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The distribution, life-history, habits, and economic importance of the termites of the United States

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THE DISTRIBUTION, LIFE-HISTORY, HABITS, AND ECONOMIC IMPORTANCE OF THE TERMITES OF THE UNITED STATES

by

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The Distribution, Life-History, Habits, and Economic Importance of the Termites of the United States.

Introduction

Termites, as has been pointed ~~t~~out by Kofoid (1934 a), present many aspects of development which are astonishing. There are few animals that are so poorly equipped for life's struggle as termites are; yet they have compensated to a marked degree for their lack of equipment states Maeterlinck, (1928). They have been able by means of instinct (or is it intelligence?) to organize a civilization which is the equal of man's in many ways. At the present time the termites threaten to become one of the most formidable enemies of man. In spite of the fact that the word termite, continues Maeterlinck, is synonomous with cruelty, darkness and selfishness, we must not forget that it's life is determined by the dictates of a powerful instinct for self-preservation. The enemy of the termite, the ant, which is much better equipped, is a relentless enemy, and it has forced the termite to perfect its life in order to survive. As many of the termites are without any means of protecting themselves, a combination of circumstances has forced them to take to a secluded life. Here again, however, they have adapted themselves to their environment by maintaining a constant temperature and a constant moisture supply. Their chief food is cellulose, a food which is plentiful throughout the year. Intestinal protozoa or cultivated fungi break down the cellulose to facilitate digestion. Law and order seem to reign, for the colony is a

cooperative one. The safety of the colony is assured, since the "sentries" or soldiers protect the retreat of the helpless termites by laying down their lives that the others may live.

Interest in Subject

Economic

Termites are organized into large colonies consisting of many castes differing in function and structure. According to Kofoid (1934 a), it is this highly organized social organization which prolongs the period of immaturity, and has accelerated the evolution of highly specialized instincts. These factors combine to raise the termites to a high level of efficiency among insects in general, and extend and accelerate their work as destroyers of wood and of cellulose throughout tropical and milder temperate regions. Thus termites are of great importance economically because of their tendencies to destroy essential materials. They cause damage estimated to amount to millions of dollars annually. The chief ways for man to prevent this damage are either to prevent the establishment of colonies by interrupting the life-cycle or to destroy existent colonies by the use of toxic chemicals. Hence, a knowledge of the life-cycle is necessary in order to deal with termites.

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Historic

Termites as a group are very ancient. Kofoid (1934 a) states that their nearest relatives are the cockroaches, from which, however, they have been distinct for many millions of years. Fossils of species now doing damage all over the United States have been found in deposits known to be many millions of years old. They have lived for great periods of time on the wood furnished by forests, wooded canyons, oak groves, and numerous arid-land and desert shrubs. We are not facing, therefore, any sudden invasion of new forms but merely an adjustment with species already present for millions of years before man entered upon the scene and began changing some of the conditions affecting the lives of termites. As civilization advances, human culture avails itself of cellulose in ever-wider uses. The competition between man and termites thus becomes steadily greater. The organized social life both of man and of termites mutually interact to enlarge the field of activities for the latter. Both unite to provide new sites of infestation for these destroyers of wood.

The writer's interest in this subject was aroused by the great unity prevalent among the termites which enables them, a race with no defense mechanism, to develop an organization ensuring great protection. A system of division of labor wherein all individuals have their place has been evolved by these insects which are on a considerably lower standard than the social bees or wasps.

Classification (After Banks & Snyder)

Order Isoptera Brulle

Superfamily Termitoidea

Family Kalotermitidae

Subfamily Termopsinae

Genus Zootermopsis (Heer)

Species _angusticollis_ Hagen

nevadensis Hagen

laticeps Banks

Subfamily Kalotermitinae

Genus Kalotermes Hagen

Species _occidentis_ Walker

marginnipennis Latreille

approximatus Snyder

schwarzi Banks

jonteli Banks

minor Hagen

hubbardi Banks

texanus Banks

simplicornis Banks

Genus Neotermes Holmgren

Species _castaneus_ Bumeister

Genus Cryptotermes Banks

Species _cavifrons_ Banks

infumatus Banks

brevis Walker

Family Termitidae

Subfamily Rhinotermitinae

Genus Prorhinotermes Silvestri

Species *simplex* Hagen

Genus Reticulitermes Holmgren

Species *flavipes* Kollar

virginicus Banks

hageni Banks

claripennis Banks

tibialis Banks

hesperus Banks

lucifugus Rossi

humilis Banks

humilis var hoferi Banks

tumiceps Banks

Subfamily Termitinae

Genus Amitermes Silvestri

Species *tubiformans* Buckley

arizonensis Banks

wheeleri Desneux

californicus Banks

(?) perplexus Banks

(?) confusus Banks

Genus Anoplotermes

Species *fumosus* Hagen

Genus Nasutitermes Banks

Species *costaricensis* Holmgren

Genus Constrictotermes Holmgren

Species *tenuirostris* Desneux

cinereus Buckley

Although there seems to be a vast number of species, all can be reduced to three or even two major types according to habitat. These types are as follows: 1) the dry-wood, 2) the subterranean, and 3) the damp-wood termites. Matters can be further simplified by grouping termites into two distinct types, namely: 1) the wood-dwelling, and 2) the earth-dwelling termites. This is perhaps more convenient, as most of the wood-dwelling termites are of several types. Economically speaking, the subterranean type is the most important of all termites.

The writer will not be able to deal with all the various species since 1500 or more have been described. The writer's aim is to deal at some length with a typical species native to the United States found in each of the three groups listed above as to distribution, life-history, habits, and economic importance. The three species to be described in this paper are: 1) *Zootermopsis angusticollis* Hagen, a damp-wood termite; 2) *Kalotermes minor* Hagen, a dry-wood termite; and 3) *Reticulitermes hesperus* Banks, a subterranean termite. Facts which apply to American termites in general will also be included.

Distribution

Zootermopsis angusticollis is confined to western North America, states Kofoid(1934 a). It abounds from British Columbia south to the Mexican border. It has a wide altitudinal range, being found usually in the more humid coastal areas, but at times in the south occurring as high as 6,000 feet. Kalotermes minor like the damp-wood termite is confined to western North America, being most common in California, Arizona, and New Mexico. It is the most destructive of the American species of wood-dwelling termites. It is ~~the~~ most common along the coast from northern California southward to Mexico with scattered stations as far north as Tacoma, Washington and as far east as Arizona. (See Plate I). Reticulitermes hesperus is found in the open woodlands of the Pacific Coast area. Other species of the same genus are spread out in widely different areas throughout the United States however, as are species of the other two groups.

Climatic Factors in Distribution

First, the effect of moisture. According to Kofoid (1934 b), one of the most important factors is an available supply of moisture. Without the latter no colony can long exist. Termites lose water rapidly, especially in their larval stages, due to evaporation. An approximately saturated atmosphere can be maintained in their closed burrows, and they appear to be very sensitive to even minute changes in humidity. In general, termites obtain their supply of water from three sources, namely: the soil, wood, and metabolism. In the subterranean species, humidity is maintained within the colony by a diffusion of moisture in the soil. These termites prefer sandy soil as a more favorable environment for locating and attacking buried wood. It has been found that the elevation of infestation in a tree is directly proportional to the supply of moisture. Thus at high altitudes in some parts of California where moisture is very abundant, the attacks by the subterranean termites may even reach at times to the tops of telegraph poles. The damp-wood termite, as the name implies, requires more moisture than the dry-wood species. Hence it abounds in such habitats as rotting logs, staves of water tanks and pipe lines, bridge piling, harbor structures near and over the sea. Even dry-wood termites are attracted where a plentiful supply of moisture is at hand. However, the fact that the dry-wood species are able to maintain a relatively high humidity in their burrows with just a small supply of moisture makes it possible for them to invade trees. They are able to advance into new localities only as long as their water supply lasts. When

it fails them they either retreat downward toward the supply, or, if it fails them completely, they die.

