweet tooth" must be regarded as a fatal mistake. Seutonius (*The Twelve Caesars* 3.34) perceptively attributed the decline of the Roman Empire to apathy and gluttony, and modern research suggests that this may have been true in a rather different sense.

It is most remarkable that the ancient literary sources are completely silent on the possible adverse health effects of lead in the boiled-down must and brine solutions. The evil effects of wines were often ascribed to other adulterants in the wine, but rarely to the lead. Pliny (23.24), for instance, declares: "As for wines treated with marble, gypsum or lime, who would not dread to touch them, however robust his health?" Martial (10.36) presumed that the smoke in the wine was the deadly toxin:

> Whatever Massilia's vile smoke-rooms, whatever jar acquires its age from the fire, comes from you Munna; to your wretched friends you consign over the sea, over long roads, deadly poison, and not at an easy price, but at one which would satisfy a crock of Falernian or Setine, dear to its own cellars. Why you do not come to Rome after such an interval, this is, I think, your reason: you shun drinking your own wines.

Dioscorides (5.9, 19) notes that "wine adulterated with brine [and loaded with lead presumably] is bad for the stomach, induces thirst, is bad for the nerves, induces diarrhoea, and is not beneficial to those recovering from illness." On the other hand, he noted (5.9) that "wine adulterated with gypsum is injurious to the nerves, induces headaches and fever and is bad for the bladder. . . . The addition of *sapa* and *defrutum* to wines may cause headaches, intoxication and stomach trouble." Continuous drinking of the doctored wines, Dioscorides (5.11) further notes, is pernicious, ruins the nerves, and causes melancholia. Clearly, such maladies are more likely to stem from the lead than from the presumed adulterant in the wine.

Athenaeus (1.33b) notes that the Zacynthian and Leucadian wines, on account of the admixture of gypsum, are injurious to the brain. When the fine Alban and Falerian wines were aged for a long time, they acted like drugs and soon caused stupor (Athenaeus 1.33a; Dioscorides, art. 11). "Those who drink toasts too constantly come to have an un-natural condition of the stomach" (Athenaeus 1.45d). The drinkers of the Troezenian wine are reputed to have been rendered childless (Theophrastus *History of Plants* 9.18; Pliny 14.22; Athenaeus 1.31f.), while the Egyptian "delivery wine" caused abortion (Pliny 14.22). Dioscorides (5.10) presented the following long list of wines that cause constipation and hurt the nerves:

> But that ye wines in Italy, which seems to excel, is called Falernum, which being old is soon digested, recalling the Pulse, binding ye belly, and good for ye stomach, but bad for ye bladder, and unfitting for ye dull-sighted and for to be much drunk of. But ye Albanian is of thicker parts than ye Falernian, sweetish, puffing of the stomach, mollifying the belly, and not working alike upon ye digestion, but less hurting of ye sinewy part, and this also when it is old grows hard. Ye Caecubum being sweet, is of thicker parts than ye Albanian, and a breeder of flesh, and of a good colour, but bad for digestion. But Surrentinum is very hard, wherefore it stays ye flux of ye entrailes, and of ye stomach, and it toucheth ye head less, being of light parts, but when old it is good for ye stomach, and becomes more pleasant. Ye Adrianum and ye Mamertianum growing in Sicily are both alike of thick parts indifferently binding, and they grow old quickly, and they touch ye sinewy part less because of mildness that is in them. And ye Praepianum, which is brought out of ye places about Adria, is of a sweet scent and milder, but being much drank of, it lies not hid, but keeps drunkenness for a long time, and brings a sleep. That which is called Istricum is like to ye Praepianum, being more ureticall. But ye Chium is more gentle than ye aforesaid, well-nourishing, potable, less making drunk, staying a flux, useful to be put in eye medicines. But ye Lesbian is easily digested, being lighter than ye Chian, and good for ye belly. But that which grows by Ephesus, and is called Phygelites doth obtain the same virtue to this, but that of Asia called Messogites from ye mountain Timotus breeds ye headache and hurts ye sinews. But ye Coon, and Clazomenian because they partake of much sea-water, are soon corrupted, are inflative, are disturbers of ye belly, and hurters of ye sinews.

The controversial epigram by Martial (6.78) should be noted here. It says: "Phryx, a notorious tippler, was blind, Aulus, of one eye, and blear-eyed in the other. Heras, his doctor, said to him: 'Beware of drinking; if you drink wine you will not see at all.' Phryx laughed, and said to his eye 'Adieu.' Immediately he orders eleven measures to be mixed for him, and frequently. Do you ask for the result? Phryx drank a vintage, his eye venom" Rutherfurd (1934), an opthalmologist, saw in the epigram a case of lead poisoning with optic neuritis, and he reasoned that the toxin was more likely to be lead than methyl alcohol. Oppenheimer (1928), however, diagnosed Phryx's problem as "alcohol eye disease," while Crawford (1913) concluded that it was a case of albuminuric retinitis (or uremic retinopathy). Stevenson (1949) also disagreed with Rutherfurd's diagnosis, but he offered no opinion as to the cause of Phryx's disease. Dr. F. J. Coodin (personal communication, 1982) notes that the scanty clinical picture given by Martial *could* fit with chronic alcoholism (and secondary vitamin-B1 deficiency), with the ingestion of wood alcohol, or with plumbism, but it may as easily, or even more readily, characterize many other eye diseases.

Both Celsus (2.30) and Dioscorides observed that defrutum and boiled *mulsum* are constipating. Pliny (23.30) pointed out the ecbolic property of sapa: "Taken with onions, it has an abortive effect, and can be used to bring out dead foetus and the afterbirth." Kolbert (1909) maintains that the onion was not guilty of such an effect, and that the lead in the sapa was the abortifacient. The use of preparations entailing boiled wine, must, or honey as contraceptives and abortifacients has been recommended by

Pliny (28.30, 24.37; 25.37), Soranus (19.62–63), Oribasios (1.116), and Aëtios of Amida (16.16–17). If lead kettles were used as was generally the case, enough lead could presumably be leached out to constitute the active ingredient.

All the maladies just described, which were acquired from drinking ancient wines or wine preparations, might just as well have been symptoms of lead poisoning. Although a number of the cited authors alluded to the appropriate syndromes, they failed to link such symptoms to the lead in the wine. Gypsum, lime, marble, salt, and the other additives seem to have served as the red herring that diverted their attention from the true toxin in their beverages. Indeed, Pliny's (14.25) animadversion on the many poisons in wines may be true, but for a reason that he did not suspect.

Saturnine Drugs and Elixirs

Lead and its compounds were among the first drugs of mineral origin to be used by mankind. In fact, they have been used medicinally from the earliest times (probably from the Stone Age) and by the rudest tribes. As noted already, galena—the most common ore of lead—was used as an eye salve in pre-Dynastic Egypt. The most ancient evidence of such application dates from the Badarian period about 6000 years ago. There is evidence that galena was used as an eye makeup and salve in the ancient Indian civilization of Mohenjo-Daro and Harappa, whose golden ages lasted from 3200–2800 B.C. Such an application for galena is also recorded in the Old Testament and in the inscriptions from the ancient Mesopotamian cultures. It is not clear whether the galena found in ancient graves of the North American Indians had any prophylactic significance (Farquhar and Fletcher, 1980). The traditional medicine of most West African cultures includes galena as an eye salve—a practice that probably dates back to antiquity.

The use of other lead compounds—particularly the oxides in *materia medica* also preceded recorded history. The prescriptions of the ancient Babylonian medical tablets employed lead compounds in plasters, although there are still philological problems in identifying the lead salts used. The pharmacopoeia of ancient Egypt preserved in the Papyrus Ebers (Bryan, 1930) and the Hearst Medical Papyrus (Leake, 1952) featured lead compounds, particularly in astringents, external cooling agents, and collyria. Hindu prescriptions containing lead *(sīsa)* and red lead *(Sindūra)* can also be found in the old Sanskrit medical compendia, such as the *Charaka Samahita, Susrata,* and *Vagbahata* (Sharma, 1972; Jaggi, 1973; Mitra, 1974; Zimmer, 1948). The ancient Chinese literary references to the lead elixir will be considered later.

At this point, the important difference in the therapeutic applications of lead in the "old west" and the "old east" should be noted. With few exceptions, lead salts were prescribed primarily for external remedies and for diseases of women in the West. By contrast, ancient Chinese texts contain

numerous recipes for saturnine elixirs that were consumed to attain immortality or longevity. The first part of this section will focus on saturnine drugs of the "old west," while the second part will address the staurnine elixirs.

Metallic lead was widely assigned chthonic properties, and as such it played an important role in ancient magicosacerdotal healing. Lead plates inscribed with invocations, abjurations, and prayers to reinforce the curative effects of remedies or simply to drive off the demonic paroxym have been found dating to prehistoric times. Lead amulets, talismans, pendants, and medallions were worn to protect health. Some interesting sidelights on lead in the medicine of folklore were given in Chapter 1.

Pliny (34.50) succinctly summarized the medicinal uses of metallic lead in ancient times: "In medicine lead is used by itself to remove scars, and leaden plates are applied to the region of the loins and kidneys for their comparative chilly nature to check the attacks of venereal passions, and the libidinous dreams that cause spontaneous emissions to the extent of constituting a kind of disease. It is recorded that the pleader Calvus used these plates to control himself and to preserve his bodily strength for laborious study. Nero, whom heaven was pleased to make emperor, used to have a plate of lead on his chest when singing songs *fortissimo,* thus showing a method for preserving the voice." Because of its cooling property, Soranus *(Gynaecology* 2.41) recommends applying a piece of lead to the navel of a newborn child after the umbilical cord has been shed—it is supposed to help the wound cicatrize and the umbilicus mold properly into a cavity. The Galenists usually compounded their lead drugs, according to their qualitative composition or homoeopathy: hot, cold, wet, and dry, in varying degrees (Multhauf, 1966, p. 216). Dioscordies (5.95) recommends using the lead "unmixed" from washed lead as a rub to help the stroke of the sea scorpion or the dragon! Several ancient authors, such as Diocles, Serapion, Erasistratus (all cited by Aurelius *Acute Diseases* 3.160, 169), and Alexander of Trailles (9.1) prescribed lead pills for intestinal obstruction. Because of its weight, the lead pill is supposed to dislodge and drive out the obstructing matter.

Galen (vol. 12, p. 231) also recommends a lead plate for noctural emissions. On this matter, Aurelius (*Chronic Diseases* 5.84) flatly states: "Provide the patient with a hard, cold bed, and have him lie on his side when he goes to sleep. . . . Place a long, thin lead plate under his loins or put sponges soaked in cold vinegar water around them." Lewin (1920) has even suggested that lead plates were used by the ancient peoples in an effort to produce sterility or at least to prevent conception.

For the treatment of ganglion, Oribasius (*De virt. simpl.* 2, cited by Adams, 1844) and Paulus Aegineta (4.26) apply "a thick plate of lead like the vertibrae, and larger than the ganglion, and bind it on, for by its weight this dissolves it in due time." Aëtios (15.9) recommends nearly the same plan of treatment: "Bind a piece of lead upon the tumor, and after some

days remove it when ganglion will be found much softened; it is then to be squeezed firmly between the thumb and the fingers by which means it will be speedily dissolved." To prevent suppuration, a special set of drugs called enhemes were used, especially on flesh wounds (Majno, 1975). One example—in the form of dry powder—contained metallic lead powered together with spodium from Cyprus, silver dross, copper scales, chalcitis, and alum (Hippocrates *On Wounds 2*). Several ancient prescriptions called for "washed lead," which has been presumed to be a basic lead hydroxide (see Pliny 34.50; Dioscorides 5.95).

Lead sulfide (galena, *plumbum combustum*, or *plumbum elotum*) found application in a large number of drug preparations in Greco-Roman times. The pseudo-Hippocratic texts, attributed to the school of Knidos, used it in emollients for ulcers (Partington, 1970, p. 33). Pliny (33.34) and Dioscorides (5.100) furnish a good detail of its medicinal applications: "It is used to make an eye-wash and for women's skins to remove ugly scars and spots and as a hair wash. Its effect is to dry, to soften, to cool, to act as a gentle purge, to fill up cavities caused by ulcers, and to soften tumours; it is used as an ingredient in plasters serving these purposes, and for the emollient plasters mentioned above. Mixed with rue and myrtle and vinegar, it also removes erysipelas, and likewise chilblains if mixed with myrtle and wax."

Pliny (33.34) then presents an account—at times confused—on how to purify the galena and prepare the *koḥl* (which typically contained black carbon and lead, or antimony):

> It is prepared by being smeared round with lumps of ox dung and burnt in ovens, and then cooled down with women's milk and mixed with rainwater and pounded in mortars. And next the turbid part is poured off into a copper vessel after being purified with soda. The less are recognized by being full of lead, and they settle to the bottom of the mortars and are thrown away. Then the vessel into which the turbid part was poured off is covered with a cloth and left for a night, and the next day anything floating on the surface is poured off or removed with a sponge. The sediment on the bottom is considered the choicest part and is covered with a linen cloth and put to dry in the sun but not allowed to become very dry, and is ground up a second time in the mortar and divided into small tablets. But it is above all essential to limit the amount of heat applied to it, so that it may not be turned into lead. Some people do not employ dung in boiling it, but fat. Others pound it in water and strain it through three thicknesses of linen cloth and throw away the dregs, and pour off the liquor that comes through, collecting all the deposit at the bottom, and this they use as an ingredient in plasters and eye-washes.

There is no record to show that the Greco-Roman physicians used lead sulfide for purposes other than those mentioned in the preceding passage (e.g., see Celsus 5.26, 36; Galen, vol. 12, p. 233). It was also used to suppress bleeding (Celsus 5.1).

Celsus (6.12) used the basic lead hydroxides (washed lead or washed calcined lead) mainly for eye salves. These compounds, however, find many more applications in the rustic or popular remedies of Pliny (34.50): "It (washed lead) has the property of acting as an astringent and arresting hemorrhage and promoting cicatrization. It is of the same utility also in medicine for the eyes, especially preventing their procidence, and for the cavities or excrescences left by ulcers and for fissures of the anus. For these purposes lead lotion is extremely efficient, while for creeping or foul ulcers ash of calcined lead is useful; and the benefit they produce is on the same lines as in the case of sheets of papyrus." Dioscorides (5.95) repeats—almost word for word—what Pliny has said.

The use of metallic rust on wounds is featured in the ancient myth of Achilles who treated the wound of Telephos with scrapings from the tip of his lance—an interesting treatment that left Pliny (34.14) wondering as to "whether he did it with a bronze or an iron spearhead" (Majno, 1975). Because of their excellent analgesic and styptic properties, the use of lead oxides on wounds began well before the Trojan War (ca. 1250 B.C.), probably as early as the Stone Age. The discovery of cupellation around 4000 B.C. provided ample supplies of the lead oxides, which could have further encouraged their general use in medicaments. The Papyrus Ebers—a compendium of ancient Egyptian drugs in use before 1550 B.C.—contains about 30 medicaments calling for red lead or "lead earth" (Bryan, 1930). The Hearst Medical Papyrus, a poorly organized medical practioners' recipe book compiled ca. 1550 B.C. (Leake, 1952), also has several confections containing lead oxides.

About 20% of all the red-lead prescriptions in the Papyrus Ebers are for the treatment of eye diseases; ailments so treated include xanthelasma, pterygium, blindness, and squint (Bryan, 1930). All forms of infectious conjunctivitis were widespread in Egypt, and the common use of leaden collyria is not surprising. Indeed, such collyria, bearing the most ancient seals, were found in Alexandria (Castiglioni, 1943). It is also interesting that most of the prescriptions containing red lead are for external applications—mostly as pastils, emollients, and plasters for burns, wounds, ulcers, and alopecia; also as poultices to drive away tremblings in the fingers, to make the "met" supple, and to draw out splinters from the flesh; and as ear plugs to cure loss of hearing or injected into the ear that discharge foul-smelling matter (Bryan, 1930). Rarely did remedies for internal disorders contain lead. The only instance, in fact, is the use of lead salts to alleviate constipation. It may be noted that the Berlin medical papyrus, compiled about 200 years later, still contains several of the prescriptions that are the same as, or similar to, those in the Ebers and Hearst papyruses (Leake, 1952). The use of medicaments containing fresh lead earth for tongue diseases and to strengthen the teeth (Bryan, 1930, p. 111) would seem to be ill-advised.

The Assyrian-Babylonian pharmacopoeia was extraordinarily extensive (Küchler, 1904; Levey, 1966; Majno, 1975). One survey showed the therapeutic use of 250 medicinal plants, 120 mineral substances, and 180 other drugs not containing those used as solvents and vehicles for the actual medicinal substances (Leix, 1940). Among them are several lead compounds that are still to be properly identified. The medicinal use of lead by these ancient cultures is suggested by the records that speak of an important traffic in drugs between Babylon and Egypt as early as 2250 B.C. (Castiglioni, 1945). The strong influence of Egyptian medicine on the pre-Hippocratic medicine in Bronze Age Greece has also been noted by several authorities (e.g., Ghalioungui, 1965; Partington, 1970; Warren, 1970). The possibility that some of the lead used for medicaments in Dynastic Egypt came from Greece (i.e., the Laurion mines) has been raised (Gale and Stos-Gale, 1981). The point to be emphasized here is that because of extensive trade and cultural links, the therapeutical applications of lead compounds by many ancient cultures of the Mediterranean region are likely to have been similar to those of ancient Egypt, as they are recorded in the Papyrus Ebers and the Hearst Medical Papyrus.

The pseudo-Hippocratic collection has about 30 medicaments with lead oxides—all for the treatment of *de ulceribus, de fistulis, de mulierum morbis,* and *de natura muliebri* (Partington, 1970, p. 32). Galen, Celsus, and their disciples used great numbers of saturnine drugs. Celsus used litharge as an exedent (5.7) and minium from Sinope as an erodent (5.6). He used litharge as an antiseptic (5.5), to check bleeding (5.19) and to clean wounds (5.19), and he also applied it to putrid flesh (5.19), to pustules (5.28), and to nasal ulcerations (6.7). For wounds, Celsus (5.19) has a list of 34 plasters and ointments, 18 of which contain heavy doses of lead oxides. Paulus Aegineta (7.17) provides a very comprehensive list of 90 ancient plasters (compiled mainly from Dioscorides, Galen, and Oribasius). Thirty eight of these contain lead salts (see Table 6.2). The following directions on how to prepare lead-oxide plasters are from the works of Antyllus (cited by Paulus Aegineta 7.17):

> In the boiling of the medicines, the litharge will be boiled with the oil; but the litharge having been previously triturated, is to be triturated again with the oil, so as to become viscid, and then it is to be boiled at a gentle fire, stirring incessantly. At first, then, it swells and bubbles; but when nearly boiled sufficiently, it becomes of a more feculent colour. It has attained its measure of boiling when the swelling subsides, and it no longer stains. The molybdaena is to be boiled in a manner similar to litharge; but the measure of the boiling of it is not only when it ceases to stain, but when it changes from a fiery colour to a yellow and strongly floridone.

Pliny (34.53) succinctly summarized the medicinal applications of lead oxides in antiquity: "If [molybdena, a lead oxide] is used in preparing a particular emollient plaster for soothing and cooling ulcers and in plasters which are not applied with bandages but which they use as a liniment to

Table 6.2 Examples of the Saturnine Medicaments of the Ancient World

Name of Medicament	Lead Compound Employed	Other Components	Principal Cure
Collyrian cygnarium	Ceruse	Burnt and washed calamine, pompholyx, starch gum, roasted opium, and tragacanth	
White collyrium cygnus	Ceruse	Calamine, opium, starch, gum, and frankincense	
Pale-colored collyrium cygnus	Ceruse	Burnt and washed calamine, terra aster, pompholyx, starch, opium, acacia, tragacanth, and gum	Ulcers
Collyrium pelarion	Ceruse	Calamine, acacia, opium, gum, starch, tragacanth, myrrh, copper, and saffron	
Brown collyrium	Ceruse	Concoction of 20 ingredients, including calamine, verdigris, antimory, alum, copper, saffron, etc.	Hypopium and great affections
Collyrium severianum	Ceruse	Calamine, tragacanth, and juice of fenugreek	
Collyrium from decoctions	Ceruse	Calamine, starch, opium, tragacanth, acacia, gum, dried roses, poppy, melilots, and liquorice	
Repellen collyrium	Ceruse	Burnt and washed calamine, sand, myrrh, gum, pompholyx, terra aster, frankincense, juice of linseed, fleawort, ptisan, and fenugreek and tragacanth	

Table 6.2 *(continued)*

Collyrium of Nilamon	Ceruse	Calamine, pompholyx, gum, tragacanth, and opium	
Collyrium spadiacon	Ceruse	Antimony, frankincense, calamine, Samian earth, gum, juice of poppy, and juice of olive leaves	Inflamations, defluxions, and chemoses
Tender collyrium from olive leaves	Burnt and washed lead; ceruse	Frankincense, antimony, calamine, Samian earth, opium, gum, and juice of green olive leaves	
Hygidium of Ammonius (collyrium)	Ceruse; burnt lead	Calamine, copper, castor, aloes, saffron, squama, flower of roses, buckthorn, stone of schistos, opium, acacia, and gum	
Collyrium Olumpus or Olympiacum	Burnt and washed ceruse	Many ingredients, including calamine, verdigris, saffron, burnt and washed copper, and antimony, etc.	
Small Theodotian collyrium	Ceruse	Antimony, acacia, burnt copper, myrrh, verdigris, aloes, meconium, and buckthorn	
Collyrium xyster	Ceruse	Many ingredients, including pumice-stone, burnt missy, burnt shells, calamine, saffron, antimony, burnt copper, and other organic materials.	
Galen's collyrium from horn	Burnt lead; ceruse	Burnt hartshorn, squama aeris, starch, frankincese, cuttle-fish, burnt shell, verdigris, myrrh, and gum.	

Collyrium from frankincense	Ceruse	Frankincense, calamine, pompholyx, starch gum, terra aster, squama aeris, tragacanth, and opium.	
Libanian collyrium	Ceruse; burnt and washed lead	Washed calamine, starch, spodium, pompholyx, terra aster, tragacanth, opium, gum, and whites of eggs.	
Collyrium called the aster of Magnus	Ceruse; lead	Pompholyx, calamine, starch, frankincense, terra aster, myrrh, tragacanth, and gum	
Collyrium from the juice of fenugreek	Ceruse	Calamine, tragacanth, starch, opium in juice of fenugreek	
Collyrium of Cleon	Lead	Saffron, pompholyx, squamata stomomatis, and gum, in rainwater.	
White collyrium from roses	Washed ceruse	Burnt and washed calamine, starch, opium tragacanth, aloes, gum, saffron, and roses without their nails.	
Collyrium from aloes	Ceruse	Calamine, aloes, green roses, starch, opium, tragacanth, and gum	
Collyrium Proteus	Ceruse	Many ingredients including arsenic, calamine, chalcitis, saffron, alum, and organic material	Also attenuates cicatrices
Collyrium from opobalsam	Ceruse	Calamine, unripe olive, white pepper, opium, gum, and opobalsam	

Table 6.2 *(continued)*

Collyrium malabathrinum, also called isotheon	Ceruse	Calamine, burnt and washed copper, opium saffron, acacia, antimony, castor, myrrh, aloe, Indian nard, Indian leaf, and Indian buckthorn	
Xerocollyrium, or prophylactic of Galen	Ceruse	Burnt and washed Asian stone, burnt copper, white pepper, Indian leaf, antimony, and juice of balsam.	
Plaster from juice of linseed	Litharge; Ceruse	Old oil, wax, Colophonian rosin, axunge, pollen frankincense, and juice of linseed	
Plaster from honey	Litharge	Wax, oil, turpentine, honey, and axunge	
Another	Litharge	Oil, Colophonian rosin, wax, and honey	
Plaster from soapwort	Litharge	Soapwort, birthwort, galbanum, squama aeris, aloe, manna, ammoniac perfume, pine-rose, and vinegar of squills	Discussing strumous swellings
Plaster smilium	Litharge	Red natron, old oil, sal ammoniac, lye of figs, rosin, galbanum, ammoniacal perfume, copperas, wax, verdigris, opoponax, and vinegar	For abscesses
Wheat plaster	Litharge; ceruse	Many ingredients, all of organic derivation	Hardness and scirrhous swelling
Plaster Pelarion	Dross of silver	Wax, fat of bulls, Colophomian rosin pitch, oil, and juice of fenugreek	Excoriations and the like
Plaster melanchlorus	Litharge; ceruse	Many ingredients including burnt copper, missy, copperas, chalcitis, verdigris, calamine, and oils and fats	Wounded nerves, punctures, and bleeding wounds
Discutient plaster of Mnasaeus	Litharge	Wax, axunge, and Colophonian rosin	
Ariobarzanian plaster	Litharge; ceruse	Cold oil, seawater, burnt baccina, yellow wax, turpentine, and frankincense	
Emplastrum myrsinatum (myrtle plaster)	Litharge; ceruse; burnt and washed lead	Sandyx, wax, and myrtle oil	
Plaster from ceruse, or egg	Ceruse; litharge	White wax, rose oil, starch, and whites of eggs	
Plaster Parygron, of Oribasius	Litharge; ceruse	Wax, swine's seam, Colophonian rosin, oil, linseed juice	Fissures of heels, but not for ulcers
Emplastrum palmulatum (palm plaster)	Litharge	Old axunge, old oil, and crude chalcitis	
Anodyne plaster phycotyche	Burnt and washed lead	Many ingredients, including calamine, bloodstone, stag's marrow, oils, fats and other organic matter	For the fundament
Plaster from molybdena	Litharge; ceruse	Molybdena, wax, and myrtle oil	Hot affections
Plaster from oil and vinegar	Litharge	Oil and vinegar	
Agglutinative plaster from dittany	Litharge	Old oil, squama aeris, diphryges, verdigris, gentian, birthwort, dittany, burnt copper, manna, Colophonian rosin, aloes, galbanum, ammoniacal perfume, bee glue, and wax	Bites of dogs and all sorts of ulcers

Table 6.2 *(continued)*

Barbaric plaster	Ceruse; litharge	Judaean asphalt, dried pitch, wax, rosin, turpentine, manna, opoponax, myrrh, oil, and vinegar	Bloody sores; promoting the formation of callus in fractures
Agglutinative plaster from willows	Ceruse	Many ingredients including misy, chalcitis, verdigris, fissle alum, asphalt, oils, fats, etc.	Haemoptysis; empyema when applied to chest
Plaster of Nicolaus	Litharge	Over 20 ingredients including verdigris, alum, copperas, sulfur, ammoniacal salts, misy, calamine, opium, etc.	Bloody wounds and agglutinant of sinuses
Icesian plaster	Litharge	12 ingredients including verdigris	Strumae, abscesses, the spleen, joints, and ischiatic disease
Plaster of Nero	Litharge	Old oil, ammoniacal perfume, galbanum, manna, myrrh, and frankincense	Blows and all pains of fleshy parts
Emplastrum melinum of serapion	Litharge	Wax, ammoniacal perfume, galbanum, verdigris, Colophonian rosin, myrrh, and oil	
Emplastrum aceratum of Galen (agglutinative plaster without wax)	Litharge	Oil of ricinus, old oil, acrid vinegar, squama aeris, chalcitis, and verdigris	Digestive and promotes suppuration of ulcers
Plaster from the juice of mulberry-tree	Litharge	Eleven ingredients including verdigris and mulberry juice	
Indian agglutinative plaster	Ceruse	Wax, roasted rosin, dried pitch, bitumen, chalcitis, misy, melanteria, alum, gall emphacitis, and rind of pomegranate	Spreading ulcers and haemoptysis
Desiccative and discutient plaster	"Sandarach"	Copperas, arsenic, hellebore, cantharides' breast, wax, roasted rosin, and oil	Altering and evacuating humors
Antiinflammatory plaster from ochre	Litharge	Attic ochre, chalk, wax, oil, rosin, and turpentine	Cases of inflammation that occur spontaneously and those from judicial torture
Plaster from salts	Ceruse	Wax, oil, common salt, vinegar, and aphronitrum	
Plaster from dragon's blood (cinnabaris) called pampathes	Litharge	25 ingredients including burnt copper, living magnet, sanguis draconis, Phrygian stone, pyrite, calamine, verdigris, oils, and wax	Tophi and all other scirrhous swellings
Plaster from the urine of mule	Litharge	Urine of male mule and old oil	Gout
Incarnative plaster	Ceruse	Rose-oil, turpentine, honey, and butter	Ulcers
Plaster for fractures, of Oribasius	Litharge	Pitch, frankincense, turpentine, bull's suet, galbanum, opoponax, wax and old oil	Fractures
Plaster of Heraclitus	Litharge	Dried pitch, manna, calf's suet, Tuscan wax, opoponax, verdigris, Cyprian copper, turpentine, oils, and vinegar	Fractures, with or without wounds

Source: Mainly from Celsus and Paulus Aegineta.

promote cicatrization on the bodies of delicate persons and on the more tender parts. It is a composition of three pounds of sulphide of lead and one of wax with half a pint of oil, which is added with solid lees of olives in the case of an elderly patient. Also combined with scum of silver and dross of lead, it is applied warm for fomenting dysentery and constipation." The similarity between the preceding prophylactic usage of these compounds and the much earlier records in the Papyrus Ebers and the Hearst medical papyrus is obvious.

It should be further noted that Galen (vol. 12, p. 225) prescribed litharge for intertrigo, but he considered the application of litharge on wounds to be a useless treatment (Galen, vol. 10, p. 196). Virgil (*Georgics* 3, line 449) notes that litharge was used for treating scabies in sheep. Celsus recommended minium (lead oxide or cinnabar adulterated with lead oxides) as an antiseptic (5.5–6, 19, 6.6) and for the treatment of nasal polypus and foul genital ulcerations (6.17). Lead oxides were at times ingredients in eye salves (Celsus 6.6; Paulus Aegineta 7.16). Archagathos (ca. 220 B.C.), who was credited with introducing Greek medicine to Rome (see Celsus 5.19; Pliny 29.6), invented a plaster containing misy, burnt copper, white lead, litharge, and turpentine resin. Herakleides of Tarentum (ca. 75 B.C.) listed many prescriptions containing litharge, alum, vitriol, vendigris, white lead, copper scales, galls, earth wax, cocus, turpentine, and opium. Menekrates of Zeophleta (ca. the first century A.D.) is reputed to have invented the diachylon plaster (very popular in ancient times) that contained litharge, oil, marrow, and herb juices (Partington, 1970, pp. 184, 188–189).

The medicinal properties of white lead (ceruse, *psimithium,* or sugar of lead) basically "are the same as those of other lead compounds mentioned above, only it is the mildest of them all, and beside that, it is useful for giving women a fair complexion" (Pliny 34.54). It is a very common ingredient in ancient ophthalmic medicines or collyria (see Table 6.2). About one half of the 55 ancient ophthalmic collyria listed by Paulus Aegineta (7.16) contain white lead (Table 6.2). The most popular of all the Roman collyria, however, seems to have been the collyrium of Cythion or Tethrion, which contained opium, lead oxide, acacia juice, gum, starch, and tragacanth (Castiglioni, 1945). These ingredients were rubbed together, mixed with a small quantity of rainwater, and then applied to the appropriate areas in complaints of the eyes, tonsils, and suppurated ears. Soranus (2.14) suggests the anointment of any part of an infant bruised in delivery with white lead, while Celsus (6.17) recommends the application of a white-lead ointment to the umbilicus of prominent navels, in order that surgical measures need not be used.

Sory or inkstone—a mixture of lead, iron, and copper sulfates—was used in a prescription for loosening a carious tooth (Celsus 6.9). Many other by-products of lead pyrometallurgy were also used in ancient medicaments, mostly as constitutents of plasters, cataplasms, emollients, and pastils. Examples noted by ancient authorities include slag of silver, dross

of lead, golden ash, flower of silver, lead stone, and *spuma plumbi, cadmea spodos,* and so forth. The efficacy of these secondary materials may be exemplified by those of *scoria argenti* (Pliny 33.35), which is said to be a by-product of the lead-smelting process. "It has an astringent and cooling effect on the body, and like sulphuret of lead, of which we shall speak in dealing with lead, it has healing properties as an ingredient in plasters, being extremely effective in causing wounds to close-up, and when injected by means of syringes, together with myrtle-oil, as a remedy for straining of the bowels and dysentery. It is also used as an ingredient in the remedies called emollient plasters used for proud flesh of gathering sores, or sores caused by chafing or running ulcers on the head." One can certainly appreciate Pliny's (34.51) remark on the "marvellous efficacy of human experiment, which has not left even the dregs of substances and the foulest refuse untested in such numerous ways."

We can surmise that many ancient medicaments were contaminated with lead. Most ores of copper and zinc contain lead, and the various drugs using the drosses of the two metals would therefore have also contained lead. This would hold true too for medications employing calcined brass and bronze. Dioscorides (5.84) notes that one of the frequently used zinc preparations (calamine) was often contaminated with lead from the scoriae. The efficacy of some of the metallic drugs may be due—at least in part—to their lead contents. A small number of such metallic drugs were used internally (Celsus 2.12).

Galen (*On Antidotes* 1.2; see Brock, 1929, p. 199) was particularly wary of the widespread adulteration of commercially available drugs:

> I also sailed to Lemnos, and for no reason (as the gods know) than to get the Lemnian earth or "seal," whichever it is called. This then—whether we call it Lemnian earth or Lemnian seal—they counterfeit, so that nobody is able to distinguish the true from the false. Like the so-called Indian lycium and many other substances, in which the distinction of genuine from counterfeit is difficult to make, these should be collected by people who travel to the countries in question. . . ."

The adulteration of the Lemnian *miltos* or *rubrica* (red earth) with the cheaper red lead is not inconceivable.

The use of leaden pestles and mortars would have been another common source of contamination. The use of lead mortars and pestles seems to have been particularly favored by ancient physicians for the preparation of cold, astringent liquors (e.g., Aurelianus *Chronic Diseases* 4.44; Milne, 1907). The large number of these implements found at Olynthus suggests that their use was quite common (Robinson, 1941). A number of leaden jars have been found for storing medicaments (Milne, 1907), and they seem to be favored in storing solid substances (Castiglioni, 1945). Dioscorides gave precise instructions concerning containers for various medicaments to ensure that the remedies retained their efficacy. He recommended that the

remedies for eye diseases and those containing vinegar, tar, and other resins be stored in lead or pewter boxes. Galen (vol. 14, p. 48), however, has some reservations about the use of such leaden containers.

Ancient physicians frequently prescribed boiled-down must and wines for a wide variety of ailments. According to Hippocrates (*On Regimen in Acute Diseases,* Ch. 4):

> One must determine by such marks as these, when sweet, strong and dark wine, hydromel, water and oxmel, should be given in acute diseases. Wherefore the sweet affects the head less than the strong, attacks the brain less, evacuates the bowels more than the other, but induces swelling of the spleen and liver; it does not agree with bilious people, for it causes them to thirst; it creates flatulence in the upper part of the intestinal canal, but does not disagree with the lower part, as far as regards flatulence; and yet flatulence engendered by sweet wine is not of a transient nature, but rests for a long time in the hypochondria. And therefore it in general is less deuretic than wine which is strong and thin; but sweet is more expectorant than the other. But when it creates thirst, it is less expectorant in such cases than the other wine, but if it does not create thirst, it promotes expectoration better than the other.

This opening section was followed by a detailed account of the "excellent examples of the beneficial and injurious effects of wine, all of which were left undetermined by my predecessors." Celsus (2.30), as well as Galen (vol. 13, p. 45, vol. 15, p. 632), prescribed boiled-down must, while every ancient medical text extant has a therapeutic use for wine. The basic distinction between the consumption of such beverages (that are prone to lead contamination) as food or medicine is certainly not very distint. Furthermore, sapa, defrutum, and wines were extensively used as sweetners, solvents, or vehicles for the medicinal ingredients. Wines and boiled-down must thus should be considered as a common source of lead in medicaments used internally. There is nothing in the literary records to suggest that the ancient physicians were aware of the lead contamination of their medications or ascribed any ill-effects to the lead adulteration.

There was, of course, the fraudulent adulteration of ancient medicaments with lead. Pliny (34.25) spoke forcefully on this matter: "But of all these facts the doctors, if they will permit me to say so, are ignorant—they are governed by names: so detached they are from the process of making up drugs, which used to be the special business of the medical profession. Nowadays whenever they come on books of prescriptions, wanting to make up some medicines out of them, which means to make trial of the ingredients in the prescriptions at the expense of their unhappy patients, they rely on the fashionable druggists' shops which spoil everything with fraudulent adulterations, and for a long time they have been buying plasters and eye-salves ready made; and thus is deteriorated rubbish of commodities and the fraud of the druggists' trade put on show." It is equally

inauspicious that at the time of the Roman Empire, apothecaries were sometimes called *pigmentarii*—a term denoting dealers in dyes and paints— but it also referred to those who prepared the medicines ordered by the physicians, as has been remarked previously by Pliny. Lead pigments were quite common in Roman times (see Chapter 5), and some adventitious lead contamination of drugs might have been occasioned by the use of improperly cleaned shop equipment and dispensatories.

The preceding review of the extant literary sources of the Old World thus indicates that saturnine preparations were rarely prescribed for internal use. Pliny (33.41) rightly tells us why not:

> And cinnabar and red lead are admitted to be poisons, all the current instructions on the subject of its employment for medicinal purposes are in my opinion decidedly risky, except perhaps that its application to the head or stomach arrests hemorrhage, provided that it does not find access to the vital organs or come in contact with a lesion. In any other way for my own part I would not recommend its employment.

The application of lead compounds to excoriated skins over an extended period of time could, however, lead to chronic, if not acute, lead poisoning (see Baker, 1767; Tanquerel des Planches, 1839). A number of medicaments used internally were contaminated with lead either fraudulently or from the use of leaden, or lead-tainted, morters, pestles, jars, and dispensatories. The maceration of the medicinal ingredients with wine or boiled-down must would be another important source of lead contamination in ancient medicaments.

The ancient peoples were very much aware of the effects of lead on the human reproductive system. In his *Historia animalium,* Aristotle (*Works* 4.583a) notes that some women of his time prevented conception "by anointing that part of the womb on which the seed falls with oil of cedar, or with ointment of lead or with frankincense commingled with olive oil." The pseudo-Hippocratic text *On the Nature of Women* recommends an aqueous solution of *misy* as a contraceptive potion (Littré 7, 415). *Misy* remains one of those "undeterminable" inorganic compounds, some varieties of which may contain lead. In his classic text *Gynaecology* (1.61), Soranos of Ephesus (98–138 A.D.) advocates the following rational contraceptive technique: "Further, conception is prevented by smearing the mouth of the womb with old (sour) oil or honey or cedar gum or opobalsam, either alone or mixed with ceruse (white lead), or with ointment which is prepared with myrtle oil and ceruse, or with alum, which is likewise to be watered before coitus, or galbanum in wine." Lead, of course, is an excellent spermicide (Bell and Thomas, 1980). Soranos then goes on to suggest boiled-honey mixtures (1.62) and wine concoctions (1.63) for inducing menstruation and for preventing conception or for inducing abortion (Himes, 1970, p. 90). Recall the previous discussion on the lead con-

tamination of wines and hydrmel–oxymel. Oribasios (*Medical Collection* 10.23) states that collyria, which often contain lead (see Table 6.2), were applied to the uterus, presumably for contraceptive purposes.

In the eclectic compilation *On Medicine in Sixteen Books or Discourses,* Aëtios of Amida (16.16) notes that "smearing the cervix before coitus with honey or cedar resin alone, or in combination with lead or liquid ointment with myrtle and lead or liquid alum or galbanum with wine, aids contraception. These medicaments, when they are astringent, unctuous and refrigerant, close the orifice of the womb before coitus and prevent the sperm of the man from entering the uterus." He continues by saying (16.17): "Or else, (prepare) lead with oil in pessary; put in the vagina before coitus or sooner."

Several moralists and satirists—notably St. Jerome, Juvenal, and Martial—spoke about the practice, which was relatively common among women at the time of the Roman Empire, of drinking potions with the intention of preventing conception or inducing abortion. The following excerpts from Juvenal may be indicative of the general deprivation of his age:

> At the moment, when Julia was relieving her fertile womb and giving birth to abortions that display similitude of her uncle. (*Satires* 3.35)

> So great is the skill, so powerful the drugs, of the abortionists, paid to murder mankind within the womb. Rejoice, poor wretch; give her the stuff to drink whatever it may be, with your own hand: for were she willing to get big and trouble her womb with bouncing babes, you might perhaps find yourself the father of an Ethiopian: and some day a coloured heir, whom you would rather not meet by daylight, would fill all the places in your will. (*Satires* 6.595)

There is no way of knowing the number of such contraceptive decoctions, if any, that contained lead as an active ingredient.