Second, the effect of temperature. Temperature as well as moisture is an important factor in the behavior of insects, states Kofoid (1934 b). Colonies of subterranean species in buildings often make burrows about furnace rooms, near steam pipes and the like. Their tunnels are placed on warmed surfaces or toward the sources of warmth. In desert regions where the temperature is known to fluctuate rapidly and markedly, termites shift the location of burrows accordingly to avoid exposure to the cold or to the sun. Winter slows down the activities of termites and drives them downward, while summer hastens their activities and brings them upward.

Geographical occurrence also is influenced and determined by maximum and minimum limits of temperature. Thus Zootermopsis angusticollis might be subjected to low ranges of temperature while farther south, termites of the same genus and species abound in fairly high temperature conditions. Reticulitermes is the only genus that really extends into temperate regions. Kalotermes minor occurs usually in warm and sheltered regions; but as it enters the heated desert, it descends below the surface of the ground.

Together, moisture and temperature may act in diametrically opposed ways on different species in the same locality at the same time. Thus a certain degree of heat and moisture might be adequate for one species e. g.--Kalotermes minor. But this latter species will be checked from spreading by a lower temperature in the new territory--for example, the coastal belt,

while another species such as <u>Reticulitermes hesperus</u>, does not enter the desert region because of the lower humidity there.

On the other hand, Reticulitermes requires both a high temperature and high humidity for its dispersal flight. Thus this species emerges on sunny afternoons just after a heavy rain which has lasted till late in the afternoon. Kalotermes has its dispersal flight mostly on days after a sudden rise in temperature when the humidity is low and there has been no rain preceding. Both however, have their dispersal flight during the most brilliant sunshine. Zootermopsis has its dispersal flight in the same locality in late afternoon or evening when the temperature is falling and the humidity is rising.

Because of the protection their nests afford, termites are more or less immune to cold although most activity ceases during the winter months.

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Dispersal

As in the rest of the Animal Kingdom, if we cite the causes or factors governing the dispersal of one species of termites they are applicable in general to all other species, states Kofoid (1934 b). The chief agent in the dispersal of termites is man. He causes their spread in three principal ways.

First. Erecting wooden structures in close proximity to other wooden dwellings and buildings makes it easy for termites to spread into new and hitherto unoccupied areas.

Second. The transport of infested furniture, second-hand infested timbers, or even living plants may be a source of future infestation. Thus, colonies of termites become established in newly-developed centers of human population and in regions wholly new for the species.

Third. Our modern civilization with all the different aspects of trade and commerce is sometimes responsible for the transportation of infested soil or rotten wood into hitherto termite-free localities.

Wind and air currents during the time of the dispersal flight also affect the spread of termites.

Life-History

In all species of termites the life-cycle is, in general, the same. One of the most critical periods in the life of the termite is during the dispersal and mating season. The different species emerge from the mother colony at different times of day or even in different months. Emergence may last several days, but is, of course, only intermittent. The individuals that emerge are winged sexual forms. Feverishly these positively-phototropic insects emerge and fly away. A vast, dark cloud rises to the sky. Termites have countless enemies which assemble as if by magic to await their "coming-out" party, but it is not a party for the termites. According to Bodenheimer (1937), the dangers awaiting the reproductives upon leaving the parental nest are manifold: predacious insects, birds, lizards, mammals, and so on, all feed on them.

The dispersal flight of the survivors lasts only a few minutes so that the distance the reproductives normally fly is seldom more than half a mile. The reproductives of <u>Kalotermes minor</u> may travel as much as one-half mile or more, but, their flight is aimless and wavering while those of Reticulitermes are known for their well-directed flight. The latter are capable of changing direction at will. They sometimes alight to investigate structures and then resume flight. After they alight they remove their wings.

As soon as dealation is complete, a nervous and feverish racing about of the termites begins, due to the influence of two fundamental urges, namely: (1) the mating urge, and (2) the urge

to escape the light which had been so strongly sought before. Perhaps the latter is nature's method for getting them back into shelter and thus protect them from complete extinction at the hands of their numerous enemies. The females make rapid, excited movements, raising their abdomens, perhaps to emit an attractive odor. The termites arrange themselves in pairs with the female in front and the male behind, following all the movements made by the female, keeping his antennae playing over the tip of her abdomen, possibly because of the odor. Then is noticed a remarkable reversal of tropistic behavior. Each pair runs off seeking a crack or a crevice in suitable wood or earth, depending on the species to which it belongs. In either case, they set to work enlarging the opening to permit entrance. The original pair do not leave each other, even if a number of unpaired termites approach, or are close by. Both male and female may work together enlarging the opening to permit them to enter one at a time, but the female is the more efficient worker. The particles removed either from the tree or the soil are piled about them. It takes sometimes as long as forty-eight hours to complete entrance. Eventually the hole is made large enough, about three-eighths of an inch deep, for both to enter. (See Plate II). They at once turn and begin to seal the opening behind them, using a plug of hard brown material consisting of a mixture of partly chewed wood and a cement-like secretion. Thus starts the cryptobiotic type of existence of termites. The original pair forms the nucleus of a potential future colony. Relatively few pairs succeed in starting a colony, still fewer are able to

survive the first winter. The growth of the colony proceeds at an extremely low rate. Thus many factors enter in ~~th~~ to cut down the number of successful colonies.

Shortly after sealing themselves in, copulation occurs for the first time and is repeated at varying intervals. At the end of several weeks, depending on the species, the first eggs varying from 2-5 in number are laid and these soon hatch into nymphs. Then a period of inactivity follows which may last as long as nine months. During the second year the queen lays from 8 eggs up to a maximum of 12 or 15. As time goes on the king and queen turn their activities ~~w~~ entirely to reproduction and they become dependent on the nymphs for their food and care. The fecundity of the queen increases each succeeding year and reaches a maximum when she is 10-12years old. The abdomen of the queen becomes enormously enlarged. The queen is now a mere egg-laying machine which may lay as many as sixty eggs per minute. The king is of the same size as he was at the time of the dispersal flight or he may even have shrunk in size. As the queen becomes older her fecundity decreases and a younger secondary queen is substituted.

Nymphs go through different stages of development and shed their skin several times. From birth to the mature stage, termites go through seven stages or instars. (See Plate III). Nymphs normally are non-functional sexually, but may become functional later. After they have developed to some extent, they begin to enlarge the cavity. As they become older they begin to differentiate into the various castes found in a termitary or termite nest. Some become soldiers at the end of the second year

of the colony. It is their duty to protect the colony. Masculinity is not meant to be inferred however, for soldiers may be of one or the other sex.

If isolation from the queen should occur in some manner, or, if she loses her reproductive ability in whole or in part, one or more supplementary queens are developed. These supplementary reproductives usually develop from nymphs in the sixth instar, rarely from those in the seventh or fifth, and never from those in the lower instars. Authorities seem to differ as to the fertility of secondary queens. According to the Termite Investigations Committee supplementary queens are not as fertile as the primary queen and some time is necessary for them to develop to sexual maturity. It may take as much as three months following isolation. Heath (L1928) however found that supplementary reproductives may be almost, if not as, fertile as the primary reproductives. No further knowledge seems to be available, however, in regard to the egg-laying and development of a colony with seventh instar supplementary reproductives. Heath in his investigations has shown that in an orphaned colony soldiers may become reproductives at a faster rate than their parents, and with some of the secondary characteristics of the regular soldier remaining.

When a colony is three or four years old, it begins to resemble a complex colony consisting as it does of many individuals. Besides soldiers and nymphs, we also find numerous alates in the colonies from late June or early July until dispersal time in September or in October. These winged individuals may not leave the nest for three months or more while waiting for the right

climatic conditions for a dispersal flight.

When suitable external conditions prevail, that is, a sunny day or afternoon with proper amount of humidity, the workers seem to become reckless and make an opening to the outside. The soldiers stand guard near the exit with their antennae pointing to the outside while they apparently regulate the emergence of the young reproductives. The latter, which have never seen the light of day, and have even shunned the light, now, hastily fly away followed by dealation and mating, and finally search for a nest-site. After emergence of the alates, the workers immediately set about closing up the emergence hole, sealing it, and making their home secure from attack.

General Habits of Termites

The interesting habits of termites are of great importance. By knowing the conditions they prefer, we can better control them, according to Light (1934 b). As a matter of fact, all the remedial measures used are based on a knowledge of these habits even though incomplete. Termites are closely interrelated with other organisms whose services to termites make it possible for these insects to damage man's possessions. The methods used by a particular species in feeding and in making a home must also be considered important, for knowing the kind of nest each species builds, we know where we should look for it. Grooming is also an essential habit among termites. These insects are always perfectly cleaned by other members of the colony. This phenomenon suggests a means of control in spreading poison dusts through the colony. These insects have a system of communication to spread alarm through a colony. The utmost caution must be used when one attempts to exterminate a colony, otherwise, he may only succeed in driving them farther into the tree or ground, and not be able to check them. Finally, there is the remarkable social organization, which Wheeler (1923) feels parallels in so many of its features that of the most highly specialized Hymenoptera. Maeterlinck (1928) states that the termite civilization is the most curious, the most complex, the most intelligent, and the most logical and best fitted to the difficulties of existence of any social animal. Perhaps that is a little too exaggerated, but, we must admit that it is remarkable that these social animals not only struggle and compete with one another for

food, mates, and safety, but, also cooperate to insure to one another these same indispensable conditions for existence, according to Wheeler (1922).

Feeding Habits

Association with Protozoa.

Termites feed almost exclusively on cellulose of wood invaded by fungi. This is usually obtained from the timber in which the colony is located. Tiny shavings are eaten and pass to the lower intestine where they are acted on by numerous species of protozoa which aid in digestion, and thus serve an important function in the economy of termites according to Light & Sanford (1928), Kirby(1930; 1931) and Dickman (1931). They help to return the component elements of the wood to the air by the breaking down of the cellulose in wood to Carbon Dioxide and water. Cleveland (1926) stated that intestinal protozoa are present in practically all termites, though in some, they are found in small numbers, as in the Termitidae. Cleveland is not certain whether the termites are losing their protozoa or are just beginning to harbor them. He finds further, that these microscopic organisms weigh almost as much as the insects themselves. In a later paper, Cleveland (1928) states that he finds many spirochaetes which he believes may have a similar function in the breaking down of cellulose in all families of termites. Cook (1932) reports that normal termites emit an undetermined gas and it is conjectured that this gas may be either hydrogen or methane gas or perhaps both. On the other hand, defaunated termites (or termites with their protozoa removed) do not produce this gas. He concludes that the protozoa are responsible for this phenomenon.

Cleveland believes that the protozoa are transmitted from one

individual to another by means of the pellets that are extruded by the termites. The association of termites and protozoa is a mutual relationship, and is known as symbiosis or the living together of two organisms on a partnership basis. Each partner gets some benefit from the other.

The source of proteins in the food of termites is uncertain. We know that the amount of protein in the heartwood of trees is small. It is still ~~a mystery~~ unknown where protein formation takes place. It may be by bacteria or other micro-organisms in the gut of the termites or in the wood prior to ingestion, or in the pellets of the termites.

From these experiments, Light and Sanford (1928) conclude that the faunas of the different termite species are characteristic for each species. All members of a colony of a particualr species throughout its range have the same species of protozoa, some or all of which are found nowhere else. But, the same investigators found that the protozoa of one termite species can live and multiply within the hind-gut of another termite species. This is known to apply only to Zootermopsis whose protozoa can live in Kalotermes for 100 days and multiply, as Light and Sanford have shown.

Association With Fungi

The fungi which grow in wood, and which are partially responsible for its decay, aid the termites in breaking down cellulose to its constituents. It has been shown by Hendee (1933) and Kofoid (1934 a) that fungi exist wherever termites do, since each requires the same environmental conditions. Hendee (1933) found fungi belonging to Phycomycetes, Ascomycetes, Basidiomycetes, and Fungi Imperfecti in association with each of the three species of termites, namely: Kalotermes minor, Reticulitermes hesperus, and Zootermopsis angusticollis. She has shown also that the ~~fungi~~ galleries of Kalotermes always have an extensive flora of fungi. Both Reticulitermes and Zootermopsis are closely associated with fungi, also, in soil as well as in decaying wood. Hendee conjectures that fungi are ingested along with the wood and that spores are carried about by the termites. The digestive tract and even the pellets of the termites almost universally yield fungi.

According to Wheeler (1923) fungus gardens, in the case of fungus-growing termites, are really the nurseries of the termitarium and are full of newly-hatched young. The king, queen, and the other reproductive forms, as well as the young, make use of the fungi as food.

Proctodeal and Stomodeal Feeding

Feeding of ~~among~~ termites may be of one or two types, ~~either~~ proctodeal or stomodeal. The former is the expulsion of pellets from the hind-gut; the latter, ~~is~~ the regurgitation of food from the foregut.

Andrew (1928) describes the method of proctodeal feeding thus:" The termite desiring food palpates with the antennae the abdomen of an animal almost ready to drop a pellet. This stimulus apparently assists in relaxing the rectal musculature and the pellet is wholy or partly extruded. If it drops, the termite which elicited it usually picks it up and walks away with it, eating as he goes. Often others induce him to let them eat also or take it from him by force. It is not uncommon to see three eating together, and a fresh pellet may pass to eight or ten termites before being consumed or discarded. Sharing willingly is the rule, but occasionally selfish tendencies may be observed in some determined hoarder who gives battle for his acquisition and guards it even after he has ceased eating.

If the pellet does not drop, the termite endeavoring to get it frequently follows the other, nibbling it as he does so. If the pellet is not almost out, this is often annoying to the pursued, and he turns and kicks until left alone. Moist pellets are preferred to dry ones. This feeding custom is very common. In proctodeal feeding no transfer of liquid intestinal contents is involved but merely the transfer of the fecal pellets. It has been shown that protozoa occur in the pellets;" hence they must be transfered from one termite to another in this way.

[illegible]

Hegh (1922) points out that there is a considerable variation in the composition of the regurgitated food which has only passed through the anterior part of the digestive tube. This rules out the possibility of refaunation by stomodeal feeding since protozoa are not to be found in the foregut. The workers alone can eat and digest cellulose and as it is the workers which abound in a colony, the feeding of others devolves upon them. Adults are usually fed by the workers on the excreta from the hind-gut; however, if the individual begging for food is young, perhaps a future winged form, the worker regurgitates whatever it has in its stomach. Workers are not to be judged as gluttons when seen gorging themselves; they must of necessity do this to be able to feed the rest of the colony.