Lead was also featured in the treatment of other diseases of women. The Hippocratic corpus referred to the use of leaden instruments to dilate the cervix (Littré 8, pp. 281, 427). Leaden tubes for intrauterine medication and for insertion into the vagina and rectum to prevent postoperative cicatrical contractions and adhesions are mentioned (Milne, 1907, p. 15). Mal Samuel (ca. 180–254 A.D.)—rabbi, physician, astronomer, and one of the most important sages of the Talmud—recommended the use of "leaden tubes whose edge is bent inwards" for examining the uterus (Niddah: 66a; Rosner, 1977, p. 164). The use of lead oxides in the treatment of ulcerous wombs is recommended in the Hippocratic text (Littré 8, pp. 117, 219, 265). Galen (vol. 8, pp. 645–646, 939) and Celsus (5.15, 18, 27) prescribed lead salts for ulcers, abscesses, and indurations of the breast. The lead applied to such private parts may exert an adverse health effect. Indeed, Sir George Baker (1767, p. 206) reported a case of "most violent and obstinate colic, which seemed to have been occasioned by some litharge mixed in cataplasm and applied to the vagina with a view to allay a troublesome itching."

There are a few other anecdotes on saturnine drugs. The excavations of a Roman military hospital near Baden in Switzerland has yielded bottles of leaden ointments (Kolbert, 1909). The Bible did not specifically mention any saturnine medicaments, but among the remedies mentioned in the Talmud are various powders, potions, plasters, and collyria (Rosner, 1977, p. 16; Preuss, 1978, ch. 15) that probably included lead as an ingredient. For the treatment of *rushcheta,* a mixture of aloe, gum arabic juice, white lead *(aspidka),* litharge *(martika),* malabathrum berries, and glaucium has been recommended by the Talmud. All the ingredients are to be placed in a thin rag in summer or in cotton wool in winter and then be applied to the site of the ailment (Gittin, p. 69b; Preuss, 1978, p. 185).

Unlike the situation in the West, the consumption of mineral elixirs and drugs assumed a religious fervor in ancient China and other ancient cultures of the East. The basic features of Chinese *wei tan* and *nei tan* alchemy pertaining to macrobiotics or physiological medicine of longevity and material immortality have been articulated nicely by Needham (1974, p. 11):

> Macrobiotics is a convenient term for the belief that it is possible to prepare, with the aid of botanical, zoological, mineralogical and above all chemical, knowledge, drugs or elixirs *(tan)* which will prolong human life beyond old age *(shou lao),* rejuvenating the body and its spiritual parts so that the adept *(chen jen)* can endure through centuries of longevity *(chhang shêng),* finally attaining the status of eternal life and arising with etherealised body as a true Immortal *(shêng hsien).* Such was the Taoist concept of material immortality. . . . But there was another predisposing cause for alchemical ideas in China, the absence of any prejudice against the use of mineral drugs analogous to that which existed so long under the Galenical domination in Europe; indeed the Chinese went to the other extreme, compounding with remarkable persistence through the centuries all kinds of dangerous elixirs containing metallic and other elements (mercury, arsenic, lead, etc., as well as gold) which caused untold harm to those who resolutely took them. However the Taoist, if he chose, could avoid these dangers, for there were many other techniques available in the quest for material immortality, not only alchemical and pharmaceutical but also dietetic, respiratory, gymnastic, sexual, heliotherapeutic and meditational. With all these could he aspire to incorporation into the ranks of the invisible bureaucracy of the universe as a Heavenly Immortal *(thien hsien);* or else seek for transformation into a *ti hsien,* an Earthly Immortal, purified, ethereal and free, able to spend the rest of eternity wandering as a kind of wraith through the mountains and forests, enjoying the company of similar enlightened spirits and the cycle of the seasons ever repeated yet with glory ever renewed. These are the beings that one can discern, tiny against the immensity of the landscape, flitting across remote ravines in many beautiful Chinese paintings.

Compared to Hellenistic chemistry, the Chinese alchemistry was much closer to medicine than to metallurgy, with the result that the use of inorganic and metallic substances in therapy began in remote antiquity. A com-

pendium of chemical substances in the text, *Chi Ni Tzu* (presumed to be of fifth century B.C. vintage) listed metallic lead and a number of its compounds which probably had pharmaceutical uses (see Needham, 1976, p. 14). The legendary Shunyu I (ca. 216–147 B.C.), who has left us with one of the earliest records of the medicinal uses of inorganic substances (The Five Minerals), had in his possession a book entitled *Discussion on the Use of Mineral Drugs* which probably dates to at least the second half of the third century B.C. (Needham, 1976, p. 47). The earliest Chinese pharmacopoeia extant, *Shen Nung Pen Tshao Ching,* lists 41 inorganic substances, including mercury and cinnabar. The manuscript, considered to be of Early Han and presumably containing material from Chou and Warring States period, notes that cinnabar is "found in mountain valleys, its sapidity is sweet and slightly cold, it controls the hundred diseases of the body and the five viscera, it nourishes the *ching* and *shen* vitalities, calms the *hun* and *pho* 'souls,' benefits the *chhi,* clears the eyes, kills *mei* parasites and destroys malignant humors *(hsieh o chhi).* It can change into mercury *(hung).* If taken constantly it puts one in touch with spiritual beings and gives longevity *(thung shen ming pu lao).*" The text highlights the main point of interest here, namely, that the toxic mineral drugs were used internally from very early times. Needham (1974, 1976) has presented a near-catalog of ancient emperors, high officials, and adepts who ingested such metallic elixir preparations that undoubtedly included the lead salts.

The literary records suggest that elixir preparations made from lead and other toxic metals began to be consumed in heavy doses or administered on long-continued basis during the Later Han, or about the first or second century A.D. (Needham, 1976, p. 45). For many centuries after that, the adepts and their disciples continued the hard and painful process of testing the effects of metallic preparations upon the human mind and body. It would be quite unwise and fortuitous to even try to follow the web of references to the saturnine elixirs. Sivin (1968) has found over 1000 titles on elixirs of immortality in the alchemical literature, while Okanishi Tameto (1936) indexed 2405 recipes for elixirs (defined by the occurrence of the word *tan* in the title) in only 321 medical compilations. A few examples will suffice to show that large amounts of lead were often employed in the preparation of some common elixirs.

In *Tshan Thung Chhi* (Kingship of the Three), dated to about 142 A.D., Wei Po-Yang, who is widely regarded as the father of alchemy, gave detailed instructions for the preparation of the famous "cyclically transformed elixir" (see Needham, 1976, p. 73):

> *Chin* (lead, or the metal) is used as an embankment (to prevent mercury from escaping), so that *shui* (mercury) can be put in and run about freely. The amount of *chin* is fifteen (oz.) and so is the amount of *shui* (mercury). Weighings should be made when the furnace is about to be heated. An excess amount of *shui* (mercury) by half should be used. These are the two genuine substances. The weight of *chin* will be the same as it was originally. A third (substance) therefore does not come in. But when fire (which is also represented by the number) Two is introduced these three will interpenetrate each other and marvellous changes (*pien hua'*) will take place. Below (the reaction-vessel) is the *chhi* of Thai-Yang (i.e. the fire). After a short time of heating (lit. steaming, *chêng*) first liquefaction and then solidification take place. (The substance thus formed) is called the 'yellow carriage' (*huang yü*). As the time (lit. month and year) draws to a close, the nature (of the original substances) is destroyed and their life shortened. (Eventually a transformation of) their form and matter comes about giving a sort of powdery ash, resembling 'bright window dust.'
>
> (The substance) is ground, mixed well and enclosed (in another reaction-vessel) before being introduced into the opening of a red (-hot furnace). Attention should be paid to the sealing of the edges of the container so as to keep the whole intact without leaking. The dazzling flame plays below, making a noise both day and night. At the start the flame should be gentle so as to be controllable, but eventually its strength should be increased until it reaches maximal intensity. The regulation of the temperature should be watched over with the greatest care. There are twelve periods in the (diurnal) cycle. At the end of each period one should be particularly careful. When the *chhi* (i.e. the fire) is about to be let down, the (original) bodies have been killed, and the *hun* and *pho* 'souls' have disappeared (i.e. the substances have changed their nature). The colour has already turned purple, and thus is the 'cyclically-transformed elixir' (*huan tan*) achieved. This is then made into pills which can be taken, and is magically effective even if (only) a knife-point of it is administered.

Unfortunately, Wei Po-Yang did not say what *chin* and *shui,* the two main ingredients, were. An anonymous commentator surmised that *chin* represents an abbreviated form of *chin hua* (metallic lead) while *shui* derives from *shui yin* (mercury) (Needham, 1976, p. 73). Irrespective of the ingredients and reactions involved, the final product was certainly potent since only "a knife-point of it" was all that was required.

Ko Hung (ca. 283–343 A.D.), the systematizer of Chinese alchemy, maintained that material immortality could only be attained by the consumption of one of the major elixirs such as *huan tan* (cyclically transformed elixir) and *chin i* (portable gold elixir). He devoted Chapter 4 of his *Pao Phu Tzu (Nei Phien)* (Book of the Preservation-of-Solidarity Master: Esoteric Chapters) exclusively to the preparation and types of elixirs (see Wu Lu-Chhiang and Davis, 1932; Ware, 1966; Needham, 1976, pp. 75–113). Of the 27 elixirs listed, cinnabar was used as an ingredient in 21 of them, mercury in about 12, and realgar in 8 instances. The lead-containing elixirs and preparations included *tan hua* (a deadly mixture of mercury, realgar, alum, lead, lead carbonate, salt, red bole clay, oyster shells, soapstone, and other ingredients); *thai-chhing tan* (a mixture of mercury and its salts, lead, gold, vinegar, mineral sulfates, and so on); *yin tzu tan fa* (cinnabar, molten lead, and mica suspensions); *chang tzu-ho tan fa* (mercury, copper oxide, lead, red pinacled millet with crushed jujube-dates as vehi-

cle) and *chou hou tan fa* (cinnabar, mercury, lead, and copper or one of its alloys) (Needham, 1976, pp. 90–92).

Ko Hung—rather uncharacteristically—described a relatively detailed procedure for the preparation of *tan hua* or "elixir flower" (Needham, 1976, p. 83): "The first elixir is called 'elixir flower' *(tan hua)*. One should first prepare *hsüan huang* ('mysterious yellow ingredient,' presumably a lead–mercury amalgam or a mixture of the two metal oxides). Add to it a solution of realgar and a solution of alum. Take several dozen pounds each of rough Kansu salt *(jung yen)*, crude alkaline salt *(lu hsien)*, alum, powdered oyster shells, red bole clay, (powdered) soapstone, and lead carbonate; and with these make the Six-One Lute [and seal (the reaction vessel) with it]. After 36 days heating the elixir will be completed, and anyone who takes it continuously for 7 days will become an immortal. Now if this elixir is made into pills with "mysterious fat" *(hsüan kao)* and placed upon a fierce fire, it will very quickly turn into gold. Gold can also be made by taking 240 *chu* (10 oz) of this elixir and adding it to 100 catties (lb) of mercury, then upon heating, it will all turn into gold. If this works, we know that the elixir is right. If it does not, reseal the constituents and heat for as long as before. This never fails."

The paradigmatic process described above has been the subject of conflicting interpretations (Chikashige, 1936; Needham, 1976, p. 84), and the mention of projective aurification is certainly noteworthy. The ancient text *Huang Ti Chiu Ting Shen Tan Ching Chueh* [Explanation of the Yellow Emperor's manual of the nine-vessel magical elixir], which contains material earlier than Ko Hung's time, gives the composition of *hsüan huang* as 10 lb of mercury and 20 lb of lead (Ware, 1966, pp. 78–79). Another alchemical text, the *Thai-Chhing Chin I Shen Tan Ching* [Manual of the portable gold and magical elixir—a Thai-Chhing scripture], states that *hsüan huang* is prepared by heating 9 lb of mercury and 1 lb of lead in an earthenware vessel over a strong fire from morning until dusk (Needham, 1976, p. 85). The consumption of such elixirs that contained large quantities of toxic metals certainly would have been an anathema to the health of the adepts.

The Thang theoretical treatise *Tan Lun Chüeh Hsin Ching* [Mental Mirror Reflecting the Essentials of Oral Instruction about the Discourse on the Elixir and the Enchymoma] saw a close parallel between geological processes and the preparation of the familiar cyclically transformed elixirs (Needham, 1980, p. 232):

> Natural cyclically-transformed elixir *(tzu-jan huan tan)* is formed when flowing mercury *(liu hung)*, embracing Sir Metal *(chin kung = chhien,* lead), becomes pregnant. Wherever there is cinnabar there are also lead and silver. In 4320 years the elixir is finished. Realgar *(hsiung)* to its left, orpiment *(tzhu)* to its right, cinnabar above it, malachite *(tshêng chhing)* below. It embraces the *chhi* of sun and moon, Yin and Yang, for 4320 years; thus, upon repletion of its own *chhi*, it becomes a cyclically-transformed elixir for immortals of the highest grade and celestial beings. When in the world below lead and mercury are perfected by an alchemical process *(hsiu lien)* for purposes of immortality, (the elixir) is finished in one year. The fire is first applied in the eleventh month, when the Single Yang *(i Yang)* comes into being, and the elixir is finished by the eleventh month of the next year. The natural cyclically-transformed elixir is what immortals, celestial beings, and sages of the world above gather and eat. What (the alchemist) now prepares succeeds because of its correspondence on a scale of thousandths *(hsiang erh chhêng chih, ta chhien chih shu)*. Taking the product also results in eternal life, transformation into a feathered being, and power *(kung*[11]*)* equal to that of heaven.

We shall return shortly to the association of cinnabar with lead ores in relation to the lead–mercury theory of metallotherapy.

Simple and practical details for the preparation of saturnine elixirs are given in the text *Thai-Chhing Tan Ching Yao Chüeh* [Essentials of the Elixir Manuals for Oral Transmission, a Thai-Chhing Scripture], written ca. 640 A.D. by Sun Ssu-Mo (ca. 581–672 A.D.). He listed 67 different elixirs but gave the recipes for only 32, most of which entailed large quantities of lead, mercury, and/or arsenic as the active ingredients (Sivin, 1968, pp. 145–214). Thus, the formula for a "minor cyclically transformed elixir" was given by Sun Ssu-Mo as 4 oz of amorphous sulfur, 1 lb of mercury, 3 oz of massicot, and 1 oz of gold. The mixture is to be forcefully ground fine, heated in a tightly sealed lute for seven days and nights, cooled for half a day and the product made into pills, using jujube pulp as the vehicle (Sivin, 1968, p. 175). On the dosage and efficacy of such an elixir, Sun Ssu-Mo says: "Every day after eating, take three pills wrapped in jujubes. It cures epilepsy, melancholia, possession by goblins, and so forth. Taken over a long period, it hardens the bones and marrow, aids circulation of the blood, moistens the skin, brings out color in the face, quiets the soul, and puts one in touch with the immortals." The osteological effect of overexposure to lead is properly adduced, and the remark that the elixir "puts one in touch with the immortals" is not at all surprising.

For making the "lead elixir," Sun Ssu-Mo recommends 4 lb of lead ripened in fire and 1 lb of quicksilver cleaned by grinding with salt. Details for preparing the elixir are given as follows (Sivin, 1968, pp. 187–188):

> Take two *tou* of millet and steam it until the grains decompose. When it is ready, make it into vinegar by adding vinegar leaven and stopping it up tightly for five or six days. Next take earth collected from cart tracks, sift it, and put it into the container, stirring to mix, until the contents resemble wheat paste which has been fried in cakes. Take the lead, melt it, and pour it into the paste and mix. After mixing, heat the lead again in a good footed vessel until melted. Warm the mercury and pour it into one *chin* of the lead. Wait until the whole flows and then resolidifies. Bind it with cord and suspend it in a kettle [of vinegar] for 14 days. Its essence will of itself descend into the vinegar. Collect it and wash it clean. Mix it with one *liang* each of mirabilite and Epsom salts [$MgSo_4 \cdot 7H_2O$]. Sublime the combination three times, three days for each cycle, following the method for preparing the elixir

> sublimation. Collect the essence and mix it with cooked rice to form pills, each the size of hempseed. It will cure anyone afflicated with disorder due to hot factors, possession by demonic forces, epilepsy, and autumnal intermittent fevers.

The principle of sympathies is again evident, and the use of the lead elixir seems to be predicated upon the cooling and chthonic properties of lead.

The common association of lead and mercury in all of these elixirs should have become quite evident. Mahdihassan (1979) has noted that the prehistoric Chinese and other ancient cultures regarded blood as the vehicle for the soul, and they typically associated blood with redness. In essence, soul = blood = redness, or bright-red ore. Mahdihassan maintains that the ancient peoples smeared their dead initially with a red ocher, later with red lead (minium) and/or cinnabar. Since the prehistoric Chinese could not readily differentiate between minium and cinnabar (for a similar confusion in the Hellenistic world, see Chapter 5), they were able to recover lead or mercury from the pyrometallurgical treatment of the propitious red ores. Consequently, blood = soul = (the propitious red mineral) = lead + mercury. The two elements and their compounds thus became ubiquitous among the drugs of immortality or longevity. Indeed, few other people interred cinnabar or minium—its common adulterant—with the dead, nor did they take it orally as a drug or elixir in such quantities as the ancient Chinese (Mahdihassan, 1979). Such a conceptual association perhaps formed the basis of their lead–mercury theory of metallotherapy.

One of the earliest recipes for the lead–mercury elixir is given in the *Yellow Emperor's Canon of the Nine-Vessel Spiritual Elixirs,* written before 142 A.D. (Needham, 1980, p. 255). For preparing the "black-and-yellow" *(hsüan huang)*, an intermediate step in the synthesis of the nine elixirs, the Canon advocates (see Needham, 1980, p. 256):

> Take ten pounds of quicksilver and 20 pounds of lead. Put them into an iron vessel, and make the fire underneath intense. The lead and the quicksilver will emit a floreate essence *(ching hua)*. This floreate essence will be purple, or in some cases may resemble yellow gold in color. With an iron spoon, join it together and collect it. Its name is "Black and Yellow," and it is also named "Yellow Essence" *(huang ching)*, "Yellow Sprouts" *(huang ya)*, and "Yellow Weightless" *(huang chhing)*. The medicine is then put inside a bamboo tube and steamed a hundred times. It is mixed with realgar and cinnabar solutions and volatilized.

At times, however, the "realized lead" (silver) and "realized cinnabar" (mercury) are used in the elixir preparation. The excerpts in which Mêng Yao-Fu (Sung Dynasty) defined the two paradigmatic terms have already been cited (see Chapter 1; Needham, 1980, pp. 258–259). Any further discussion of the lead–mercury theory of metallotherapy would seem irrelevant to the present chapter. It may be noted in passing that such a concept

was the subject of a ninth century A.D. treatise *Chhien Hung Chia Kêng Chih Pao Chi Chhêng* [The complete compedium on the lead–mercury a-g perfected treasure] by Chao Nai-An. The text gives the following recipe for the "yellow sprouts great elixir" (see Needham, 1980, p. 294):

> Orphiment, 0.5 oz; sal ammoniac and arsenic, 0.25 oz each. First grind the orphiment; then grind the arsenic and sal ammoniac separately, fine as flour. Take an egg and make a hole in it. Get rid of the yolk but keep the white. Spread half the arsenic and sal ammoniac on the bottom inside the egg; put the orphiment in the middle, and half the arsenic and sal ammoniac to cover it. Take somewhat less than half an egg-shell to cover the hole, and seal it on with iron oxide solution *(chiang fan shui)* which has been mixed with the egg-white. Then take a pound of minium *(huang tan)* and an iron reaction vessel *(ting)*. Put half the minium into the vessel and place in its center the medicines in the egg. Then cover them with the rest of the minium, applying a little pressure. Fill the vessel with lime *(shih hui)* and lute it tightly. Using half a pound of charcoal, heat it gently in an ash bath. When it is taken out, it will be finished.

It would be futile to describe other potentially deadly saturnine elixirs that have been cited frequently in many other ancient Chinese texts and inscriptions. The few examples I have given should be sufficient to suggest that any adepts habituated to such elixirs were liable to have suffered lead poisoning. Perseverance in the taking of the elixirs was counseled repeatedly in many of the ancient texts (see Needham, 1974, p. 283)—a rather unfortunate piece of advice. There is also ample evidence that large numbers of the members of ancient Chinese society indulged in the practice of taking metallic elixirs (see Ho Ping-Yü and Needham, 1959). Metallic-elixir poisoning certainly hastened the demise of many emperors and high government officials, as is recorded in many ancient texts (see Ho Ping-Yü and Needham, 1959). It is not inconceivable that such poisoning reached epidemic proportions in certain segments of society who could afford the preparations. Many a purveyor of such elixirs certainly would have received unhealthy doses of metallic fumes from the furnaces and reaction vessels. Metallic poisoning also would have been a serious problem among the Chinese adepts of the *nai tan* or "inner elixir" (Lu Gwei-Djen, 1973). The actual discussion of elixir poisoning will be deferred to the next section.)