Cannibalism

As Wheeler (1923) has pointed out, termites also, at times, become cannibalistic. This habit fits in very well with the economy program and the sanitation system of the termites. When an insect is injured, it becomes useless to the community and is consequently done away with, for, every one in the community must do his share of the allotted work. Usually cannibalism is resorted to in case of dire need such as, when the colony is slowly starving to death, or, when a dead comrade is in the way and is impeding the work of the rest.

How does cannibalism start? That is hard to say. According to Wheeler (1923), it is known that during the grooming process, an appendage of the groomed individual may be brushed off. The outpouring "blood" fluid may be tasted and appreciated. The desire for more body fluid will then become "associated" with the rest of the body of the termite, and, cannibalism will begin for that individual. Then again, workers are forever trying to get at some of the rich excreta of the queen. The soldiers guard the queen from these greedy workers. Yet many get by and while trying to seize the emerging excreta, may cut the abdomen of the queen. As a matter of fact, many such scars caused by workers have been found on queens whose nests were opened. And, as mentioned above, this habit once started, or, the mere taste of body juices or flesh of another termite may incite the workers to cannibalistic tendencies.

Experimental Work

Several investigators have attempted to study the effects of foods on the growth of termites. Filter paper has been used as a food, but this has not been very successful. Roessler (1932) found that termites can live, although they don't grow well, on almost pure cellulose, as for example, filter paper. However, Roessler found that one one-thousandth molal solution of potassium nitrate, calcium nitrate, and ammonium nitrate added to filter paper have a slightly accelerating effect on the rate of growth of the termites.

Lund (1936) found that in the use of different carbohydrate diets, such as the dissacharides and monosacharides, the intestinal protozoa of termites died very quickly, more quickly than on the less soluble higher sugars and the starches. With the dying of the protozoa, of course, there is complete cessation of growth and early ~~g~~ death. Much work remains to be done in this as in other phases of this subject to clear up certain points in order to give us a clear picture of the entire termite problem in all its aspects.

The Grooming Habit

This is one of the most interesting habits of termites, for grooming in termites resembles that of human beings and monkeys. Castle (1934) found that the individual being groomed stands quietly while the one which acts as the groomer carefully cleans the legs, thorax, and abdomen. Both mandibles and palps are used in the process. The white areas between the abdominal segments are more carefully cleaned. The individual which is being groomed cooperates with the groomer by turning the body and flexing the abdomen as to lend easy access to the ungroomed parts of the body. The termite may even turn on its side so that the lower portion of the body can be groomed.

The connection between grooming and the origin of cannibalism has already been mentioned. Grooming is of value economically for it serves as a means for controlling colonies of termites in portions of wooden structures. Finely ground powder, having toxic properties, is blown into the runways. Some grains adhere to the bodies of the termites and due to grooming the poison is spread throughout the colony.

Means of Communication Between Termites

When a colony becomes very large, its members may be compelled to seek new sources of moisture and food. Such a far-flung "empire" must have some means of communication. As a matter of fact, termites are in constant contact with each other. They instinctively communicate with each other by playing their long sensitive antennae over the surfaces of their neighbors.

Intense excitement and commotion permeates the whole community when the alarm signal is given. According to Kofoid (1934 a) it is communicated throughout the colony by stridulating movements of the soldiers, feebly imitated by other members of the colony. The hard heads of the alarmed soldiers are rattled against the resonant walls of the narrow burrows, producing sounds which may be heard by applying one's ear closely to the surface of an infested post or pole. At the approach of an ant, or if an opening is made to the nest, the alarm is sent out all over the colony. Fear and the instinct for maintaining their cryptobiotic existence cause the soldiers to rush to the danger spot to ward off an attack or repel the invaders and close the nest again. Thus, some individuals may be sacrificed, but the colony itself lives on if the alarm is given in time, which is usually the case. Termite soldiers stick to their post even when it means certain death. If, as sometimes happens, one colony works its way through into an adjoining colony's nest, a death struggle ensues till either one or the other of the two colonies is exterminated, or, perhaps, even both. This is a strange behavior, but, termites seem to have as much antipathy

for termites of other nests as they have for their enemies.

Social Organization

According to Light (1934 a), all of the 1500 or more species are social. The development of a society is possible only where individuals are long-lived, and this is possible only where there is an adequate and continuous food supply. Because of their ceaseless work, a division of labor has been evolved; in spite of the fact that termites are simple, primitively organized insects, they have a highly organized caste system.

Wheeler (1922) believes that caste systems have evolved from three fundamental appetites or drives, namely: hunger, sex, and fear. As animals become social the functions of the individual become more limited. Specialization results, and a caste for each drive is developed. Thus a worker caste is evolved for the securing of food for the other castes and brood of the colony, according to their needs. A reproductive caste is developed to promote unlimited procreation of progeny. Finally, a soldier caste is evolved to take over the defense duties of the colony. Snyder (1926), while not putting forth any theory in regard to the origin of the castes, calls attention to the theory of Grassi and Jucci.

The Various Castes

According to Light (1934 a), a division of labor among the termites is very ancient. Individuals of different types are fitted by inherited structure and instincts, to perform various important duties in the life of the colony. All genera except Anoplotermes have at least two distinct castes, namely; reproductives and soldiers. This genus has no soldier caste and the duties of the soldiers fall on the workers. The species of the families Kalotermitidae and Zootermopsidae have no special worker caste; hence, immature stages of the other castes perform the duties of the workers.

In general, there are three types of reproductive termites: primary, secondary, and tertiary. The primary reproductives constitute the original mated pairs that established the nests. The females are capable of producing eggs in fantastically enormous numbers. The secondary reproductives are immature termites as far as molting is concerned. Apparently with some slight change in diet these develop more rapidly and begin to reproduce. But their fecundity is rather unimportant in comparison with that of primary reproductives. Rarely soldiers become modified into reproductives; these are known as tertiaries. Secondaries and tertiaries are, after all, supplementary reproductives to keep the colony going after the loss of the queen, or because of a falling birth-rate due to an aging queen.

Besides these three types of reproductives in a typical mature colony, there may be found winged reproductives, ready for their dispersal flight. In a few genera, there may be two

or three types of soldiers differing in size and structure, or, there may be workers as well, of two or three types differing chiefly in size; however, the latter statement applies only to some tropical species.

Functions of Each Caste

The Reproductive Caste

According to Light (1934 a) the especial function of the reproductive caste is to reproduce. Typically among social insects, as Wheeler (1922) has pointed out, a few individuals perform this task among the hundreds or thousands of individuals that make up a colony. Furthermore, this caste brings about the distribution of the species by means of the dispersal flight. It chooses a site for a new colony, performs the excavation of the first galleries and sees to the feeding and care of the first young. With the arrival of the first nymphs, food-getting for the community, construction of the colony, and care of young, are completely relegated to the nymphs. The primary pair does not engage in any more household duties and gives itself over to reproductive activities. It is first fed by the nymphs and then by the workers. When the colony further increases in size and number, the primary pair is well supplied with food by the workers, and the ovaries of the queen begin to increase in size with the consequent increase in egg-laying powers. There is also a gradual distention of the abdomen.

In many cases, supplementary reproductives are as effective as the primary pair if not more so. It has been estimated that in the case of Reticulitermes a supplementary queen lays more eggs in a day than a primary queen lays in the first two years of development of the colony. Thus they are important as a means to increase the population. They accelerate distribution and hence are important factors in the further spread of damage.

To distinguish between the primaries and supplementaries, we would find that in the former, wing scales are left (after the dispersal flight), characteristic pigmentation, exoskeleton and compound eyes. The latter lack wing scales and exhibit all degrees of size, pigmentation, and development of eyes and wings ranging between the conditions found in the various older instars and the fully-developed primary reproductives.

The Worker Caste

In general, workers resemble~~s~~ nymphs states Light(1934 a). At times it is hard to distinguish them from the latter. The mandibles are heavy, chitinous structures with toothed edges, facing toward the middle and working over one another. It is by means of these mandibles that workers are able to bite off fragments of wood. The development of a worker caste whose members are destined to remain active within the colony throughout a long life has made possible the production of large colonies among the earth-dwelling termites. The Kalotermitidae or wood-dwelling termites have no worker caste, the work being performed by the immature stages of reproductives and soldiers. Very populous colonies are not to be expected in the family Kalotermitidae because the mature reproductives leave the colony for their dispersal flight and the soldiers, present only in small numbers, are incapable of feeding themselves.

Workers are necessary to enlarge the nest, to take care of, and feed the young, and to feed the primary pair and soldiers.

The Soldier Caste

As the other inhabitants of the termite colony are extremely vulnerable, soldiers were necessarily evolved to prevent extermination of the colony states Light (1934 b). The chief enemy of the termite, as mentioned before, is the ant, which can readily overcome and carry off a termite two or three times its size. Termites try to prevent invasions by ants by keeping their nest hole-proof. However, breaks into c olonies do occur but, as these openings are small, the termite soldier serves his purpose well.

There are several types of soldiers. In general, we may say that they have a large head and a thick, hard, and darkly-pigmented, chitinous exoskeleton. The long mandibles may become massive or toothed crushing weapons as in the wood-dwelling termites or slender, pointed, and piercing weapons as in the Rhinotermitidae and Termitidae. Then again, some soldiers form a living plug, standing in the path of onrushing foes, not only fighting but announcing alarm to the rest of the colony and trying to beat off the enemy all at the same time. Eventually, they may lose their lives but, the rest of the colony will be saved.

Another method of defense is the use of the secretions of the cephalic gland in the center of the head. The effects of the secretion deter, stupify, or impede the attackers mechanically and chemically. This method of defense is more highly developed in certain species.

Thus, all the castes together work for the common good of the colony. Each with his own task to perform, goes about that

task endlessly it seems, till something extraordinary happens. When the alarm is spread through the colony all the "firemen" rush to their posts, some guarding the entrance, and others removing the young to safer places. Thus termites go on about their work always prepared to help the population to start afresh, if necessary.

Economic Importance
Extent of Damage

There is no doubt but that damage to wood by termites is considerable, states Light (1934 b). Many methods of control and prevention have been attempted with little or no success. The use of chemicals and their value can only be ascertained after years of experimentation. Each chemical so far used has had some disadvantage attached to it. It may be the cost or perhaps the danger in handling of the chemical to the person using it. In short, nothing has as yet been found fully satisfactory. With this as a brief insight into the state of affairs as to control and preventive methods, the writer wishes to present first, where the damage originates, and a survey of the damage, followed by the use of chemicals and methods of construction.

Location of Colonies or Nests

The nests of some termites, e. g. Reticulitermes, Heterotermes, and Amitermes, are in the earth and in dead and decaying wood. The subterranean termites are the most common and most injurious species. They live in forests, building their nests in logs, stumps, in cleared land, and in a series of underground passages in the earth underneath wood or vegetation. The workers attack the timber and trees only through the ground. The nests of others, Zootermopsis, Kalotermes, Neotermes, and Cryptotermes however, are excavated in wood and trees by the sexual forms. These are not as common as the subterranean termites. Following land-clearing and the consequent destruction of the natural breeding places in the dead trees, decaying stumps, and logs of the forests, wood termites have attacked and raised havoc in the woodwork and contents of buildings, telephone poles, posts, fences, or any timber in contact with the ground, as well as in fruit and shade trees, shrubs, flowers, field crops, and grapevines. Both Snyder (1937) and Hegh (1922) mention a countless variety of structures that termites attack (See Plates IV, V, VI).

The emergence of large numbers of the flying termites is an indication of infestation and the point of emergence indicates the approximate location of the colony and the region of attack. Further, the discarded wings of the mated pairs or dead adults can be found usually near infested timbers after the dispersal flight. The presence of ejected earth or shavings of wood from crevices are evidences of the presence of termites. Branching

shelter tubes of a small diameter through which these insects travel from the ground to the woodwork above and made of earth mixed with tiny particles of wood on impenetrable foundation material, timbers, woodwork, or over the surfaces of stone or brick, may sometimes be seen. Additional evidence (especially of the non-subterranean termites) of damage are the impressed pellets of excrement which are expelled from the wood. These pellets are more or less characteristic of the different species. Finally, entrance holes of the sexual colonizing adults about the size of BB shot are further indications of termite infestation.

Costs and Types of Damage

According to statistics compiled by Snyder (1929), the cost of damage caused by termites has been and is important. When we speak of the cost of repairing termite damage to buildings we mean both the loss due to the damage and the cost preventing further attack. As a general average, he says, the cost ranges from $500 to $2,000. In some cases, the damage may be as high as $10,000 up to $25,000. Then there are exceptional cases where expenditures exceed these. One of the most startling examples is that of a government building at Washington, D. C. which was damaged to such an extent that satisfactory repair entailed a cost of $140,000. Eighty per cent of the frame buildings in New Orleans and fifty per cent of the business buildings at Pasadena, California were harmed, some dangerously.

At Washington, D. C., damage to government buildings is still serious; and in Illinois, the loss suffered amounts to a million dollars yearly.

Preventive Measures

Improper construction is responsible for the gradual deterioration of the wooden structures of our homes from termite infestation. Numerous examples can be cited which describe the complete surprise of those concerned when parts of their homes fall apart. The chief factor which makes us realize the extreme importance of the correct use of preventive measures is this very uncertainty. We can never tell when our homes, buildings, and factories are termite-infested and likely to give way. Infestation may even reach the point where the whole flooring and supporting blocks may become weakened. The results are only too evident. Besides, thousands and thousands of dollars a year are lost by the destruction of trees, for, termites follow the path of least resistance, eating the soft parts of the trees. Further, termites may even extend their attacks to cotton products, papers, and pamphlets, for it is, after all, the cellulose that they desire wherever possible.

We now have a knowledge and appreciation of the termite menace and are ready to turn to means of termite control. The eradication of an existing infestation whether it be in our homes or our trees is much more difficult than preventing fresh attacks. We know fairly well how to improve our construction of homes to prevent infestation. According to Pickens (1934) examinations made on scores of buildings attacked by termites point definitely to the conclusion that buildings can be so constructed as to be almost, if not entirely, free from attack.

The Use of Chemicals

The Termite Investigations Committee conducted experiments for several years to learn the efficacy and practicability of various chemicals in the campaign against termites. Toxicity was expected to increase with concentration but this expectation did not always agree with the experimental data. For one thing, termites may be repelled from an area where a strong concentration of chemical is present and eating becomes restricted.

These results were based on the following experiments. From 10-50 insects were used for each test group. The insects were kept in Petri dishes with filter paper for food. When water was necessary, it was put in a very shallow moisture cup with a screen cover. Chemicals were tested in various forms: 1) Water-soluble chemicals were tested by soaking filter paper supplied as food in solutions of the chemical and drying it before testing, 2) Chemicals for which no suitable solvent was found were usually tested as dusts or powders. Although the Committee intended to repeat all the tests made in a more exact routine manner, their program was never completed. Thus the rough values in the tables below represent the only data available on the toxicities of some of these materials. Most of the work done in this connection was by Randall and Doody (1934) and in collaboration with them were two other workers, Herms and Weidenbaum (See Table I).