Chinese protoscientific influence becomes increasingly manifested in Japan from about the beginning of the sixth century A.D. (Needham, 1976, pp. 174–180). Because the country was richly endowed with gold and silver, the ancient Japanese generally eschewed the chrysopoia (aurifiction and aurifaction) dogma, but they eagerly accepted the chemotherapeutic (elixir) elements of Chinese alchemy. The extant historiographies reveal that throughout the Heian period (ca. 795–1185 A.D., which is well within the Japanese Iron Age [see Tylecote, 1976]), the imperial court and mem-

bers of the nobility were consistently devoted to longevity medicines derived from plant and metals (Needham, 1976, pp. 178–180). The general propensity for saturnine drugs and elixirs in ancient Japan is amply documented by the time-capsule specimens deposited in the Shōsōin Treasury in 756 A.D. and preserved there to this day (Yamasaki, 1954, 1959, 1967; Masutomi Kazunosuke, 1957). Among the 600 or more items (including 60 substances labeled as "medicines") were 128 small triple-wrapped packages containing about 100 kilograms of lead oxides. The contents of the packages were graded into ranks of "superior," "medium," and "low" quality on the basis of the intensity of the orange-colored powder (Yamasaki, 1959, 1967). The lead oxides in the packages no doubt were used for medicinal purposes and in beauty aids.

Chemistry in ancient India also evolved chiefly as a handmaiden of medicine and—somewhat later on—as an adjunct of the Tantric cult (Ray, 1956, p. 38). The Vedas—the sacred scriptures of the ancient Hindus—contain some of the earliest ideas or notions about chemistry and medicine. The *Atharva-veda,* (ca. the tenth century B.C.), which deals with recipes for longevity and curing of diseases, regarded gold as an elixir of life and lead as a dispeller of sorcery (Ray, 1956, p. 38). It contains an interesting incantation dealing with lead:

> To the lead
> Varuna gives blessings
> To the lead
> Agni gives help
> Indra gave me the lead
> Unfailingly dispels sorcery.

Later alchemical and medical texts of ancient India list a catholicity of herbal, metallic, and herbo-metallic drugs *(rasayana)* for immortality and/or longevity (e.g., see Wise, 1867; Hoernle, 1907; Zimmer, 1948; Ray, 1956; Bose et al., 1971; Sherma, 1972; Jaggi, 1973; Mitra, 1974). For example, the Siddha system of medicine and practice—followed mostly in the *Tamilnadu* (dating to the sixth or seventh century A.D. or earlier)—has firm ideas about mercury-based elixirs relating to longevity (Bose et al., 1971, p. 355). The remarkable thing, however, is that lead was rarely an ingredient in these early *rasayama.* The exclusion of lead may perhaps be related to the popular ancient belief that the aged person has a cold body, whereas the body of a youthful individual is warm (Mahdihassan, 1979, p. 24). Such a concept of warmth characterizing robust health certainly would have precluded the use of "cold lead" in any rejuvenation drugs.

Saturnine medicaments—as opposed to rejuvenative drugs—undoubtedly were used in ancient India, often as internal remedies. Charaka (ca. the second century A.D.), who is generally regarded as the first to codify

medicine in India, mentions the use of gold, silver, copper, lead, tin, and iron as well as their calces as drugs (Ray, 1956, p. 61). Although the *Sushruta Samhita* dealt mostly with vegetable drugs, it also contains one sloka in which lead and other metals, as well as their calces, are recommended for use as drugs (Ray, 1956, p. 65). Lead and zinc were described as vermifugal, and they are recommended for internal use in the *Sushruta* (1, p. 531, 3, p. 342). The medicinal use of lead is also alluded to in many other ancient Indian canonical texts, such as the *Mahāvagga, Anguttaranikāya, Jātaka, Visuddhimagga, Vinaya Pitaka,* and so forth (Mitra, 1974).

Galena was described as an ingredient in collyria *(anjanas)* by Charaka, while lead oxides and lead sulfate were prescribed with vegetable drugs for use as plasters in both the *Sushruta Samhita* and the *Charaka Samhita* (Ray, 1956, pp. 62, 65). Medicinal preparations presumably containing lead were used in the eye disease called *timira (Kādambari,* p. 313; Sherma, 1972, p. 226). The same text (*Kādambari,* p. 643) also noted that one eye of the old Dravidian religious man was lost by the use of collyrium named *siddhānjana* (formulary unknown), which was administered by some quack (Sherma, 1972, p. 226). The Bower Manuscript (pt. 2, p. 131; Hoernle, 1907), which dates to about the second half of the fourth century A.D. but which contains material from a much earlier period, also refers to the use of galena in medicine.

Alchemical practices really began to blossom in India during the fifth century A.D. (Bose et al., 1971; Mahdihassan, 1979), and with them came an ever increasing reliance on metallic-drug preparations. This development is clearly reflected in the famous treatise the *Astangahridaya,* by Vaghbata (ca. A.D. 800–850), which articulates medical principles of earlier times. It lists many more prescriptions of lead, gold, silver, copper, iron, and tin than any other earlier Indian text. One such recipe recommends roasting in a closed crucible a mixture of 30 parts of lead, 5 parts of sulfur, 2 parts each of copper and orphiment, 3 parts of stibium, and 1 part of tin (*Uttarasthanam,* ch. 13, pp. 31–32). For making a collyrium, Vagbhata recommends equal parts of lead and mercury with an equal weight of stibium and camphor (*Uttarasthanam,* ch. 30, p. 36). The days when Vagbhata lived basically mark a transition in the progress of Hindu medicine, insofar as materia medica is concerned. Every medical text published after this period prescribes metallic compounds that can only be synthetically prepared. This contrasts with the largely herbal and vegetable drugs and a few simple and readily available products of the mineral kingdom used in the preceding periods (Ray, 1956, p. 108). I shall return to such an historical development in the next volume. It is of anecdotal interest, however, that an aboriginal tribe of Bengal—the Santals—use red lead not only for preparing external medicaments, but also as an ingredient in pills that are either ingested or smoked in a pipe (Bodding, 1927).

The following are some of the important medicinal applications of lead and its compounds, vis-à-vis the arsenical and mercurials, in the Ayurbedic system of medicine (Bagchi, 1969, p. 63):

Mode of Use or Application	Disease
External in medicated oils	Parasitic infections of skin, eruptions, and itchings
External in dusting powder or in ointment	Chronic skin diseases, piles, leucoderma, baldness, alopecia, leprosy, etc.
External ingredients of oral gurgle	Mouth and throat diseases
Ingredients of medicinal cigars	Imbalance of first and third humors, migraine, hemicrania, earache, diseases of the gum, drowsiness, etc.
Internal in linctus, pills, or medicated ghee	Oedema, carbuncle, dysentry, toxicosis, night blindness, etc.

These uses just mentioned were probably adduced in bygone days from the *Sushruta-Semhita* and the *Charaka-Semhita* texts.

ANCIENT DESCRIPTIONS OF LEAD POISONING

To a very large degree, pharmacology owes its early development to "poison lore"—the term itself being derived from *pharmakon,* which means poison (Allbutt, 1921, p. 347). In this light, the preferential use of lead compounds for external remedies in the Ebers and Hearst medical papyruses suggests genuine appreciation of the toxic properties of lead at such an early date (i.e., before 1550 B.C.). Such an empirical knowledge probably evolved from observations of the reactions to ingested saturnine drugs, embellished perhaps by actual experimentation with other animals. Any records of the manifestations of plumbism accumulated by these early prototoxicologists, however, seem to have since been lost.

As noted in Chapter 1, lead compounds were probably employed in the secret poisons that have been featured widely in the history and folklore of every ancient or primitive culture. The history of secret poisons, which is quite long, lies outside the aims of the present chapter; any interested reader may refer to Beckmann (1846), Lewin (1920), Allbutt (1921), Thompson (1925), Massengill (1943), and Bagchi (1969). Of particular interest, however, are the so-called slow or timed poisons that were usually circulated by the practitioners of alchemy and astrology, and by those who professed to possess magical powers. The efficacity of such poisons is

rooted in the cunning manner in which they were administered. In order to avoid suspicion, the poison was probably given first to the victim in small quantities, then the dosage was gradually increased until it was decided to administer a lethal dose. This poisoning strategy could thus wear the guise of chronic disease, and it is particularly suited to the administration of inorganic toxins. Stevenson (1949) has, in fact, suggested that such slow poisons sometimes included lead and arsenic.

The use of lead in slow poisons can be rationalized further on the grounds of the ancient somatological conception of the primary effect of poisons as being the impairment of vital heat, which then actuates the loss of sensibility and muscular energy (see Adams, 1844–1847, vol. 2, p. 215; Stevenson, 1949, p. 7). Considering that lead was widely regarded as a "cold" metal, its surreptitious use to chill the vital heat would seem rather logical to the ancient poisoner. At any rate, there is no doubt that they acquired detailed knowledge about the pathological effects of lead and other metallic poisons. Unfortunately, their craft was guarded with great secrecy, and little of their substantial understanding of the mechanisms of lead toxicity would have been published. Even the study of poisons was forbidden in the early Christian era, and Galen mentions the fact that only a few philosophers dared treat the subject in their works (Massengill, 1943, p. 318).

At this point, it must be stressed that the correct diagnosis of lead poisoning has always remained problematic. I recently described the symptoms of subclinical lead poisoning to two general practitioners. The doctor in North America prescribed rest and tranquilizers, while the doctor in a developing country suspected malaria. Hippocrates and many other ancient doctors must have smiled in their graves at these later prognoses. The problem of correct diagnosis stems from the fact that the symptoms of lead toxicity are vague and notoriously nonspecific. At high doses, lead affects many target organs, including the hemopoietic, vascular, renal, hepatic, cardiovascular, immunological, reproductive, gastrointestinal, endochrine, and central nervous systems (Tanquerel des Planches, 1848; EPA, 1977; WHO, 1977). Indeed, McCord (1954, p. 125) has justifiably called lead poisoning "an aping disease." Its manifestations are so variable that it may simulate 100 other conditions. The early symptons of lead poisoning—such as vague abdominal pains, loss of appetite, headache, listlessness, clumsiness, fatigue, and nausea—are likely to be identified as a virus or as some noncritical stress syndrome and thus be dismissed (David et al., 1979; Needleman and Landrigan, 1981). The supervening of acute plumbism cannot always elicit proper diagnosis as the following excerpt from Repko and Corum (1979, p. 141) clearly shows:

> The diagnosis of lead poisoning requires the integration of several types of information since no single symptom or laboratory test is definite. For example, colic, anorexia, headache, and muscular discomfort of the abdominal syndrome may also indicate acute appendicitis, renal colic, duodenal ulcer,

> gastric ulcer, acute gastroenteritis, acute porphyria, heat exhaustion, or intestinal parasitic infestation. . . . Similarily, peripheral neuritis, weakness, or paralysis of the muscular system may be caused by infection, malnutrition, metabolic disease (diabetes), or arsenic. The central neurological syndromes are similar to any intracranial pressures, such as infections of the meninges, neoplasm (tumors), tuberculoma, syphilitic infection, or uremia. Even "lead line," a black ring on the gums once frequently reported, is not specific to lead and may be caused by infectious gingivitis, normal pigmentation of dark-skinned races, bismuth or other metals forming a black sulfide, or dental discoloration due to poor hygiene.

The absence of any unequivocal clinical pattern of symptoms and signs certainly underscores the fact that ancient doctors were unable to associate widespread saturnism syndromes with the lead in the food and drink of the victims. It would have been unusual for an ancient doctor, who based his clinical diagnosis solely on what the eye saw, the fingers felt, the ears heard, and the nose smelled, to associate miscarriages and male infertility with the action of lead. Even if they were unable to ascertain the exact etiological factor, many an ancient physician, however, displayed unusual acumen in articulating the symptomology of numerous diseases. On this score, one can see illusions of lead poisoning manifested by the pathognomonic features of many of the case histories recorded in the ancient medical literature. Any interpretation of the syndromes (not directly associated with ingestion of lead salts) as evidence of lead poisoning must be regarded as tentative. This point needs to be borne in mind in reading the following section.

Some exegetes can see allusions to lead poisoning in a number of syndromes recorded on the clay tablets of ancient Assyria. One good example is as follows (Ebeling, 1915; von Soden, 1953; translation by Wilson, 1967 p. 725):

> If a man is currently suffering from major or minor seizures, and an *alû*-demon then begins to inflict him with ideas of persecution so that he says—although no one will agree with him that it is so—that the finger of condemnation is being pointed at him behind his back and that a god or goddess is angry with him; if he sees horrible, alarming or immoral visions and is (consequently) in a constant state of fear; if he engages in periodic outbursts of anger against god or goddess, is obsessed with delusions of his own mind, evolves(?) his own religion, and says—although (again) they will not allow it—that his family are hostile towards him and that god, king, his superiors and elders treat him unjustly; if all his muscles are subject to paralysis, if his eyes exhibit colours of red (or brown), yellow and black, if he has some speech disorder with spells of forgetfulness, has no desire for female relationships and no inclination to pursue any activity [at all] . . . , (details of the action to be taken follow).

In this syndrome, the disturbance of memory and loss of interest, the symptoms of neurosis and paralysis, the ocular neuritis, the convulsions, all fit metallic (lead?) poisoning as well as many other chronic disorders.

The same medical compendium from the library of Ashurbanipal also described the following interesting syndromes (Küchler, 1904; Leix, 1940): "If a man eats and drinks until he is satiated, and he then has a pain in his stomach so that his viscera seem to be on fire and he has colic, it is *mushekînu*." The name for the malady remains to be determined. "If the stomach is distended and at the same time there is muscular contraction and nausea. . . . If the stomach is puffed up (constipated) and utters cries. . . . If the stomach is full of acid. . . . If the chest is attacked, the stools liquid like urine, if the neck hurts when one speaks, if there is vomiting." No name was given for the latter syndrome.

The observed phenomena and symptoms described fit many chronic diseases, including lead and other metal poisoning. Lead was widely used during the Middle and Late Assyrian periods (Chapter 4), and the possibility of contracting plumbism from food and drink contaminated inadvertently with lead is not inconceivable. Lead kettles and tumblers dating to that period are known, and they could be the source of dietary lead. The sequential arrangement for the related prescriptions in the clay tablets is equally intriguing. The remedies are listed to be given successively for cases of colic, constipation, vomiting, lack of appetite and voracious appetite, for ineffectiveness of purgatives and emetics, severe intoxication, dry cough, gallbladder trouble, and jaundiced eyes (Küchler, 1904). No less than 14 prescriptions are listed for colic, which would suggest the recognition that colic may be due to very different causes (Leix, 1940, p. 679).

It may seem fatuous to state that the previously mentioned syndromes pertain to lead poisoning. By the same token, it seems unlikely that the Babylonian physicians who were capable of making such acute and penetrating clinical observations would have missed the pathognomonic features of acute lead intoxication.

The ancient Egyptian medical papyruses also refer to a cornucopia of symptoms reminiscent of plumbism—belligerent abdomen, irritability, anorexia, myalgia, nausea, lethargy, paralysis, convulsions, and so forth. The listed therapeutic armamentarium for each syndrome suggests an apprehension of possible involvement of multiple causative factors. We can only speculate as to whether lead poisoning was recognized as one of the causative factors.

The Bible and the Talmud contain references to syndromes that are highly suggestive of lead poisoning. Colic *(kolos)* is said to be dangerous. When Rabbi Joshua ben Levi became ill with kolos, Rabbi Chanina suggested that he pulverize cress, place it in aged wine, and speedily drink it so that his life not be endangered (Jerushalmi Shabbath 14:14; Jerushalmi Abodah Zarah 2:40). The recommended remedy in fact was a typical ancient antidote for lead poisoning. Indeed, Preuss (1978, p. 182) equates this ailment with the special type of (lead) colic that Pliny (26.6) claimed first occurred during the reign of Tiberius, ca. 14–37 A.D. Reference to podagra or gout *(ẓinit)* occurs in the story of King Asa of Judea (915–875 B.C.), who is said to have been diseased in his feet during his old age (1 Kings 15:23;

2 Chronicles 16:12). In two separate discussions the Babylonian Talmud commented on King Asa's illness (Sanhedrin 48b; Sotah 10a).

Since *kordiakos* is mentioned several times in the Talmud but not in the Old Testament, it may be regarded as a "new" disease. The Jerusalem and Babylonian Talmuds state (Grittin 7:1; Terumot 1:1): "If a man is seized with kordiakos and says 'Write a bill of divorce for my wife,' he has said nothing. If he says, 'Write a bill of divorce for my wife,' and is then seized with kordiakos and retracted and said, 'Do not write it,' his last words count for nothing. . . ." The Talmud gives the following explanation of what kordiakos represents (*Grittin* 67b; see Rosner, 1977, p. 61):

> What is kordiakos? Samuel said: "Being overcome [lit. bitten] by new wine from the vat." Then why does it not say if one is overcome by new wine? The mode of expression teaches us that this spirit (or demon which causes the dizziness) is called kordiakos. Of what use is this [knowledge]? For a charm. What is the remedy for it? Red [i.e., without fat] meat broiled on the coals, and highly diluted wine.

The Jerusalem Talmud further says:

> The signs of a fool *[shoteh]* are as follows: he goes out at night [alone], he sleeps in the cemetery, he tears his clothes, and he loses what he is given. . . . Kordiakos has none of the above symptoms. What is kordiakos? R. Jose answers, *hamim*. A case came before R. Jose concerning a weaver who was given red in black [diluted red wine or red thread while working with black thread?] and he babbled [Heb.: *velu'a*, i.e., he talked nonsense]. Then he was given black in red and he babbled. This is the kordiakos of which the sages spoke; sometimes he is mad and sometimes sane. At a time when he is considered like a madman in all respects and when he is sane, he is sane in all respects [i.e., a bill of divorce should be written for his wife as per his instructions]. . . .

The condition is thus characterized by confusion, delirium, dizziness, and mental impairment following the imbibing of new wine from a vat. The Jerusalem Talmud makes it categorically clear that kordiakos does not mean folly, idiosy, or insanity. The syndrome is temporary, and is readily cured by the ingestion of red meat and dilute wine. The identity of kordiakos has been a matter of controversy (see Jastrow, 1950; Gordon, 1963; Hankoff, 1972; Rosner, 1977; Preuss, 1978). The possibility that lead was involved as an etiological factor also has to be raised. Heavy wine drinking by the Jews in the Roman colony in Palestine was common (McKinlay, 1950, McCarthy, 1959). As discussed before, there were numerous ways of contaminating wines with lead at that time.

There are divergent views as to whether lead poisoning was actually described in the Hippocratic corpus. The conflicting prognoses for "the diseased man from the mines" (*Epidemics* 6.25) have already been discussed. In addition, exegetes have associated other pathological features described in the corpus with lead poisoning. Littré (vol. 2, pp. 487–497), for example,

identified the following Hippocratean symptoms of dry cholera (*On Regimen in Acute Diseases*, ch. 19) with the dry bellyache of the eighteenth-century English physicians:

> In dry cholera the belly is distended with wind, there is rumbling in the bowels, pain in the sides and loins, no dejections, but on the contrary, the bowels are constipated. In such a case you should guard against vomiting, but endeavor to get the bowels opened. As quickly as possible give a clyster of hot water with plenty of oil in it, and having rubbed the patient freely with unguents, put him into hot water, laying him down in the basin, and pouring the hot water upon him by degrees; and if, when heated in the bath, the bowels be moved, he will be freed from the complaint. To a person in such a complaint it will do good if he sleeps, and drinks a thin, old, and strong wine; and you should give him oil, so that he may settle, and have his bowels moved, when he will be relieved. He must abstain from all other kinds of food; but when the pain remits, give him asses' milk to drink until he is purged. But if the bowels are loose, with bilious discharges, tormina, vomitings, a feeling of suffocation, and gnawing pains, it is best to enjoin repose, and to drink hydromel, and avoid vomiting.