The actual way in which toxic substances act on the termites is not definitely known. Results have shown that it is probably due to a change in the osmotic pressure in the termite's

digestive system. This change in osmotic pressure would kill intestinal protozoa on which the insect depends for digestion of its food. However, toxicity may not be essential in treatments used in actual practice since, if the preservative is sufficiently distasteful or noxious to termites, it will repel without killing. Of course, such treatment is not strictly termite-proof. ~~The~~ A toxic substance is needed to cause the elimination of the termites.

Petroleum Oils

Light petroleum greases such as vaseline are effective in killing termites. Tests were performed that showed that volatile petroleum products produced an anaesthesia but not death. Light oils were very toxic since they clog the tracheae and thus suffocate the termites. Heavier oils become less effective with an increase in gravity.

Wood Preservatives and Protective Treatments

The primary requisites of a good wood preservative are toxicity, permanence, and harmlessness to the wood. The treated wood must be able to take and retain paint, must have a low electrical conductivity, small fire hazard, and must be workable when tools are used. Further, there must be no danger to the workman using the preservative. The practicability must also be considered, that is, expenses must be kept down to keep within the limited resources of the average man. Finally, the treated wood must serve to save the consumer money eventually.

A detailed description of the types of treatment would entail much that is beyond the scope of this thesis. Briefly the main types are the brush application with a retention of one-half pound per cubic foot of wood, and full-cell pressure treatment with a retention of 20 pounds per cubic foot of wood. The type of treatment will depend on the cost of preservative and length of service to be expected from the treated wood. Treatments are usually applied only to thoroughly seasoned wood. Green or unseasoned wood cannot be treated satisfactorily by either of the two processes since the preservative cannot permeate the cells of the green wood which are still filled with sap.

Preservative Substances

Much information has been gathered on this score by the Termite Investigations Committee through rather extensive researches. In most cases, preservatives were resorted to whose chemical natures were known. It seems, however, that the so-called "standard wood preservatives" are the only ones that withstood the tests (See Tables 1-4). These are coal-tar creosote and zinc chloride. Economically these two are very advantageous. Other preservatives have, of course, been discovered and used, but the standard ones have furnished us with service, records of fine accomplishment and economic value.

Paints and Termite Damage

The use of paint to protect wood from termite damage was investigated by the Committee for paints were supposed to be toxic to termites. The results of the Committee's tests and observations have demonstrated that paint is valuable only in connection with the dry-wood termite Kalotermes minor, which infests wood directly from the outside. Paint will not kill the termites in infested wood. While a continuous paint film makes the wood highly-resistant to dry-wood termite attack, termites can readily infest wood through a break in the film of paint. No conclusive instances were found in the field where wood attacked by termites had been infested through a painted surface. Wood was attacked where there were cracks due to imperfect framing of the lumber, and where the paint did not cover the wood surfaces in the joints, or where there were holes in exposed timber. Further, plane exposed wood surfaces were seldom found to be attacked by termites. But as paint was generally found to be covering plane surfaces, it is as yet unknown whether it is the paint that repelled attack or the mechanical difficulties of infestation. Paints that have been used for this purpose are: flexible lacquer, creosote shingle stain, synthetic resin varnish, cumar resin varnish and others.

Poison Dusts

Dusts seem to be effective in combating *Zootermopsis angusticollis* and *Kalotermes minor*. It has been found that the finer the dust particles the more effective they are, for they are better ~~equip~~ adapted to irritate the sensory hairs of the termites. Apparently the best dusts to be used as found by the Committee are: arsenical smelter dust, paris green, sodium fluosilicate, and barium fluosilicate. The poisons are of two kinds: 1) contact poisons, 2) stomach poisons. The former are more rapid, but not as effective. With the latter, no recovery is possible. Poison dusts are good for the destruction of the termites already established in poles or wooden structures.

Dust is blown into the galleries through a hole made in the vicinity of a nest. The hole must be closed after injection of dust, for termites are negatively phototropic and will close off that region. A colony is a "closed system" of narrow-burrows, and so all movements of termites are limited. Once inside the galleries, the termites spread the poison by grooming one another and thus large numbers are soon killed .

Treatment by Fumigation

In general the use of fumigants is not satisfactory for a number of reasons. A prolonged fumigation is required and even then the fumigants may not penetrate to all parts of the nests. Fumigation gives no guarantee against future infestation. Fumigation agents are expensive and many of them are extremely

dangerous to handle.

Of the fumigants hydrogen cyanide is most effective in killing termites. Chloroform and arsenic sulfur fumes and benzene are all fairly effective. Carbon bisulfide and carbon tetrachloride kill some termites but are less effective.

Proper Construction

Snyder (1937) describes the provisions necessary for building codes to protect homes from termite damage. The following suggestions have proved successful and are based on scientific knowledge and experience.

First, wood or fiber products, when not impregnated with an approved preservative should be placed 18 inches or higher from the ground except for wood columns or posts over a concrete floor. Such columns should be provided with non-corroding metal or concrete base plates or footings 6 inches above the floor. This applies to steps which should be laid over a concrete base projecting at least 6 inches beyond the supports of the steps.

Second, where wood is to be used in contact with the earth, it should be thoroughly impregnated by a standard pressure process with coal-tar creosote or other equivalent preservative. Timber should be completely framed before treatment whenever possible. When cutting after treatment is necessary, the exposed surfaces should be coated with coal-tar creosote or some other preservative.

Third, masonry foundations and footings should be laid in portland cement mortar. The foundations should be capped below the woodwork with at least one inch of portland cement mortar, or with mortar and slate, or with a non-corroding metal or seal.

Fourth, in frame buildings, a metal termite shield or mechanical barrier should be provided around the top of the masonry foundation both inside and outside (See Plate VII). To form

such a shield, a strip at least six inches wide of non-corroding metal (such as copper, zinc, or alloy) is inserted in the surface of the masonry or between the foundations and the wood. This extends outward horizontally at least two inches from the face of the foundation and then has the projecting edge bent downward at an angle of 45 degrees for an additional two inches. The corners are "soldered or crimped". Shields are set in the masonry at a height of at least 18 inches above the ground. At times, it is not necessary to insert the strip of shield on the outside surface of the foundation or it may be used in modified form.

Fifth, when only part of the space under the house is to be excavated for basement rooms, the rest should be so arranged as not to be within 18 inches of the wood, and this area should be cross-ventilated. Openings for ventilation should be proportioned on the basis of two square feet for each 25 linear feet of exterior wall. Ventilating openings, even those in attics, should be provided with 20-mesh non-corroding metal screening.

Sixth, where timber is used in flat roofs, there should be a slope and run-off, to provide adequate drainage unless protected on the weather side with some water-proof covering.

In another connection Snyder (1937 b) advises the use of chemically-treated wood for interior woodwork, furniture and so on. Wood pulp or fibre products, for interior finish or for exterior use can be protected from attack by termites by adding certain poisons such as coal-tar creosote at the rate of two gallons per 1,000 sq. feet to the pulp or fiber laminated boards in the course of manufacture. The principal object is to keep

all untreated wood from contact with the ground, where the termites live and from which they get their moisture.

Further recommendations are necessary in repairing damage caused by non-subterranean termites.

First, it is advisable to remove and replace the wood if the damage is slight and localized.

Second, where the wood is not structurally weakened, the saturation of the wood with orthodichlorobenzene is satisfactory.

Third, wood structurally weakened should be removed and replaced by chemically treated wood or strengthened with structural steel. ¶ In protecting or repairing trees or shrubs the following hints may be helpful.

First, properly executed tree surgery sometimes is effective in repairing injury to old fruit and shade trees. The termite-infested wood should be carefully cut out, and the dead heartwood should be coated with coal-tar creosote but treatment should not extend to within an inch of the living sapwood.

Second, prevention of infestation is more easily obtainable if the trees do not become scarred, especially near the base. Coal-tar creosote mixture should be used but care must be taken not to injure the living tissues just beneath the bark.

Third, it is ~~wai~~ wise to remove and burn all prunings and loose wood from dead and decaying trees since such debris may harbor termites which may spread into healthy trees.

Summary

Interest in termites is both historic and economic; the former traces termites back to millions of years before the advent of man on earth, and the latter is apparent when we find that termites are working counter to man's activities, destroying what man is building. Naturally enough, ways and means have been devised and are still being devised to eliminate the menace of the termites in our homes, forests, orchards, and vineyards. However, these measures would be impossible of achievement if we did not possess an extensive knowledge of the habits and life-history of termites.

We now know considerable concerning the life-cycle of termites. We have seen that it follows the general rule of dispersal flight, mating, founding a colony, gradual development of the young and increased activity until a continuous or practically continuous reproduction stage is attained with the final maturing of the winged reproductives resulting in the dispersal flight.

It has been shown that protozoa and fungi are associated with termites. These protozoa are located in the hind-gut of the insects but also are passed on to their neighbors probably on the fecal pellets which are extruded "upon request". This is called proctodeal feeding; there is also stomodeal feeding of the young or sexual ~~habits,--is~~ termites. Perhaps cannibalism, which also enters into the feeding habits, is quite important as far as control is concerned. Experimental work has shown that cannibalism does often occur. Finally, it has also been shown that pure cellulose as a diet is not sufficiently nutritious for growth,

but termites demand other elements to round out their staple-diet.

The grooming habit is significant for it is an opportunity for termites to check themselves for one thing. The injection of poison dusts into the gallery or galleries by means of a dust gun relies on the grooming habit of termites. Since the passages are narrow and confined, some termites will get particles of poison on them. Others in grooming them transfer some to themselves and soon these particles will adhere on all the members of the colony and in this way exterminating them. The above control measures apply to what are called contact poisons, but stomach poisons can be transmitted to the rest of the colony through proctodeal or stomodeal feeding.

A colony can be located by various means such as the presence of tunnels or towers, entrance and emergence holes, or pellets extruded by the colony.

It has been estimated that damage caused by termites runs into many millions of dollars annually. Posts and foundations as well as roofs, floors and so on, have crumbled suddenly resulting even in injury to people. It is important to prevent such occurences. Two chief control methods are employed; the use of chemicals, and proper construction.

A wide assortment of chemical compounds have been used in combatting termites. All of these have their drawbacks. Some chemicals are far too costly to be practical; while others, are dangerous for human beings to handle. Besides, some substances do not render a locality termite-proof, for if too strong a concentration of the chemical is used, it serves merely as a

deterrent, and the colony does not visit that section again.

Finally, proper construction of buildings must be resorted to, in order to prevent termite infestation. Placing foundation posts and other wooden structures of a new home in direct contact with the earth invites infestation. The diffusion of more knowledge among laymen will help materially in cutting down the damage by these insects. Ultimate victory, over termites is not yet in sight, but our knowledge concerning their habits is constantly increasing and perhaps some day we will bring them under control.

Table 1.

Preliminary Tests on Toxicity of Chemicals (1).

	Per Cent Preservative by weight	Time (hrs.) required for 100% Kill		
		Reticulitermes hesperus	Kalotermes minor	Zootermopsis angusticollis
Untreated paper	....	400	1000 +	Live indefinitely
Arsenic (white dust)	....	16	88 -	....
Paris green dust	....	16	47 -	....
Sodium arsenite dust	....	3	....	....
Barium carbonate dust	....	310	....	....
Calcium arsenate dust	....	29	24	....
Copper sulfate (paper soaked in 30 % of $CuSO_4 \cdot 5H_2O$ sol.)	29.5	430	....	270 +
Copper sulfate (paper soaked in 15 % sol.)	11.6	....	480 +	770 +
Mercuric chloride (paper soaked in 6 % sol.)	8.3	24	46	33
Sugar (sucrose) granular	....	....	....	....
Zinc chloride (paper soaked in 10 % sol.)	17.0	228	....	....

(1) Randall, M., Herms, W.B., and Doody, T.c.:
"The Toxity of Chemicals to Termites"
In Termites and Termite Control Pg. 341
Table 27 (in part)

Table 2.

Data on Toxicity of Wood Preservatives. (2).

Preservative	Douglas fir % Preservative	Douglas fir LBS. Per Cu.Ft.	Douglas fir Days to Kill 80%	Douglas fir Days to Kill 100%	Redwood % Preservative	Redwood LBS. Per Cu.Ft.	Redwood Days to Kill 80%	Redwood Days to Kill 100%	Sugar Pine % Preservative	Sugar Pine LBS. Per Cu.Ft.	Sugar Pine Days to Kill 80%	Sugar Pine Days to Kill 100%
Untreated Controls	.....	.....	110	>170	.....	.....	94	>160	.....	.....	105	>170
Ac - Zol. 10% sol.	3.78	1.30	65	86	3.78	0.817	33	47	2.67	0.76	39	66
Anaconda Neutral 3.44%	4.73	1.46	4	7	7.77	1.67	2	4	6.65	1.66	3	6
. . . .	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Creosote 100% not dried	48.0	29.2	1	1	53.8	30.1	1	1	41.7	21.3	1	1
25% " "	10.7	6.3	1	2	13.42*	7.53	0	1	11.95	5.32*	3	4
10% " "	4.80*	2.92*	0	1	5.38*	3.01*	0	1	4.8*	2.13*	0	1
1% " "	0.48	0.292	24	43	0.54*	0.361*	12	33	0.48*	0.213*	41	75
Creosote 100% dried at 50°C	42.8	25.2	1	3	44.0	26.6	2	3	32.0	11.3	4	5
25% " " "	15.9	6.2	4	5	16.1	5.12	5	6	15.1	4.19	6	13
10% " " "	4.28*	2.52*	6	12	4.4*	2.66*	7	10	3.2*	1.13*	9	17
1% " " "	0.43	0.252	67	106	0.44	0.206	67	116	0.32*	0.113*	87	107
Zinc chloride (Comm.)	5.02	1.73	84	137	6.48	2.65	118	139	6.68	3.32	106	>170
0.75%	0.501	0.182	49	57	0.822	0.194	70	94	0.100	0.114	72	104
1.0%	0.621	0.201	90	116	0.930	0.218	79	128	0.234	.106	78	105
2.0%	1.115	0.377	61	69	2.22	0.401	74	79	1.86	0.400	81	86
4.0%	1.78	0.668	70.	75	3.80	0.828	50	67	4.56	1.03	90	134

* figure computed.

2. Randall, M., and Doody, T. C.:
"Wood Preservatives and Protective Treatments."
In Termites and Termite Control P. 380-1
Table 29 A (in part).

Table 3.
Toxicity Tests of Commercial Proprietary Preservatives on the Damp-Wood Termites. (3).