Galen (cited in Stevenson, 1949, p. 86) wondered whether the latter part of the syndrome also referred to dry cholera or was independent of the preceding account. The similarity between the recommended therapy and the ancient remedies for lead poisoning is equally suggestive.

There are also allusions to lead poisoning in a number of the Hippocratic aphorisms (see Stevenson, 1949, p. 87):

> Those cases in which there are tormina, pains about the umbilicus, and pains about the loins, not removed either by purgative medicines or otherwise, usually terminate in dry dropsy. (4.11)

> If persons free from fever be seized with tormina, heaviness of the knees, and pains of the loins, this indicates that purging downward is required. (4.11)

> When pains in the joints take place after fevers, the patients are using too much dainty (contaminated?) foods. (7.65)

The corpus also describes endemic forms of colic and constipation that are reminiscent of endemic lead colic. The *Third Book of Epidemics* (Chadwick and Mann, 1950, p. 66) refers to frequent disorders of the belly: "Painful colic and malignant flatulent colic also occurred; in these going to stool did not relieve the pains, the stools being such that much remained within the bowel after attempted evacuation. This condition responded only with difficulty to medicine, and in most cases purgatives did additional harm. Many of those with this complaint perished soon; others lasted rather longer."

The preceding excerpts show that Hippocrates (or the authors of the corpus that bears his name) was fully aware of the various syndromes now regarded as being symptomatic of endemic lead poisoning. However, there

is nothing in the corpus to prove conclusively that lead was regarded as an etiological factor in any of the case histories reported.

Sympathetic pathological features described in other ancient medical texts have likewise been interpreted as plumbism. Spencer (1935) believed that lead poisoning was one of the antecedent causes of Celsus' (4.31) "joint troubles in the hands and feet (that) are very frequent and persistent, such as occur in cases of podagra and cheiragra." Among remedies suggested were drinking asses' milk, blood letting, inducing sweat (a good route for excreting toxicants), and the use of diuretics or an emetic. Furthermore, Celsus (4.31) emphasized that some persons "have obtained lifelong security by refraining from wine mead, and venery for a whole year; indeed this course should be adopted especially after the primary attack, even though it has subsided." Recall the contamination of classical alcoholic beverages with lead. In a different section, Celsus (5.25) notes that the pill formulated by Cassius (probably a second century B.C. Alexandrian physician) for colic "contains saffron, anise, castory, 12 grms. each, parsley 16 grms., pepper both long and round, 20 grms. each, poppy-tears, round rush, myrrh, nard, 24 grms. each; these are taken up in honey. It may be either swallowed as it is or dissolved in hot water." Kolbert (1909) believes that such a mixture can assuage the pain of a lead colic and has a laxative effect.

Aretaeus the Cappadocian (2.8) notes that there are many causes of colic and that patients are speedily cut off by volvulus and tormina. Symptoms he described include torpor, loss of appetite, sleeplessness, flatulence, ischuria, and pains in the testicles and cremasters. These may be complicated by abscesses, ulcers, dropsies, and phthisis. Aretaeus (*Chronic Diseases,* 2.6; *Acute Diseases,* 2.8) also described an unusual melancholic, nervous colic that is reminiscent of endemic lead colic: "The patients do not sleep well and waste away; the lower part of their abdomen is dry and contracted; at times, however, they vomit material that is round, dry, and black but as if tinged with yellow; there is almost no flow of urine, and the hypochondria are filled with flatus; purgatives must be administered energetically for such illnesses. . . . Sometimes the disease becomes incurable; when this occurs, it engenders in the system a progeny of other diseases—spasms, mania and paralysis."

Pliny (26.6) regarded colic as one of the "new" endemic diseases attributable to the increase of luxury in food and drink:

> This itself is a wonderful fact, that some diseases should disappear from among us while others remain endemic, as for example colic. It was in the principate of Tiberius Caesar that this malady made its way into Italy. Nobody suffered from it before the Emperor himself, and the citizens were greatly puzzled when they read in his edict, in which he begged to be excused because of illness, a name they had never heard before. What are we to say that this means, what wrath of the gods? Were the recognised kinds of human disease, more than three hundred, too few, that they must be increased by new ones also to add to man's fears? No fewer either are the troubles which man brings upon himself by his own agency.

Pundits may view Pliny's observation in relation to the widespread dietary exposure to lead in his days.

Galen also refers to pernicious colic and gives a long list of remedies for it. They consist principally of narcotics such as opium, henbane, euphorbium, and mandragora, along with carminative aromatics, among others (Adams, 1844–1847; Kobert, 1909). Alexander of Trailles (9.1) realizes the difficulty in distinguishing colic from diseases located in the adjoining parts. He first treats colic pain occasioned by cold humor, and recommends such remedies as thinning food, including white wines in cases of flatulence, the use of a sulfurous bath if convenient, purging with aloes, scammony, and the like, administering clysters of hot oil, either alone or with some carminative, giving narcotics, such as opium and henbane, when the humors are thin and acrid but not otherwise, and sometimes giving emetics (see Adams, 1844–1847). When the colic is attended by constipation, he suggests giving water, oil, and mead, or administering the same in clysters. In obstinate cases he recommends inflating the bowels with bellows and injecting afterward some niter and oil and water; he is not averse to prescribing pills or pellets of lead.

The beginning of Caelius Aurelianus' (*Chronic Diseases* 4.7) chapter on colic is lost. As additional symptoms, he notes "a feeling of heaviness, thirst, loss of appetite, and during an attack or exacerbation of the disease, cold numbness and leaden color of the limbs, sweating, dullness of the mind, and a small, thick pulse. There are also hiccoughs, suppression of bowel movements or else painful evacuation, difficulty of urination, heaviness of the head, and intestinal churning and rumbling (Greek *borborygmos*). In the increasing phase of the disease the patient vomits thick fluids (Greek *phlegmata*), then bilious matter. And there is distention of the membrane, called *peritonaeos,* which is situated underneath the skin and encloses the abdominal cavity. If this distention persists, the parts when struck with the palm of the hand resound like a drum; this is due to the puffing-up of the membrane. Again, there is abdominal swelling and much rumbling; during the remission wind is passed noisily through the anus." Paulus Aegineta (3.43) describes the pathological features of (lead?) colic: "there is a sensation in the abdomen as if it were pierced by a wimble; they are troubled with tormina, eructations, nausea, and vomitings of all kinds, but more especially of phlegm. The belly is greatly constipated, so as not to allow the passage of even wind; and any faeces which are discharged seem like the dung of oxen, light and windy. . . . When the attack proceeds from flatulence, there is rather a sense of distension. When it is from inflammation, there is a sense of heat in the part, and no inconsiderable fever, retention of the urine as well as the faeces, pulsation in the belly, thirst, and troublesome heat, nausea, and vomitings, more especially of

bile, which afford no relief. In short, this is the most severe of the colic affections, and threatens to pass into ileus. When acrid and sharp humours are the cause of pain, the patients, as in the case of inflammation, have heat, thirst, and sleeplessness. . . ."

In the same chapter, Paulus Aegineta (3.43) described pandemic attacks of colic followed by paralysis of the extremities and sometimes accompanied by epileptic-like seizures and death (see Major, 1945, p. 313):

> I consider moreover a colicky affection, which still becomes violent from a kind of collection of humors, which took its origin from regions in Italy, moreover in many other places in Roman territory whence like the contagion of a pestilential plague. Wherefore in many cases it passed into epilepsy, to some there came loss of motion with sensation unhurt, to many both, and of those who fell victims to the epilepsy, very many died. Of those indeed who were paralysed, not a few recovered, for the cause which attacked them ended by crisis.

The preceding is generally regarded as the first extant account of epidemic lead poisoning (Baker, 1767; Tanquerel des Planches, 1839; Major, 1945). Like Pliny (26.6) before him, Paulus claims the colic to be a relatively new pandemic disease, but he says nothing of the possible antecedent causes. It is clear, however, from the preceding section that colic was familiar to many ancient doctors who presumably did not realize the pandemic nature of the disease in their own time.

Caelius Aurelianus described a number of acute diseases, sometimes caused by wines and luxurious dishes, which are very reminiscent of saturine encephalopathy. Among such syndromes are seizure *(catalepsis),* which is supervened by benumbed and blunted senses, ocular neuritis, persistent failure to evacuate the stomach, abdominal distention with rumbling of intestines, failure to draw back the limbs again after they have been stretched out, or to stretch them out again after they have been contracted, and so forth (*Acute Diseases* 2.10). Among the acute diseases associated with intemperance, Aurelianus (*Chr. Dis.* 2.1) refers to paralysis with such supervenient symptoms as the stiffness and numbness of the parts, pallor, feeling of heaviness in the parts in question, atrophy, apoplexy, and catalepsis. The association of these Aurelianian diseases with a life-style liable to have been subjected to extensive dietary exposure to lead would implicate lead as a possible etiological factor in the syndromes described. Even the remedies prescribed would provide relief in cases of acute plumbism.

The most vivid description of lead poisoning really comes in the following poem by an anonymous Greek or Roman hermit on the curse of intemperance (transl. by Humelbergius Secundus, 1829):

> Hence gout and stone afflict the human race;
> Hence lazy jaundice with her saffron face;
> Palsy, with shaking head and tott'ring knees.

> And bloated dropsy, the staunch sot's disease;
> Consumption, pale, with keen but hollow eye,
> And sharpened feature, shew'd that death was nigh.
> The feeble offspring curse their crazy sires,
> And, tainted from his birth, the youth expires.

The author indeed mentions the principal warning symptoms of classic lead poisoning.

Ingestion of Lead Compounds

As suggested before, lead was recognized as deadly poison in prehistoric times. The earliest extant work that describes the toxic effects of lead, however, is the *Alexipharmaca* by Nicander (or Nikander)—a second century B.C. Greek poet, physician, and grammarian. In his text written in verse, Nicander lists 22 poisons, including white lead and litharge. The precise and detailed account of the symptoms of lead poisoning and the remedies recommended suggest that he was merely compiling or copying a body of knowledge that was already considerable and probably quite old (Allbutt, 1921, p. 364; Stevenson, 1949). Stevenson (1949, p. 13) speculates that Nicander based his description of acute poisoning on an earlier account in a nonextant book by Apollodorus (ca. 300 B.C.), who presumably drew his information from much earlier sources.

In the description of symptoms arising from the ingestion of white lead, Nicander (*Alexipharmaca,* lines 75–85) mentions constriction of the palate and gums, pallor, asperity of the tongue, singultus, colic, a very dry cough, palsy, nausea, ocular disturbances, and torpor. The following poetic transliteration is from Major (1945, p. 312):

> The harmful cerussa, that most noxious thing
> Which foams like the milk in the earliest spring
> With rough force it falls and the pail beneath fills
> This fluid astringes and causes grave ills.
> The mouth it inflames and makes cold from within
> The gums dry and wrinkled, are parch'd like the skin
> The rough tongue feels harsher, the neck muscles grip
> He soon cannot swallow, foam runs from his lip
> A feeble cough tries, it in vain to expel
> He belches so much, and his belly does swell
> His sluggish eyes sway, then he totters to bed
> Complains that so dizzy and heavy his head
> Phantastic forms flit now in front of his eyes
> While deep from his breast there soon issue sad cries

Meanwhile there comes a stuporous chill
His feeble limbs droop and all motion is still
His strength is now spent and unless one soon aids
The sick man descends to the Stygian shades.

The remedies suggested by Nicander (*Alexipharmaca,* lines 88–114) are quite extensive and include, interestingly enough, the "sweating off" of the lead:

> Give the patient at once a cupful of oil of the premadia- or orchis- or myrtle-olive, so that the stomach being lubricated may avoid the evil drug; or else you may readily milk the udder's swelling teat and give it to him; but skim the oily surface from the draught. And you may infuse sprigs or leaves of the mallow in fresh sap and dose the sufferer with as much as he can take. Or again pound sesame seeds and administer them also in Wine; or else heat and cleanse in water the ashes of vine twigs, and strain the lye through the interstices of a newly woven basket, for this will retain the sediment. Moreover if you rub down the the hard stones of the persea in gleaming olive oil, they will ward off injury. . . . Or else you should break in roasted barley the sap which congeals upon the frankincense bushes of Gerrha; also as helpful you should dissolve in warm water the tears from the wallnut-tree or from the plum or those which ever drip in plenty on the elm-twigs, and drops of gum so that he may vomit up part of the poison, and part render wholesome as he yields to the hot water when the sweat moistens his body. Again he might sate himself with a meal which he has taken or with strong Wine and so escape an inglorious death.

Dioscorides (cited by Tanquerel des Planches, 1839) gives the manifestation of plumbism following the ingestion of white lead, red lead, or litharge as hiccups, coughing, dryness of tongue, coldness of the extremeties, hebetude, paralysis of the limbs, epigastric heaviness, very acute colic, and griping and suppression of urine that takes on a leaden hue. The counteractive measures recommended by Dioscorides are practically the same as those suggested by Nicander.

Scribonius Largus (*Compositiones,* pp. 183–184) added to the symptoms of white-lead poisoning the whitening of both the tongue and the commissures between the teeth, nausea, vertigo, dimming of sight, and dyspnea. Aëtios (4.1) described with graphic exactitude the morbid effects of swallowing ceruse or litharge: "We can observe heaviness of the stomach and excruciating, twisting pain, similar to volvulus, especially around the navel; there is anxiety and general agitation. The body becomes livid and takes on a leaden hue. Finally, burning pains are felt in the articulations. If the disease takes a turn for the worse, paralysis of the extremities appears as well as delirium and convulsive trembling."

Paulus Aegineta (5.59) did not add anything really new, either to the symptomology or treatment of white-lead poisoning:

> Ceruse, owing to its colour, cannot be mistaken, and when taken voluntarily it whitens the palate, tongue, and the intervals between the teeth. It also brings on hiccup and cough, dryness of the tongue, and coldness of the extremities, with disorder of the intellect and difficulty of moving. In this case it will be proper to give honied water or the decoction of figs, or of mallows, or hot milk, or sesame triturated with wine, or the lye of vine shoots, or the oil of marjoram, or iris; also the bones of peaches, with a decoction of barley or frankincense, or the gum of prunes, or the juice of the elm which is contained in its follicles, along with tepid water; but let them immediately vomit. The juice of thapsia will also be proper for them, or three oboli of the juice of scammony, when drunk with honied water.

Celsus (5.27) certainly knew of the toxicity of white lead, for he precribed "mallow or walnut juice rubbed up in wine" as an antidote to white-lead poisoning.

Nicander (*Alexipharmaca,* ll. 595–611) also describes the intoxication symptoms induced by swallowing litharge as borborygmi, violent colic, retention of urine, swollen limbs, and leaden discoloration of the skin. His remedies include warm stimulants, diuretics, and carminatives:

> Also do not neglect *litharge,* which brings suffering when its hateful burden sinks into the stomach and wind circulates and rumbles about the mid navel, as in a violent colic which overpowers men, smiting them with sudden pains. The victim's flow of urine fails; then the limbs swell and the skin has the appearance of lead.
>
> Give the patient either a double obol's weight of myrrh or a fresh infusion of sage, or else cut him hypericum from the hills, or sprigs of hyssop, or again a spray of the wild fig and seed of celery from the Isthmus. Or else you should roast pepper along with rue and grate them into wine, and so rescue him from deadly sickness. You should also give fresh buds of henna, or the firstling fruit of the pomegranate with the flower still upon it.

Additional signs of litharge poisoning adduced by Scribonius Largus include a sensation of weight, inflammation and pain in the stomach, a marked leaden hue in the face, and suppuration of many parts. As remedies, he recommends emetics and calefacient medicines such as pepper, myrrh, and parsley. Paulus Aegineta (5.61) merely articulates the well-known pathological features of litharge poisoning in the following passage: "Litharge, when drunk, brings on heaviness of the stomach and bowels, with intense tormina; sometimes by its weight it wounds the intestines, occasions retention of urine and swelling of the body, which becomes of a leaden hue, and assumes an unseemly appearance. In such cases it will be proper, after vomiting, to give the seed of the wild clary (horminum) to drink with wine, three oboli of myrrh, wormwood, parsleyseed, pepper, the flower of privet with wine, and the dried dung of wild pigeons, with nard and wine."

Paulus Aegineta (5.62) also states that the shavings of lead or its soils induce the same symptoms as those from litharge, and that it is to be treated in the same manner. Furthermore, the very close similarity between the pathological features of mercury and litharge poisoning is noted by Paulus (5.63), who adds that a copious draught of milk seems to be beneficial, and that vomiting ought to be encouraged.

When the writings of the ancient physicians—from Nicander to Paulus—are compared, it appears that the authors drew upon wide experience that was supported by a body of knowledge that had existed for centuries. None of the ancient authorities dealt with the prognosis and sequelae of lead poisoning. Furthermore, the circumstances surrounding the ingestion of lead salts—whether accidental, suicidal, or homicidal—are not recorded. There is a noticeable divergence of opinion in the speculative theories about the pathology and treatment of lead poisoning, depending on the school to which the practitioner belonged and personal conviction. The available literary records generally evince common sense in the treatment of patients known to have swallowed lead. The descriptions of lead toxicity within the framework of occupational or other exposures given, for example, by Pliny (14.22, 34.41, 34.50) and Vitruvius (8.3, 8.6) have already been referred to.

The ancient literary sources thus clearly show an important dichotomy in their apprehension of lead poisoning. On the one hand, there was the precise understanding of the toxic effects of ingesting lead or its salts. On the other hand, we have the documentation and diagnosis of a mysterious disorder with pathognomonic features reminiscent of plumbism, but it was apparently not associated with lead in the minds of the ancient clinicians. This failure to diagnose lead as the causative factor of the mysterious and often vague syndrome is believed to have caused much human suffering, even in modern times, and also to have been particularly inauspicious for aristocrats in the Roman Empire.

Accounts in Ancient Indian and Chinese Texts

Lead poisoning was rarely described as a unique disease in the ancient Indian works extant. However, the premonitory symptoms given for an elixir or metallic poisoning sometimes are fairly identical to those of plumbism. In other words, plumbism was likely to have been properly diagnosed and treated as "metallic poisoning" without actually implicating lead as the etiological factor.

The Sanskrit text *Sushruta* listed white arsenic and yellow orphiment as the two mineral poisons, and it excluded the lead salts. Nevertheless, there is a very close resemblance between the syndrome of acute plumbism and the following premonitory symptoms of the weak and slow mineral poisons

(Dushi-Visha). ". . . heaviness of the limbs, yawning, a sense of looseness (in the joints), horripilation and aching of the limbs. These are followed by a sense of intoxication after meals, indigestion, disrelish for food, eruptions of circular patches *(Mandala)* on the skin, urticaria *(Kotha)*, fainting fits, loss of the vital principles of the organism, atrophy of the hands and legs, ascites *(Dakodara)*, vomiting, epileptic fits, Vishama-jvara, high-fever and an unquenchable thirst. Moreover, some of these poisons produce insanity. Some of them are characterised by an obstinate constipation of the bowels *(Ánáhara)*, others, by an involuntary emission of semen while a few others produce confused speech, or some other similar disease" (*Sushruta Samhita: Kalpa Sthanam*, ch. 2). The sequelae given for *Sthávara* (mineral or vegetable) poisoning are also interesting, in the sense that most of the symptomatological features mentioned are manifested by acute lead poisoning:

> The second stage is marked by such symptons as shivering, perspiration, burning sensation, itching and pain in the body; when seated in the *Ámáśaya* (stomach) it causes pain in the region of the heart. The third stage is marked by a dryness of the palate and severe (colic) pain in the stomach. The eyes become discoloured, yellow-tinted and swollen. When seated in the *Pakvášaya* (intestines) it produces hic-cough, cough, and a sort of pricking pain rumbling sound in the *Antra* (intestines). The fourth stage is marked by an extreme heaviness of the head. The fifth stage is marked by salivation, discolouring of the body and a breaking pain in the joints. It is marked also by the aggravation of all the *Dosdas* and pain in the *Pakvádhána* (intestines?). The sixth stage is characterised by loss of consciousness or excessive diarrhoea; while the seventh stage is marked by a breaking pain in the back, the shoulders and the waist and a complete stoppage (of respiration). (*Sushruta Samhita: Kalpa Sthanam*, ch. 2)

The treatments recommended for *Sthávara* poisoning include the immediate inducement of vomiting, the administration of *Agada* (antipoisonous potions) mixed with honey, clarified butter, or a decoction of *Yashti-Madhu*, and the use of *Nasya*, or medicated snuffs. These excerpts are presented here merely to suggest that the ancient Indian doctors were conversant with the symptoms of lead poisoning, even if they did not recognize lead as the causative factor.

Needham's forthcoming monograph will shed much-needed light on exposure to lead and the pathogenic poisoning by it and other heavy metals in ancient China. Only a brief discussion of elixir poisoning will be given here, which is based primarily on a paper by Ho Ping-Yü and Needham (1970).

It has already been noted that many ancient Chinese elixirs contained large amounts of lead. The numerous cases of death from elixir poisoning have been documented by Needham (1974, 1976, 1980). There is also ample textual evidence that some of the adepts were aware of the toxicity of

the elixir preparations since very early times. One of the earliest cases of elixir poisoning was a certain Sui—the personal physician to the prince of Chhi (ca. 216–150 B.C.) who ingested his own preparations containing the five minerals and died of ulcers *(chü)* in the chest after 100 days (Ho Ping-Yü and Needham, 1970). The Chin emperor Ai Ti (reigned: 361–366 A.D.) "abstained from cereal grains, but consumed elixirs. As a result of an overdose, he was poisoned and no longer knew what was going on around him" (Ho Ping-Yü and Needham, 1970). Other examples are given in the paper by Ho Ping-Yü and Needham (1970), and also in other works by Needham (1974, 1976). The strongest warning against the toxicity of elixir preparations is the following excerpt from a much later work—the *Pen Tshao Yen I* [The meaning of the pharmacopoeia elucidated], which was probably written around 1100–1119 A.D. by Khou Tsung:

> Although there are medical recipes that include mercury, great care should exercised because of its toxic effects. For a woman an overdose causes sterility. Nowadays people often use it for treating convulsion, fever, and increasing the flow of saliva *(ching jê hsien chhao)* in children. Not a word about these uses can be found in the *(Shen Nung Pên Tshao) Ching* (written around first century B.C.). Hence the matter requires further elucidation. (Mercury when) mixed with lead forms an amalgam *(ning;* lit. coagulates). It has an affinity for *(chieh;* lit. ties with) sulphur (forming mercuric sulphide). It breaks up *(san;* lit. disperses) when ground together with the fleshy part of a date. In one of its applications it can be heated to form face powder *(ni fên)*. Calomel *(fên shuang)* ground with saliva can be used for killing fleas. Copper brightens when (mercury) is applied to it. If poured into a corpse mercury will delay putrefaction. Gold, silver, copper and iron will float when placed on mercury. With lead *(tzu ho chhê)* mercury is subdued *(fu)*.
>
> Han Yü of the Thang (period) said: "Li Chhien, a Professor of the Imperial Academy *(Thai Hsüeh Po Shih)*, met the alchemist Lui Pi, a man from Hsinan, who could heat mercury and convert it into an elixir. The method consisted of filling a reaction-vessel *(ting)* with lead, leaving some space at the centre for the introduction of mercury, and when the cover was replaced and sealed all-round, the contents were heated to form lead amalgam. After taking (the elixir) (Li Chhien) passed blood in urine and faeces, and after four years he got worse and died. I do not know exactly when the teaching about elixirs first began. (Although) it has resulted in countless deaths among people, yet the art is still admired and sought after even today. (Many instances of) such delusion have already been recorded in the literature. Without quoting from hearsay evidence I shall now refer to six or seven persons known to me personally who came to grief after taking elixirs. I witnessed these things myself and set them forth here to serve as a public warning. . . ."
>
> "These (examples) should (be sufficient) to serve as warnings. Is it wise to try to avoid death in such a way as to hasten one's death instead? The five cereals, the three kinds of animals used for offerings *(san shêng,* i.e., fowls, fish and pigs), salt, vinegar, fruits and vegetables are the things that men normally eat; they constitute the essential foods which give us strength. Now misguided people clamour that the five cereals shorten human life and should be eaten as little as possible. They only feel sorry for themselves when death is approaching. How regrettable this is!"
>
> Nowadays there are people who roast mercury into cinnabar, but without being aware of (the poison) some physicians use (the cinnabar) for coating medicines or as ingredients of prescriptions. Is not this a great mistake and can we ever be off our guard?" (Transl. by Ho Ping-Yü and Needham, 1970, p. 323)

The awareness of elixir toxicity by the ancient Chinese adepts is further attested to by attempts at toxicological experimentation by Wei Po-Yang (a second century A.D. adept), using white dogs, and by Thopa Kuei (ca. 400 A.D.), using condemned criminals. Chhen Shao-Wei—a Thang alchemist—stresses that lead, silver, copper, tin, gold, and iron are all poisonous. In the *Chen Yuan Miao Tao Lüeh* [Classified essentials of the mysterious Tao of the true origin of things], which contains material dating back to about the fourth century A.D., the putative author Cheng Ssu-Yuan gives case histories of people who died from ingesting elixirs made from lead, mercury, cinnabar (usually a lead–mercury amalgam), and silver. He also cites people who became seriously ill through drinking "liquid lead" made by heating "black lead" (see Ho Ping-Yü and Needham, 1970).

There was, however, a different school of alchemists who totally ignored the health risks from metallic elixirs, and who even considered the toxicity syndrome, following the taking of the preparations, to be quite normal and propitious. One striking passage to this effect comes from the *Thai-Chhing Shih Pi Chi* [Records in the rock Chamber: a Thai-Chhing scripture]—an early sixth century A.D. text, but with some material dating back to the third century: "After taking the elixir one feels an itch all over the body and the face, rather like having the sensation of insects crawling over one. The body, the face, the hands and legs may become swollen. One may experience a feeling of repulsion at the sight of food, and vomiting usually follows after a meal. One feels rather weak in the four limbs. Other symptoms include frequent defaecation, vomiting, headache and pains in the abdomen. No alarm should be caused by these effects, because they are due to the work of the elixir in dispelling all the inherent disorders (in the human body)" (Ho Ping-Yü and Needham, 1970, p. 331).

From the preceding account, it is clear that the ancient Chinese adepts and doctors were familiar with the many symptoms of lead, and other metallic, poisoning. The premonitory symptoms of elixir poisoning given in the preceding literary sources include loss of appetite, headaches, oedema, weakness of the extremeties, severe abdominal colic, cramps, vomiting, nausea, formication, muscular tremor, or paralysis, and severe impairment of mental faculties. Whether lead poisoning per se was recognized as a unique disease is not clear from these sources.

Considerable effort was nevertheless devoted to developing mitigative measures against elixir poisoning: "The five metals and the three *lung* (mercuries) together with the nine *chhien* (leads) and the eight minerals are

all poisonous. Without procuring the original formulae of the ancient (masters) any attempt to use newly acquired recipes described verbally in a few words is doomed to failure. Hence Hu (Kang) Tzu says, 'the five metals have to be purified from all poisons caused by heating. If they are not properly treated the poison will turn to a powder form, and if (the ingredients) are used for making elixirs without having their poison removed, and ingested for any length of time, death will be caused when the rules are not followed.' " The preceding excerpt is from the *Huang Ti Chiu Ting Shen Tan Ching Chüeh* [Explanation of the Yellow Emperor's manual of the nine-vessel magical elixir]—a large tract of Thang or Early Sung vintage that includes material dating back to the second century A.D. (Ho Ping-Yü and Needham, 1970).

According to this text, the method used by the ancients to render the lead harmless was to "heat it in vinegar together with red salt and cinnebar." Several ancient texts endeavored to neutralize the elixir toxicity by the proper blending of the *yin* and *yang* ingredients, according to the theory of categories. Others recommended potent herbal mixtures that could serve both as an elixir and as an antidote for ordinary elixir poisoning. The necessity of building up one's constitution before embarking on the elixir diet is stressed in the *Chen Chung Chi* [Records of the pillow-book], attributed to the legendry Sun Ssu-Mo who died ca. 682 A.D.: "One must take vegetable and plant drugs at first until their beneficial effects are felt; then only can one take mineral drugs for the purpose of achieving longevity" (Needham, 1976, p. 135). The techniques for "killing" the metals are typically encountered in the Indian alchemical texts, and they serve basically the same objective. The more traditional detoxifying treatments were of course, also employed. A good example of this comes from the *Thai-Chhing Shih Pi Chi* that has been referred to previously:

> When the elixir takes effect one should immediately bathe oneself with hot and cold water and take a mixture of scallion, soya-bean sauce and wine. The same cure is to be recommended (for relieving the after-effects of) *hsün huang* (a dark variety of realgar). If relief does not come, then a hornet's nest *(lu fêng fang)*, some *Euphorbia sieboldiana (kan sui)*, some Solomon's Seal *(Polygonatum officinale)* (wei jui) and some *Ephedra sinica (ma huang)* may be separately extracted with boiling water and combined for use as a medicine. One dose is sufficient to bring relief.

Such a therapy may be compared with the treatments administered by the Greco-Roman doctors, which were discussed before.

Saturnine Gout among the Aristocrats of the Roman Empire

The pathogenesis of saturnine gout is of great interest in terms of possible pandemic lead poisoning in ancient times. Unlike the syndrome for plumbism, the symptoms for gout in its acute and chronic forms and associated

lithiasis have been familiar to physicians and the common people since remote antiquity. Furthermore, the history of gout has been a more fertile field for study, and the wealth of information garnered can shed some light on the catenated incidence of lead poisoning. Any reader interested in the history of gout should consult, for example, the following authors: Garrod (1876), Duckworth (1889), Delpeuch (1900), Schnitker (1936), Ludwig (1957), Bywaters (1962), Rodnan and Benedek (1963), Copeland (1964), Mertz (1971), Talbott and Yü (1976), and de Vries (1976). A succinct review of saturnine gout has been presented by Wyngaarden and Kelley (1976).

Although Musgrave (1723) is generally credited with the first report of coexistent gout and plumbism, it was Sir Alfred B. Garrod (1859) who clearly demonstrated the high incidence of plumbism in gouty subjects and adduced a causal relationship. Garrod (1859, 1876) reported that roughly 25–33% of his gouty patients were plumbers and painters who had acquired their plumbism from occupational exposure. Studies in many countries have confirmed Garrod's observations, and the literature of the latter half of the nineteenth century is particularly voluminous with case reports and controversies regarding whether or not the lead acted in a secondary-excitant or primary-causal manner (see Ludwig, 1957).

Ball (1971) has inferred that the epidemic of gout among the British gentry of the eighteenth and nineteenth centuries resulted from the consumption of prodigious amounts of wine contaminated with lead. In another important study, Ball and Sorensen (1969) found that 37 of their 43 patients acquired saturnine gout from prolonged exposure to the relatively small amounts of lead in the illicit alcoholic drink called "moonshine." Apparently, the damaged tubules cause the retention of uric acid, which many clinicians believe is responsible for gout (Wyngaarden and Kelley, 1976; Wessel and Dominski, 1977). Did gout also stigmatize "the noblemen of fashion and wasted fortune" of the Roman Empire who had a similar bacchanalian disposition?

Before considering the incidence of gout in ancient times, it should be noted that the term "gout" was only introduced into the medical literature during the thirteenth century by the famous French historian Geoffroi de Villehardouin (Neuwirth, 1943; Hartung, 1957). The Greek and Roman authors used the equivalent term *podagra*—a cognomen for an affection of the joints of beasts of burden (Skinner, 1949). Later, classical authors also used other terms for pains or seisures in other joints of the body, such as *chiragra* for the hand, *gonagra* for the knee, *pechyagra* for the elbow, *dentagra* for the teeth, *cleisagra* for the clavicle, *omagra* for the shoulder, *rachisagra* for the spine, and *sciatica* for an involvement of the hip (Caelius Aurelianus *Chronic Diseases* 5.2; Schnitker, 1936). In these various guises, gout may be regarded as one of the most common diseases in classical times.

The Hippocratic corpus is generally credited with the earliest clinical

description of podagra. The corpus recognized that rich foods and wines had something to do with its cause, that there was a rich-man's gout and a poor-man's gout, that eunuchs were hardly ever affected by it, and that its onset only occurred after puberty in young men and after the menopause in women (*Aphorisms* 6.28–30; *Prognostics* ch. 15). The consumption of fermented beverages was no longer considered a taboo in these two age groups. Hippocrates believed in the value of the diet in management, and he administered purgatives by the mouth or by injection, noting that "the best natural relief of this disease is an attack of dysentery." Severe colic and constipation are also indicative of acute lead poisoning. These views were widely espoused by ancient and medieval doctors throughout the Western world.

Seneca (*Epistle* 95) regarded gout as a monstrous example of the depravity of his age—that the women, by their luxurious habits, had become subject to gout. It is significant that the prohibition against bibulous wives was relaxed in the late Republic times (Balsdon, 1962, p. 213). It became a topic of much satire and ridicule by the literati of the Roman Empire—Virgil, Martial, Athenaeus, Juvenal, Ovid, and Musonius commented on gout in their writings. Such a posting suggests that it must have been a very common disease then. Pliny (*Natural History* 26.64) remarked that podagra "was a rarer disease within the memory, not only of our fathers and grandfathers, but also of our own generation. It is also itself a foreign complaint; had it existed in Italy in early times it would have received a Latin name. It must not be considered incurable, for many cases have been cured without treatment, and yet more with it." The large number of remedies subsequently recommended and Pliny's frequent allusions to podagra also suggest that this disease had become a matter of common concern.

Celsus (*De medicina* 4.24) stressed the value of regular exercises and the avoidance of obesity in the management of podagra, and he observed that most of the Roman emperors suffered from gout. The excruciating pains from recurring bouts of acute gout eventually led the consul Agrippa to commit suicide (see Talbott and Yü, 1976). Galen *(De medicina: Commentary on Hippocratic Aphorisms)* added that venery was also a cause of gout and is reputed to have coined the aphorism "podagra is the daughter of Bacchus and Venus" (Schnitker, 1936). Arataeus (*Extant Works* 2.12) reported a higher incidence of gout in males, and he postulated that the cause of gout was a toxic substance—a *pecant humour*—rather than the accumulation of natural humors that was espoused by Hippocrates, Galen, and others. He is credited with the first use of hellebore, a mild purge, in gout pharmacognosy, and he clearly recognized the intermittent nature of the disease. Psellus (*Opus medicum,* cited in Adams, 1844, p. 668) believed that gout was occasioned by an atony of the nutritive faculty that engendered the collection of a thick humor in the system.

Caelius Aurelianus (*Chronic Diseases* 5.2) reiterates that intemperance, indigestion, and debauchery are the usual precursory causes of gout, and

he describes the disease as a "sensation as if ants are crawling over the part." He reported a prevalence of gout in Cairo and Alexandria, even though podagra is reputed to be uncommon in the economically deprived, non–wine-producing tropics. He reviews the well-known supervenient symptoms that certainly elicit some comparison with plumbism: numbness of joints, difficulty in movement, feeling of heaviness, intense heat or cold, sleeplessness, severe distress, constipation, and so forth. He strongly favors a sparse diet in treatment. Alexander of Tralles (*Works,* ch. 11) is famous for introducing colchicum (hermodactyl) into the management of gout. He also realized the seasonal and intermittent character of the disease, and he devised a "cyclic treatment" based on the regulation of diet, catharsis, and abstinence from liquor and dainty dishes. He lists some 40 prescriptions for the treatment of gout—some containing as many as 30 ingredients. Paulus Aegineta (*Seven Books of Paulus Aegineta* 3.78) outdid Alexander in listing over 70 prescriptions for the disease. The variety of remedial measures employed by these Byzantine doctors suggests that gout continued to remain a very common endemic disease.

Soranus of Ephesus, Serenus Samonius, Scribonius Largus, Aëtius, Oribasius, Actuarius, Nonnus, and Octavius Horatianus also left a fine heritage on the subject of gout (see Adams, 1844, p. 667). Particularly noteworthy in the ancient annals on gout is the tragicomic poem entitled "Tragopodagra," which is usually attributed to the famous Lucian. It is a witty ridicule of the many pretended nostrums for this particular ailment:

> from hands and feets extremitys
> th' impetuous fiery ichor flyes;
> a furious spirit thro' every vein.
> rushes with unrelentive pain.
> whilst every member, as it come,
> th' encaustic pestilence consumes
> as the rock Aetna's furnace burns,
> and marble into pumice turns:
> so by thy chemistry we find
> our bones and joints to chalk calcin'd;
> or knotty made and motionless
> O who can thy dire dills express!
>
> LUCIAN

The pestilential nature of gout in those days is recorded in the poem.

The profusion of the ancient literary records clearly suggests that podagra was a pandemic disease, particularly during the Roman Empire. How much of this was of the saturnine variety? Running thematically through the ancient annals on gout is the relationship between this disease and the consumption of dainty dishes and alcoholic beverages. In summarizing the

ancient precepts of clinical gout, Garrod (1876) remarked that "no truth in medicine is better established than the fact that the use of fermented liquors is the most powerful of all the predisposing causes of gout." He then wondered "whether gout would have been known to mankind had such beverages not been used." Morris Longstreth (1882) shared the same view: "Screw up the vice as tightly as possible, you had rheumatism; unscrew it and there was gout." Of all the likely constituents in ancient wines, lead—in fact—is the one that most actively potentiates gout, particularly during continuous exposure (see Ball, 1971).

The bibulous enthusiasm of the Romans is certainly legendry. Pliny (14.29) estimates that there were at least 185 brands of wines in his time, and double that number if one counted the varieties. Athenaeus knew of 85 brands of wines, Galen enumerated 60, and Strabo 30 (Forbes, 1965). The average annual consumption of wines in ancient Rome has been estimated to be about 1 to 5 l/day^{-1}/person (based on data from Loane, 1938; Frank, 1959; Forbes, 1965). On special days, however, immense quantities were consumed. For example, Lucullus needed about 4 million liters for his triumphal banquet (Loane, 1938). The drunkenness of the Roman aristocrats is certainly well known and need not be pursued here. In terms of their bibulous habits, there is thus a commonality between the noble "gouty" of eighteenth- or nineteenth-century Britain (Bywaters, 1962; Ball, 1971) and the aristocrats of the Roman Empire. The analogy is even more profound: The two privileged classes assuaged their prodigious thirst with wines believed to be contaminated with goutogenic lead.

The proscription of dainty dishes was another strategy in gout management used by many ancient doctors previously mentioned. The efficacy of such a treatment becomes comprehensible with the realization that most of these dishes were particularly liable to be contaminated with "goutogenic" lead. The often mentioned seasonal and intermittent nature of the gouty attacks also fits the well-known symptoms of plumbism (Chisolm, 1971; Wessel, 1977).

The English gentry of the eighteenth and nineteenth centuries also ingested much lead from dietary sources—a fact ignored by Ball (1971). In addition to contamination from lead pipes as well as pewter pots and pans, the spices and sauces used in their dainty dishes, their confectioneries, and their tobacco were often adulterated with lead (see, for example, Robertson, 1781; Accum, 1820; Filby, 1934). Here again we see a common thread in the life-styles of the gouty English nobility and the aristocratic Romans—they were liable to have acquired unhealthy quantities of lead from their voracious appetites.

Credence for the hypothesis that saturnine gout was pandemic among the aristocrats of the Roman Empire comes in the form of an actual eyewitness account. Musonium (ca. 20–90 A.D.), in fact, has left us the following perceptive account of coexistent gout and plumbism among the aristocrats (i.e., the "masters") of his time who lived on prepared dainties:

> That masters are less strong, less healthy, less able to endure labour than servants; countrymen more strong than those who are bred in the city, those that feed meanly than those who feed daintily; and that, generally, the latter live longer than the former. Nor are there any other persons more troubled with gouts, dropsies, colics, and the like, than those who, condemning simple diet, live upon prepared dainties. (Transliteration by Humelbergius Secundus, 1829)

Crediting Musgrave (1723) with the "discovery" of saturnine gout seems to have been misplaced. A recent study of the skeletal remains from Corinium Dobunnorum (Cirencester, Gloucestershire) indeed confirm a high incidence of gout among the Roman-age inhabitants (*Toronto Globe and Mail,* Dec. 13, 1982, p. 14).

LEAD POISONING AND THE DECLINE OF THE ROMAN EMPIRE

Seutonius (*The Twelve Caesars* 3.4) claimed that the decline of the Roman Empire was a result of apathy and gluttony. Cicero (106–43 B.C.) shared a similar prudent foresight in his tacit comment that "the mouth claims more victims than the sword." Modern research now seems to bear out their serendipitous claims, but in a rather different sense.

During the past 500 years or so, several authors have suggested that the general contamination of food and drink with lead—particularly during the Roman Empire—would have resulted in the widespread incidence of plumbism. The venerable Sir George Baker (1767, p. 270) perceptively observed: "It will hardly be doubted, but that the juice of the grape, thus evaporated in leaden vessels, must have dissolved some of the metal; and it should seem that the wine, manufactured in the manner above described, must have been prejudicial to those who drank it, in proportion to the quantity of *defrutum* or *sapa* mixed with it." Sir Edward Barry (1775), Henderson (1824), Beckmann (1846)—all referred to the fact that contamination of Roman wines with lead would have been inimical to the health of the many imbibers. Hofmann (1883, 1885) and Kobert (1909) argue perspicaciously that lead poisoning was pandemic during the Roman Empire. In a classic paper, Gilfillan (1965) propounded the thesis that lead poisoning was the major factor in the Fall of Rome.

In the preceding sections, an attempt has been made to document the widespread contamination of Romano-Greek food and drink with lead, and to show that lead poisoning was a pandemic disease during the Roman Empire. On the basis of the available information, estimates of the lead intakes by an aristocrat, a plebian, and a slave during the times of the Roman Empire have been made (see Table 6.3). The suggestion is made that wine consumption generally accounted for 50–60% of the daily intake of all three population groups. The Roman predilection for wines is well known. Athenaeus (1.47), for instance, noted that wine is excellent for health, that it

Table 6.3 Exposure of the Subpopulations of the Roman Empire to Lead

Exposure Route	Pb Concentration in the Source (Range in Brackets)	Daily Intake Rate	Absorption Factor[a]	Amount of Pb Absorbed (μg/day)
	Case I: The Aristocrat (often bibulous and gluttonous)			
Air[b]	0.05 μg m³	20 m³	0.4	0.4
Water[c]	50(50–200) μg/liter	1.0 liter	0.1	5(5–20)
Wines[d]	300(200 – 1500) μg/liter	2.0 liters	0.3	180(120–900)
Foods[d]	0.2(0.1–2.0) μg/g	3000 g	0.1	60(30–600)
Miscellaneous[f]				5.0
Total				250(160–1520)
	Case II: The Plebian			
Air[a]	0.05 μg m³	20 m³	0.4	0.4
Water[g]	0.5(0.5–5) μg/liter	2.0 liters	0.1	0.1(0.1–1.0)
Wines[h]	50(50–400) μg/liter	1.0 liter	0.3	15(15–120)
Foods[i]	0.1(0.1–1.0) μg/g	2000 g	0.1	20(20–200)
Total				35(35–320)
	Case III: The Slave (labor hand)			
Air[a]	0.05 μg/m³	20 m³	0.4	0.4
Water[j]	50(50–200) μg/liter	2.0 liters	0.1	(5–20)
Wines[k]	5(1–10)	0.75 liter	0.3	1.1(0.2–2.0)
Foods[k]	0.05(0.05–0.5)	1000 g	0.1	5(5.0–50)
Miscellaneous[l]				5.0
Total				15(15–77)

[a]Unless noted otherwise, these absorption values, which are for present-day adults, are taken from the NAS Report (1980).

[b]Minor amounts of airborne lead probably derived from domestic combustion of wood. The pulmonary ventilation rate (20 m³/day).

[c]Water pipes to the aristocratic village commonly made of lead; hence the high Pb concentration. High incidence of enophic intake would have reduced the water consumption.

[d]These estimates are rather conservative. It is assumed that the average Pb content of *confusum* wines was 10 mg/liter (less than the value found by Hofmann [1883], or expected from the recipes given by Columella [12.19–21]), and that such blended wines were consumed 5–30% of the time. Most of the lead in the wines would have been bound to organic ligands and hence more readily absorbed through the gastrointestinal tract; the absorption factor for lead in wines is unknown, however.

[e]The voracious Roman gentry in all likelihood consumed more than 3 kg of food per day. Most of the lead in their entrées probably came from the use of sapa as a sweetner or a preservative.

[f]The aristocrats frequently took emetics and antidotes (against surreptitious poisons) which were at times adulterated with lead.

[g]The plebians generally got their water from public water supplies usually with little or no lead plumbing.

[h]The plebians probably drank a lot of the low-grade wines "doctored" by means of sapa or defrutum. They were also liable to have had a drink or so in one of the *caupona, hospitium, popina, taberna,* and *thermopolium* (neighborhood bars, cafes, restaurants, etc.) where the wines were more liable to have been doctored or mulled in leaden kettles. The daily consumption rate of only 1.0 liter is conservative.

[i]Most of the lead in the plebian foods presumably came from pewter utensils and as a contaminant in the condiments.

[j]The slaves presumably got their water from the lead-lined conduits to their master's villae.

[k]Marcus Cato (Articles 56–58) left us with a good account of dietary rations for the field hands. He recommends 4 lb of bread through the winter, increasing to 5 lb when they begin to work the vines and dropping back to 4 lb when the figs ripen. He recommends about 750 ml of the afterwine (grape skins soaked in water) per day. Lead contamination of such simple diets is expected to be minimal.

[l]Most of the exposure would have been occupationally related; that is, from working with lead or its compounds.

is the best thing to dissolve food, that it strengthens, that it assists the circulation of the blood and assures a peaceful sleep. Even Cato (arts. 56–58), a hard and thrifty man, recommended nearly 750 ml of *lora* ("afterwine") a day for each member of the chain gang. And wines were easily affordable in those days! In Rome, the price of common wine, oftentimes adulterated, was only 15 sesterces for an amphora (Columella 3.3), or less than 20 cents per gallon. In Athens, the same measure sold for no more than 5 sesterces (Soyer, 1853).

The daily intake of lead by the aristocratic class is clearly remarkable. The present estimate puts the amount of lead absorbed daily by an average aristocrat to range from 155 to 1500 μg, with a mean of about 250 μg (Table 6.3). The daily doses of lead absorbed by the hoi polloi and a slave field-hand have been estimated to be 35 μg (range: 35–320 μg) and 20 μg (range: 20–97 μg), respectively (see Table 6.3). These figures may be compared with the 30–50 μg/day absorbed by the present-day adult American (NAS, 1980; Drill et al., 1979). The current dietary intake of lead in the United Kingdom is 55–366 μg/day, with a mean of 113 μg/day (DHSS, 1980). These values translate roughly into 6–37 μg/day of lead absorbed. Estimates from various countries suggest that the lead intake from dietary sources typically is 200–300 μg/day. The tolerable dietary intake of lead recommended by the World Health Organization (WHO, 1977) is only 430 $\mu g/day_{-1}$, roughly equivalent to 43 μg of lead absorbed per day. By contrast, the average lead absorption in a pretechnological society has been estimated at only 2.4 μg/day (NAS, 1980).

Even if the estimates of lead intake by the Roman aristocrats are off by a factor of 2–5, there is still a strong suggestion that a large fraction of this population group obtained enough lead from their food and drink to be considered at risk with regard to lead poisoning. Chamberlain and colleagues

(1978) have shown that the intake of 100 μg/day of lead in the diet would elevate the blood's lead concentration by 3.6 (range: 1.4–4.3) μg/dl. The transfer rate for lead in water has been estimated by Berlin and associates (1977) to be 1.8 (range: 0.7–3.4) μg/dl blood lead per 100 μg/liter water lead ingested. We can assume that the mean figures are also applicable to the transfer of dietary and enophic lead ingested by the Romans. Using the data in Table 6.3, the lead concentration in the blood of the aristocrats is estimated to be 50 μ/dl, with a range of 18 to over 300 μg/dl. In terms of the health effects of such lead burdens, it should be noted that an adult's lead concentration in the blood of 30–40 μg/dl can cause chromosomal abnormalities, reduce fertility in women, alter spermatogenesis in men, and increase the incidence of stillbirths and preterm deliveries (Beckman, 1978; Fahim et al., 1975; Jaworski, 1979; OSHA, 1978). On the other hand, lead concentration in adult blood of 40–60 μg/dl have been known to cause anemia, peripheral neuropathy, psychological, sensory, and behavioral changes, and to impair kidney function (Waldron and Stofen, 1974; WHO, 1977; OSHA, 1978; EPA, 1979).The estimate presented here (of 50 μg/dl average) suggests that the lead level in the blood of a typical Roman Empire aristocrat puts him or her clearly above the threshold limit for the onset of plumbism. Furthermore, lead, which is a classic example of a "race" poison (see Hamilton, 1925), would have been passed on to his or her offspring.

There is no denying that there are wide individual variations in the retention of lead, and in the susceptibility to lead poisoning. Furthermore, there were many absteminous aristocrats who lived during the time of the Roman Empire. The estimate clearly pertains to the many aristocrats with voracious appetites for blended wines and dainty dishes. It is documented later that two thirds of all the emperors and usurpers who reigned between 35 B.C. and 220 A.D. fit this mold and would have been susceptible to lead poisoning. If the satirical and humorous literary men are to be believed, a comparable fraction of the entire aristocracy would seem to have been similarly disposed to ingesting large quantities of lead-tainted Apician entrées and Columellan wine blends.

The calculated daily exposure rates are fairly consistent with what has been said in preceding paragraphs regarding the prevalence of plumbism in the aristocratic class. The accounts by Pliny, Lucian, Musonius, and Paulus Aegineta about widespread syndromes believed to be lead poisoning have already been described. The evidence for an epidemic of saturnine gout among the Roman nobility has also been presented. Thus, the literary and archaeological evidence on aristocratic lifestyles in Rome leaves little doubt that a large percentage of the Roman gentry was highly likely to contract lead poisoning. Within the framework of modern toxicological results, the suspected daily intake of lead would certainly have impaired the health of the exposed population.

Evidence for overexposure to lead has been sought in the bony remains of the Romans. Since 80–90% or more of the body burden of lead is stored and fixed in the bones (see Barry, 1978), the measurement of the lead contents of archaeological skeletal samples can thus be used as an index of the total lead absorption, or the exposure of the individual to lead. Indeed, the available data indicate rather clearly that the lead contents of present-day, urban North American populations receiving elevated lead exposure from environmental sources exceed those of pretechnological populations by 1–3 orders of magnitude (see Grandjean, 1978; Ericson et al., 1979; NAS, 1980). Factors that contribute to the eccentricities in the lead contents of archaeological bone specimens have been detailed in several reports (e.g., Grandjean, 1975; Waldron and Wells, 1979; Waldron et al., 1979), and need not be repeated here.

In a pioneering effort that was unfortunately hindered by the analytical inadequacies of his day, Rosenblatt analyzed 22 ancient bones from various sites. He found lead only in the four samples from Carthage—two from before the Roman conquest of the city and two from after the conquest (Kobert, 1909). The lead concentrations could not even be quantified, and the tantalizing results are of but limited significance. On the basis of apparently nonexistent results, Gilfillan (1965) claimed that there was a marked difference in the lead contents of poor Romans vis-à-vis the rich during the Empire period. The claim, based on the unclassified bones of 40 persons, was nevertheless used to buttress his hypothesis that chronic lead poisoning was responsible for the Fall of Rome.

By far, the most comprehensive and detailed work on the use of bones to assess historical exposures to lead has been done by H. A. Waldron and his colleagues (see Waldron et al., 1976; Mackie et al., 1975; Waldron and Wells, 1979). Some of their results from British bone specimens are summarized in Table 6.4. They found that samples from the pre-Roman sites at Bath and Danebury had the lowest lead concentrations. The people who lived in the Romanized town of Cirencester experienced considerably greater exposure to lead as compared to the inhabitants of other contemporary sites (see Table 6.4). The evidence of a bimodal distribution at Cirencester perhaps is related to the difference in the exposure rates of the affluent subgroup, as compared to the hoi polloi. The samples from Verulamian with low lead values are believed to come from:

> an impoverished fringe settlement of native Britons, undoubtedly "romanized" in the sense of being under Roman rule and presumably aware of Roman technology, but probably participating in it at a relatively humble level. They may still have obtained their water from surface supplies or through cheap wooden and earthenware pipes, and seldom enjoyed the praetorian amenities of choice wine, "sugared" fruits, and other toxic delights. It is clear that these Verulamians had a very different life-style from the inhabitants of York and Cirencester, many of whom were likely to have been ex-

Table 6.4 Lead Contents of Archaeological Bone Samples from Various Sites in Britain

Site[a]	Age	Specimen	Number of Samples	Mean Pb Concentration ± (Std. Deviation)
Bath	1600 B.C.	Rib	6	33 ± 8.3
Danebury	Iron Age	Rib	35	35 ± 4.5
Verulamium	Romanic	Long bone	5	31 ± 4.7
York[b]	Romanic	Rib	77	64 ± 32
Henley Wood[c]	Romanic	Rib	41	66 ± 16
Poundbury[c]	Romanic	Rib	161	113 ± 56
Bath	Romanic	Rib	10	56 ± 28
Cirencester	Romanic	Rib	99	303 ± 136
		Vertebra	61	332 ± 139
		Long bone	144	190 ± 94
		Others	12	258 ± 148
Porchester Castle	Anglo-Saxon	Rib	21	93 ± 51
North Elham Park	Anglo-Saxon	Rib	5	151 ± 52
		Long bone	43	139 ± 80
		Others	52	123 ± 51
Red Castle	Anglo-Saxon	Long Bone	8	122 ± 58
		Others	6	102 ± 23
Jarrow	Anglo-Saxon	Long Bone	42	376 ± 217
		Others	21	424 ± 259
Monkwearmouth	Anglo-Saxon	Others	2	379 ± 69
Iona	Eighth to eleventh centuries A.D.	Long Bone	6	36 ± 4.8
		Others	6	51 ± 11
Bonhunt	Ninth to twelfth centuries A.D.	Rib	101	71 ± 33
		Others	33	79 ± 42
King's Lynn	Medieval	Rib	4	104 ± 33
St. Paul	Medieval	Long Bone	14	200 ± 155
St. Michael's	Medieval	Long Bone	17	204 ± 205
		Others	2	100 ± 53

[a]Unless noted otherwise, the data have been taken from Waldron and Wells, 1979. [b]Makie et al., 1975. [c]Waldron et al., 1976.

> legionaries, militiamen, civil servants, or well-to-do tradesmen exposed to a somewhat more elegant—and dangerous—cultural level. (Waldron and Wells, 1979, p. 113)

The Poundbury bones show some evidence (typical of modern samples) of an increase in lead concentration with age (Waldron et al., 1976).

After correcting for the differences in organic matter, blood, and water contents, the mean lead levels of samples from the Romanic cemeteries at Henley Wood, York, and Bath are found to be comparable to those of modern bones. The levels for specimens from Poundbury and Cirencester typically exceed the modern average several times over (see Waldron et al., 1976, for details). The magnitude of the excess lead in the Romano-British skeletons becomes evident when it is realized that the lead contents of modern bones exceed those of ancient, non-lead-using cultures by factors of 10–100 or more (Grandjean, 1978; Ericson et al., 1979). There are other relevant observations. The mean lead levels in the juvenile (15 years or less) bones at Poundbury and Henley Wood are unusually high, averaging about 80 and 70 μg/g, respectively, at the two sites (Waldron et al., 1976). Compared to the petrous temporal bones in modern children that often average less than 15 μg/g (Barry, 1978), "one must seriously consider whether lead poisoning (acute or chronic) played some part in their death" (Waldron et al., 1976, p. 226). The study of an interesting specimen of a 25–35-year-old woman found with the skeleton of a fetus still in her pelvis gave the lead content of the mother's rib as 88 μg/g, and that of the petrous temporal bone of the fetus as 71 μg/g (Waldron et al., 1976). The data indicate an unusually high transplacental passage of lead. "If it were representative of the rate of placental transfer for the maternal population as a whole, then some fetal damage would be inevitable, perhaps even to the extent of causing the fetus to abort (or expire)" (Waldron et al., 1976, p. 227).

In a recent major study, Drasch (1982) analyzed about 650 bones from a total of 332 individuals who lived during various times in the past, and mostly in southern Bavaria. He demonstrated a strong age dependence in the lead contents of the old bones (Fig. 6.1). He also showed that there is a well-defined geographic difference in the lead contents of the prehistoric bones (compare the data for the Peruvians with those of the prehistoric Teutons in Table 6.5). The body burden of lead obviously depends on the availability of lead in the individual's environment. Drasch (1982) noted a significant increase in the average lead concentration in the bones of late Roman age populations compared to the average level found in prehistoric Bavarian populations (see Table 6.5). However, he reached the conclusion that the lead content of the Roman age population is comparable to "that found at Augsburg through the total Middle Age and at Regensburg from the 12th century onwards [See Table 6.5]. From a similar way of life, it can be concluded that *the lead burden in ancient Rome was not significantly higher in the capital than in the legion towns of Augsburg* [italics are

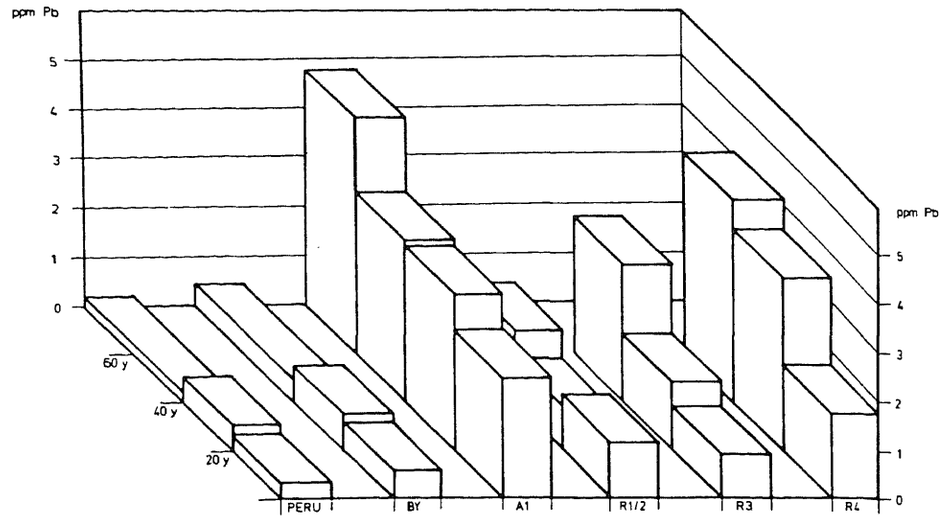

Figure 6.1. Dependence of lead concentration on age. [Reproduced with permission from Drasch (1982, p. 212).] PERU = Peru, 500–1000 A.D.; BY = prehistoric Bavarian sites (18th–5th century B.C.); A1 = Augsburg, Late Roman Age (4/5th century A.D.); R1/2 = Regensburg, Carolingian Age (8/9 century A.D.); R3 = Regensburg, Ottonian Age (10th century A.D.); R3 = Regensburg, Stauffer Age (12th century A.D.).

mine]. Therefore the theory cannot be proven that a chronic lead intoxication at the late Roman Age was the main reason for the fall of the Roman empire" (Drasch, 1982, p. 227). It is clearly fallacious to believe that the extent of exposure to lead was the same in both Rome and the provinces. Furthermore, the claim presumes that the bones he analyzed belonged only to the *aristocratic* class. Little apparently is known about the social status of the Roman Age individuals whose bones were analyzed. Interestingly enough, Drasch's data show a marked binomial (or certainly skewed) distribution:

Concentration (μg/g)	Number of Times Found
0–2	50
2–4	24
4–6	10
6–8	6
8–10	16
10–12	7
12–14	4

Such a binomial or skewed distribution would be expected in a typical Roman population where the well-to-do consumed the lead-contaminated foods and are thus marked by elevated body burdens of lead. The possibility that the bones with high lead levels belonged to the Roman administrators or possibly to the indigenous elites who lived like the affluent Romans was not considered by Drasch (1982).

The analyses of the skeletal remains thus suggest—or at least they do not disprove the suggestion—that the inhabitants of the Romanized towns of Britain and southern Bavaria were exposed to dangerous levels of lead. We can only suspect that the same is true of the contemporaneous populations in Rome and in the other provinces. Few reliable palaeontological data pertaining to these groups are currently available. It is of more than passing interest to compare the data in Table 6.4 (for the overexposed Romano-Britons) with the median lead values of 0.2 μg/g or less in the vertebrae of Danes who lived between 4000 B.C. and 1000 A.D., that is, from the Stone Age to the Iron Age (Grandjean, 1975), or the mean values of 0.5–11 μg/g generally found in the skeletal remains of pre-Columbian inhabitants in the Americas (Jarcho, 1964; Becker et al., 1968; Barry, 1978; Ericson et al., 1979).

With the preceding epidemiological picture of lead poisoning among the Roman aristocracy behind us, the chief purpose of this section can now be discussed. Lead poisoning can be seen to have affected the vitality of Roman culture in two fundamental ways: It ruined the reproductive capacity of the ruling class*, and it macerated their ability to govern effectively. The first phenomenon has been discussed extensively in the literature (e.g., Kobert, 1909; Gilfillan, 1965), but the latter feature has received scant attention.

The one incontestable historical fact about the Roman aristocracy is that its ranks declined quite rapidly during the last century of the Republic and during the early centuries of the Empire (Balsdon, 1962, 1969; Boren,

*The abortifactant properties of lead salts have been known since antiquity. A large body of clinical data has since been obtained that shows that exposure to moderate and high doses of lead can engender reproductive failures both in males and females (see reviews by Rom, 1976; Bell and Thomas, 1980). There are the numerous and well-known anecdotal reports on the higher incidence of sterility, miscarriages, and stillbirths in women employed in lead-processing factories (Hamilton and Hardy, 1974; Rom, 1976). The teratogenicity of lead in humans, as evidenced by an increased incidence of fetal macrocephaly, has been documented (Rennert, 1881; Oliver, 1911). The toxic effects of lead on the male reproductive system include teratospermia, hypsospermia, asthenospermia, and infertility (Lancranjan et al., 1975; Bell and Thomas, 1980). The undue vulnerability of newborns to lead is documented by numerous case reports of mental retardation, imbecility, convulsions, and high mortality rates among the offspring of parents with lead poisoning (Rennert, 1881; Oliver, 1911; Nogaki, 1957; Hamilton and Hardy 1974).

Table 6.5 Lead Contents of (μg/g) of Prehistoric and/or Historic Bones from Peru and Bavaria

Population	Period (approx.)	Number	Material	Mean Concentration	Range
Aubing	18th century B.C.				
Pfaffenhofen	(early Bronze Age)	4	Femur		
Wallerfing				1.92	0.1–8.1
Veldenst. Forst	18th–5th century B.C. (early Bronze-Hallstatt early La-Tène Age)	36	Femur		
Augsburg 1	4th–5th century A.D. (late Roman Age)	121	Femur	4.70	0.9–13.9
Augsburg 2	7th century A.D. (early Middle Age)	11	Femur	4.46	2.8–5.3
Augsburg 3	11th–12th century A.D. (Middle Age)	14	Femur	4.61	1.1–12.8
Regensburg 1/2	8th/9th century A.D. (Carolingian Age)	41	Femur	1.42	0.1–6.5
Regensburg 3	10th century A.D. (Ottonian Age)	3	Femur	2.37	1.3–3.9
Regensburg 4	12th century A.D. (Stauffer Age)	19	Femur	5.11	0.7–16.7
Mochica, Peru	*ca.* 500 A.D.	14	Femur	0.37	0.06–1.30

Source: Drasch, 1982, pp. 202, 222.

1977). Beginning at the time of Julius Caesar, the complexion of Senate membership changed from one of distinguished families, whose names were featured on every page of the history of the Republic, to one composed of a steadily increasing number of men from new families who were not native to Rome (Balsdon, 1969). Tacitus (3.55) observed that during Vespasian's time, only an occasional knight or senator did not betray a servile origin. By the age of Hadrian, the famous Cornelii appear to be the only surviving members of a strictly patrician family (Davis, 1967).

Ancient historical records leave ample evidence about the common infecundity of the aristocracy during this period. The oversexed Julius Caesar had only one daughter from his first wife, and no offspring at all from his subsequent two marriages. The marriage of Augustus (then Octavian) to Livia in 39 B.C. produced no issue. Trajan and Plotina had no children, and the same is true of Hadrian and Sabina. The marriage of Scipio Aemilianus and Sempronica, the sister of Tiberius Gracchus, ended in disaster because there were no children (Appian *Bella civilia* 1.83). Caligula and Caesonia had only one daughter, and Titus' two marriages produced one child—Julia (Birley, 1976). Ovid married four times, but he had only one surviving daughter. Pliny (7.39) observed that there were many marriages that produced no children or just one child, and the history of this period abounds with these kinds of examples. Of the 35 married men who lived in the aristocratic quarters in Roman Troy (Ilion), 18 were childless, 10 had only one offspring, and 7 had two or three children (Gilfillan, 1965). "From the numerous inscriptions which show rich men and women bequeathing the whole of their property to their freedmen, freedwomen or the state, it is reasonably inferred that these are cases of men and women who left no children" (Balsdon, 1962, p. 194). The absence of a male heir might encourage the wife to resort to potions, charms, and spells to induce conception, while the husband—confident of his own virility—might sue for divorce with the expectation of better success with another woman. During the Empire period, we are told repeatedly that many "a couple has separated, married elsewhere, separated again, and then resumed the old wedlock. Women are charged with flitting from one home to another, wearing out the bridal veil; and indeed, spicy instances are cited of ladies who boasted eight husbands in five autumns, a fact worthy of commemoration on their tombs; or of reckoning the years not by the annual consuls but by their annual husbands" (Davis, 1967, p. 74).

It is an historically documented fact that using the legal precedent established by Caesar, the early emperors occasionally created new patrician families as a mitigative measure against the disappearance of the older ones (Boren, 1977, p. 163). Augustus, who managed to have only a daughter, resorted to punitive laws aimed at the aristocratic bachelors. In a related action, Julius Caesar, and then Augustus, extended special priviledges (the so-called *jus trium liberorum*) to fathers of three or more children. Equally revealing is that in spite of the very large number of

bachelors and widespread extramarital relationships, we find that bastards are rarely mentioned among the truly patrician families (Balsdon, 1969). Illegitimate births, by contrast, are noted among the less-noble families, as is evidenced by Juvenal's (9.70–90) anecdote about a client who boasted that—thanks to his services—his impotent master could claim paternity to three children. Satirists attacked with sinister relish the many cases of sons of reputable men who bore uncanny resemblances to famous actors, gladiators, or to members of the household staffs (Balsdon, 1962, p. 198).

Various hypotheses have been formulated to explain the tragic sterility of the Roman aristocracy during the Empire period (e.g., see Balsdon, 1962, 1969; Gilfillan, 1965; Himes, 1970). Lead poisoning could easily have caused such a widespread phenomenon of infecundity.

Miscarriages and stillbirths were distressingly frequent during this period (Balsdon, 1962, 1969). For example, Caesar's daughter Julia, who was married to Pompey, suffered a miscarriage and later died in childbirth. Domitian's wife must have lost her child, since the expected heir never was born (Martial 3.6). Pliny the Younger's (*Letters,* p. 10) third wife suffered a miscarriage. In this connection, the embryotoxicity of lead needs to be remembered.

Infant mortality was high in all levels of Roman society. The inauspicious marriage of Julia, the daughter of Augustus, to Tiberius resulted in one child that died in infancy (Seutonius *Tiberius* 7.3), as did the only son of the emperor Domitian (Balsdon, 1962, p. 196). Nero's only child, a daughter, died before she was four months old (Tacitus 15.23). The historian Tacitus (*Agricola,* 6.3) notes that Agricola, whom Nero's daughter later married, was overjoyed at the birth of a daughter following the loss of their first son. After successive losses of five children, Fronto (*De nep amisso* 2.1) lamented: "I never had a child born to me except when bereaved of another." Only 3 of the 12 children of Tiberius Gracchus and Cornelia survived (Plutarch *Lives* 1.7), and there are inscriptions that suggest that for every child that attained adulthood, three had died before the age of 3 (Balsdon, 1969). Factors likely to account for the heavy toll of infant mortality in ancient societies include malnutrition and lack of proper medical attention. Such conditions are unlikely to have caused such a debilitating loss of numbers in the membership of the Roman aristocracy, however, considering the patronage of the best and most famous doctors by well-to-do families (see Brock, 1929). There must be other contributing factors to the distressingly high infant mortality in the upper classes of society. One tentative explanation that comes readily to mind is hereditary lead poisoning. The profound effect of parental plumbism on the viability of the offspring has been well documented in recent times (see Rennert, 1881; Oliver, 1911; Hamilton and Hardy, 1974).

The results of hereditary lead poisoning often include permanent mental or physical damage. If lead is indeed implicated in the weakening of the Roman *nobilitas,* one would expect the progeny of the great men to be

mainly imbeciles and underachievers. Aelius Spartianus (late third to early fourth centuries A.D.)—one of the six putative biographers who wrote the *Lives of the Later Caesars* (Birley, 1976)—provides a succinct answer to this question:

> Indeed, when I reflect on the matter, it is sufficiently clear that no great man has left a son who is excellent and useful. For such men either die without children or for the most part have children of such a kind that it would have been better for the human race if they had died without descendants. . . . What of Scipio? What of the Catos, who were such great men? And then, what shall I say about Homer, Demosthenes, Virgil, Crispus [Sallust] and Terence, Plautus and all the rest? What about Caesar? What about Tullius [Cicero], for whom especially it would have been better not to have had children? What about Augustus, who did not even have a good son by adoption, although he had the power of choosing from all men? Trajan himself, also, made a mistake in choosing his fellow-townsman and nephew. But to omit adoptive sons, lest the Antonines, Pius and Marcus, divine spirits of the republic, occur to us, let us turn to real sons. What would have been more fortunate for Marcus than not to have Commodus as his heir? What more fortunate for Severus Septimus, than not to have Bassianus?—who straightaway destroyed his brother, supposed to have designed a conspiracy against himself, a fratricidal contrivance; who took his stepmother—and what stepmother? rather she was his mother!—to wife, in whose bosom he had killed her son Geta; who killed Papinian, sanctuary of the law and treasury of legal learning. . . ."

There is no denying the fact that the decimation of the Roman aristocracy was caused by several interrelated factors. For example, progressive decline in the ranks of the nobilitas has been attributed variously to the perennial wars, the plague and other diseases, moral decadence that encouraged bachelorhood and childlessness, celibacy brought on by the Christian religion, the preoccupation with marrying money (a rich widow or the only daughter of a rich family was at a premium) or into political prominence, the widespread incidence of homosexuality, birth control, abortion or infantile exposure, general organismic senescence or apathy, and political tyranny (see Seeck, 1901; Frank, 1916; Spengler, 1926–1928; Boak, 1955; Balsdon, 1962, 1969; Himes, 1970; Kagan, 1978). There is really no unequivocal evidence to justify any of the preceding claims (e.g., see Gilfillan, 1965; Balsdon, 1962, 1969). If anything, the roles of any or all of these factors can be regarded as supervenient to the effects of de facto lead poisoning.

"Aristothanasia" must have been calamitous to Roman civilization. The principal weakness of the oligarchy of the late Republic was its failure to continue to admit substantial numbers of "new men" from the indigenous Italian middle class into the governing elite of the state. Until about the time of the Empire period, very limited use was made of mercenaries, and the aristocracy certainly was expected to supply all the required military and political leaders. With the progressive decline in the ranks of the no-

bilitas came an increasing reliance on the provincial *equites* to fill higher posts in the military and government. This failure of the long-sustained energy and creative power of the members of the dominant minority (i.e., the patrician families) probably marks the onset of the cancer that ultimately led to the disintegration of the Empire (Gilfillan, 1965; Rostovtzeff, 1957; Butzer, 1980).

Quite apart from any negative impact of lead poisoning on the reproduction of the aristocratic oligarchy and on the creative ingenuity of the progeny, the affliction of those in power by the so-called "aping" disease contributed to the Fall of Rome in another important aspect: It ushered in ineffective leadership and the attendant sensitiveness to criticism and libel. Many leaders became targets of treason *(maiestas)* charges. The glimpses of the life-styles and the psychological profiles we have of the Julio-Claudian, Adoptive, and Antonine emperors (roughly 30 B.C. to 225 A.D.) definitely suggest that many of them could have been distempered by lead poisoning. Among the Julio-Claudian emperors, Claudius (reigned: 41–54 A.D.) probably suffered severe clinical lead poisoning. He had disturbed speech, weak limbs, an ungainly gait, tremors, fits of excessive and inappropriate laughter, and unseemly anger, and he often slobbered (Seutonius *Claudius* 21, 30; Juvenal 6.622; Cassius Dio 60.2). The pathogenesis of Claudius' ailments has been a matter of long-standing debate (see Moss, 1963; Grant, 1975). Even if the previously mentioned syndromes do not pertain to hereditary lead poisoning, Claudius also suffered recurrent attacks of stomachache (dry gripe) that were so fierce, he complained, that they almost drove him to suicide (see Grant, 1975, p. 129). His contracting of plumbism would not be surprising, since he was an intemperate glutton:

> He was eager for food and drink at all times and in all places. Once when he was holding court in the Forum of Augustus and had caught the savour of a meal which was being prepared for the Salii in the Temple of Mars hard by, he left the tribunal, went up where the priests were, and took his place at their table. He hardly ever left the dining-room until he was stuffed and soaked. Then he went to sleep at once, lying on his back with his mouth open, and a feather was put down his throat to relieve his stomach. (Seutonius *Claudius* 33.1)

He is reputed to have found some ray of wisdom at the bottom of an amphora (Soyer, 1853, p. 332).

Tiberius was an inveterate wine drinker, as well as being schizothymic (Grant, 1975, p. 9; Esser, 1958). Caligula (Gaius) "was sound neither in body nor mind. As a boy he was troubled with the falling sickness, and while in his youth he had some endurance, yet at times because of sudden faintness he was hardly able to walk, to stand up, to collect his thoughts, or to hold up his head. He himself realized his mental infirmity, and thought at times of going into retirement and clearing his brain" (Seutonius *Gaius* 50). Perhaps this is indicative once more of hereditary lead poisoning. As an adult, he was a chronic alcoholic. His breakdown, which caused his brain and reign to take a very decided turn for the worse, has been attributed to overindulgence (and presumably lead poisoning as well):

> In the eighth month of his reign a serious illness attacked Caligula who had exchanged the more moderate, and therefore healthier, mode of life which he had followed hitherto, during Tiberius' lifetime, for a life of luxury. Heavy drinking and a taste for delicacies, an appetite insatiable even on a swollen stomach, hot baths at the wrong time, emetics followed immediately by further drinking and gluttony which goes with it, indecent behavior with boys and women, and all the vices which destroy soul and body and the bonds which unite them, attacked him simultaneously. The wages of self-control are health and strength, while those of a lack of self-control are weakness and an illness which may prove fatal. (Philo *Embassy to Gaius* [Caligula], 11, 14)

Nero—notorious for setting Rome ablaze and punishing the Christians for it—was also intemperate, prodigal, immoral, pleasure loving, and cruel (Seutonius *Nero* 51).

Vitellius has been described as "the slave of his body and his palate," which was propitious for contracting lead poisoning (Tacitus *Histories* 3.86). In his leisure time "he enjoyed coarse company, and frequented disreputable bars. But what made him notorious was his appetite. He used to drink a good deal, at midday as well as in the evening, but above all he ate, enormously: and a good deal of his most outrageous overeating was undertaken at the cost of others, as a ruinously expensive diner-out, especially after he became emperor. . . . He himself survived well enough by taking regular emetics. Some of his fellow-diners, however, had a tougher time. One of them, Quintus Vibius Crispus, who often had to be host or guest at these gigantic meals, was once compelled by illness to absent himself for some days from the convivial board. But this, he commented privately to an associate, had saved his life. "If I had fallen ill, I should have died," he declared." (Seutonius *Vitellius* 13.2; Grant 1975, p. 198). Domitian, the last of the Flavian emperors, washed his conscience clean of his crimes by using the stream of wine that nightly ran from the fountains (Cassius Dio 67, 9).

Nerva (35–98 A.D.) was inclined to be a heavy drinker of wine (Victor *de Caesars* 13.10). And of Trajan it has been written (see Birley, 1976): "It was a fault in him that he was a heavy drinker and also a pederast. But he did not incur censure, for he never committed any wicked deed because of this. He drank all the wine that he wanted and yet remained sober, and in his relations with boys he harmed no one. It is reported that he tempered his wine-bibbing by ordering that his requests for drink should be ignored after long banquets." Hadrian was a gourmand, his favorite dish being *tetrapharmacum,* or *pentapharmacum,* which consisted of sow's udder, pheasant, peacock, ham in pastry and wild boar (*Hadrian* in *Lives of the Later Caesars* 20.11). Aelius Verus (or Ceionius Commodus) was a person of joyous life and a renowned gourmand reputed to have had Apicius'

cookbook always by his bed (*Aelius* in *Lives* 4.7). The free-spirited Lucius Verus (or Commodus Verus Antoninus) is said to have displayed such "great extravagance that after he returned from Syria he even set up a cookshop at home, to which he used to resort after Marcus' banquets, with all manner of base characters ministering to him. He is also said to have played dice the whole night through, after he had taken up that vice in Syria; and to have been so much a rival of Gaius [Caligula], Nero and Vitellius in vices that he used to wander about at night through the taverns and brothels, with his head covered with a common travelling-cap, carouse with cheap-jacks and engage in brawls, concealing his identity; and often people say, he returned after being beaten with his face bruised, and was recognized in the taverns although he had hidden himself." (*Lucius Varus* in *Lives* 4.9). Among other luxury trappings, he had a crystal goblet that surpassed the capacity of any human draught (*Lives* 11.2). Such a life-style most likely entailed overexposure to lead (Tannahill, 1970, p. 24).

Avidius Casius (*Lives* 4.3) was an avid wine drinker, eager for food, but able to endure starvation. The notorious Commodus Antoninus (*Lives* 5.8) led a life of orgiastic abandonment in the palace—amid banquets and baths. He would drink until dawn, flitted through the taverns in the evening, and squandered the resources of the Roman Empire (*Lives* 4.1). Didius Julianus became a glutton in his old age (*Lives* 9.2), and Pescennius Niger was fond of wine and was of unrestrained licentiousness in other varieties of desires (*Lives* 1.4, 6.2). Clodius Albinus was a glutton, so much so indeed "that he used to consume a greater quantity of fruit than human capacities permit. For he, when hungry, ate five hundred dried figs (called *callistruthiae* by the Greeks), a hundred Campanian peaches, ten Ostian melons, twenty pounds of Labican grapes, a hundred fig-peckers and four hundred oysters. He however was moderate with wine—which Severus denies, claiming that he was drunk even during the war. With his own people he was never in agreement, either because of drunkenness, as Severus says, or because of his acrimonious character." (*Lives* 11.6). Both Antoninus Caracallus (*Lives* 8.10) and Antoninus Geta (*Lives* 3.6) were lovers of dainty dishes and wines that were variously flavored. Heliogabalus—the last of the Antonines—spent his lifetime in search of pleasures. He is reputed to have even outdone both Apicius and Vitellius in the munificence of his banquets. "He never dined for less than 100,000 sesterces, and sometimes the total cost of his dinner exceeded 3 million sesterces." He drank so prodigiously that people thought he had been drinking from a swimming pool. His own kitchen invented many exotic dishes and blended wines. He was mentally impaired (in my opinion, by lead in his diet), and he refused to have children "in case one of them turned out to be thrifty" (Heliogabalus in *Lives* 18.3–35.7). The ingravescence of voracious appetites and intemperance continued throughout the lives of the hierarchical *principes*.

The preceding account shows that roughly two thirds (18 out of 30) of the emperors and usurpers who reigned between 30 B.C. (Augustus) and 220 A.D. (Elegabalus) had a predilection for lead-tainted Apician entrées and Columellan wine blends. This figure basically is confirmed by Celsus (4.24) who observed that most of the Roman emperors suffered from gout. It may be assumed that a large number of their well-placed cohorts acquired similar tastes. This continuing parade of unproductive ("aped" by lead) rulers and administrators throughout this period of the Roman Empire no doubt contributed immeasurably to social disequilibrium and economic disaster.

Pundits obviously need to be reminded that hundreds of reasons have been suggested for the collapse of the Roman Empire. In the classic history *The Decline and Fall of the Roman Empire,* Edward Gibbon (1776–1788) listed over two dozen causes of the decline. Reasons often mentioned inlcude the following: economic stagnation, demographic decline including manpower shortages, overexploitation of the masses and natural resources, the inflexibility, or the monolithic nature, of the sociopolitical system, the barbarization of the system, the rise of Christianity, ecological stress, systemic senescence, and so on (see Bark, 1958; Remondon, 1964; Jones, 1966; Lot, 1966; Perowne, 1966; Macmullen, 1967; Vogt, 1967; Jordon, 1971; Grant, 1976; Kagan, 1978). In the final analysis, however, Rome fell to easy-to-identify invasions from outside and weaknesses from within. The present study of the production and use of lead—often referred to as the "Roman" metal—by Roman culture strongly implicates lead poisoning of the aristocratic oligarchy as one of the principal, probable causes of the internal weaknesses. Kobert (1909) and Gilfillan (1965) had previously reached the same basic conclusion.

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APPENDIX

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