Chemical	% Preservative by weight after drying	80% death (days)	100% death (days)	Amount of Eating
An-Fo	15,28	4	7	None
Avenarius Carbolineum	40.26	4	5	None
Cabot's Shingle Stain #301	13.4	4	6	None
Cabot's Wood Prese.	32.85	4	7	None
Cuprinol 50% sol. in petroleum ether	35.4	8	13	Slight chewing
Lignophol, Nat.	35.41	17	30	Feeding
Ligni-Solver	27.26	7	11	Extensive feeding
Petro-Creoleum #11	40.44	14	24	Feeding
Potassium Xanthate	9.5	2	5	None
" "	6.4	3	9	Slight Feeding
" "	2.5	24	34	Feeding
Protexwood	19.3	16	32	Feeding
Solignum	24.23	3	5	Slight feeding
Sodium Arsenite 10%	18.58	2	7	None
Termiteol	28.5	17	34	Feeding
Termitol	54.3	12	20	Slightly chewed
" dil....	4.8	16	51	Feeding
Termol	29.5	9	16	Feeding
Tetrachlorphenol	14.3	1	1	None
Zinc Chloride	55.75	14	18	Feeding

(3). Randall, M., and Doody, T. C.:
"Commercial Proprietary Preservatives"
In Termites and Termite Control
Page 399 Table 30 (in part).

Table 4.

Toxicity Tests of Commercial Proprietary Preservatives on the Dry-Wood Termites (4).

Preservative	Douglas Fir				Redwood				Pine			
	% Preservative	Lbs. Per Cu. Ft.	Days to Kill 80%	Days to Kill 100%	% Preservative	Lbs. Per Cu. Ft.	Days to Kill 80%	Days to Kill 100%	% Preservative	Lbs. Per Cu. Ft.	Days to Kill 80%	Days to Kill 100%
Avenarius Carbolineum	----	----	1	2	----	----	3	4	----	----	1	2
Cabot's Shingle Stain #301 gr.	3.2	1.1	12	17	4.5	1.2	16	24	4.4	1.3	14	60
Cuprinol diluted with 50% Pet. Eth.	4.1	1.32	64	86	6.7	1.78	92	106	4.7	1.41	33	89
Ligni-Salvor 22.26%	14.4	5.56	3	5	24.4	7.16	2	4	6.03	2.45	3	5
Protexwood	----	----	34	>180	----	----	82	117	----	----	87	100
Solignum	----	----	1	1	----	----	2	2	----	----	2	4
Termiteol	----	----	45	71	----	----	34	52	----	----	33	65
Termitol 25% in H_2O	4.58	1.50	16	25	4.1	1.12	63	92	3.88	1.12	30	89
Termitol (undiluted)	----	----	35	45	----	----	43	61	----	----	24	43
Termol	----	----	22	27	----	----	17	42	----	----	40	52
Untreated	----	----	110	>170	----	----	44	>160	----	----	105	>170

(4). Randall, M., and Doody T. C.: "Commercial Proprietary Preservatives." In Termites and Termite Control P. 400 Table 31 (in part).

Plate I

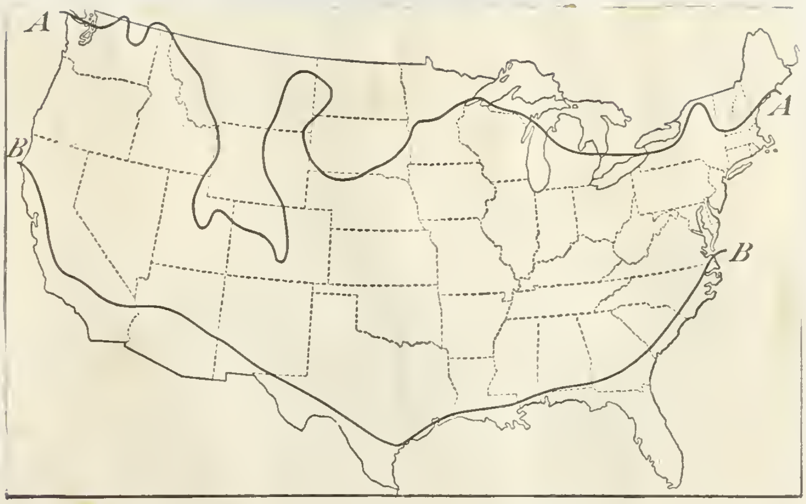

FIGURE 1.—Map showing (line A–A) the northern limit of damage done by subterranean termites in the United States and (line B–B) the northern limit of damage done by dry-wood or nonsubterranean termites.

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Plate II

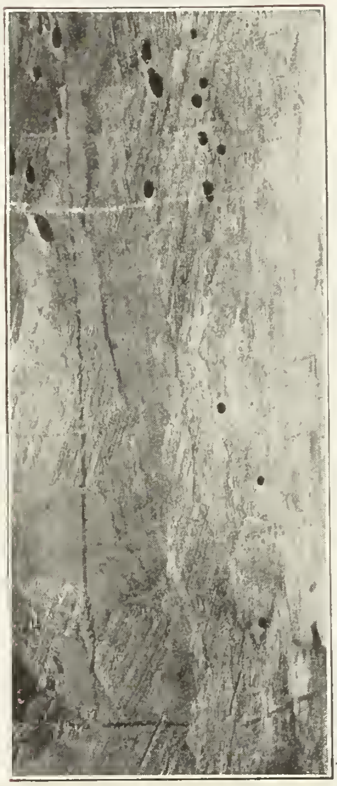


FIGURE I.—Entrance holes of sexual, colonizing adults of a nonsubterranean termite (*Kalotermes hubbardi*) in wood of dead cottonwood tree in Arizona.

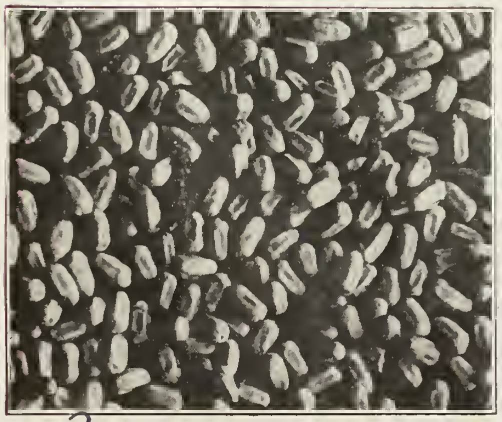


FIGURE 2.—Impressed pellets of excrement of nonsubterranean termites (*Kalotermes* sp.), which drop from infested wood. Greatly enlarged.

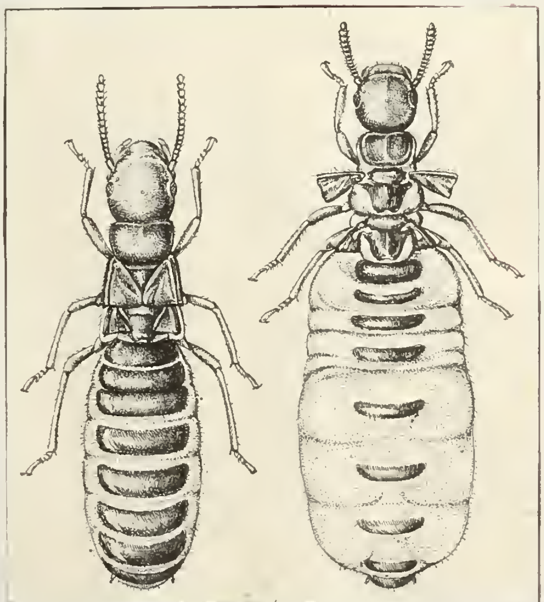


Figure 3. A primary pair of a colony about one year old. (Enlargement about six times.)

Plate III

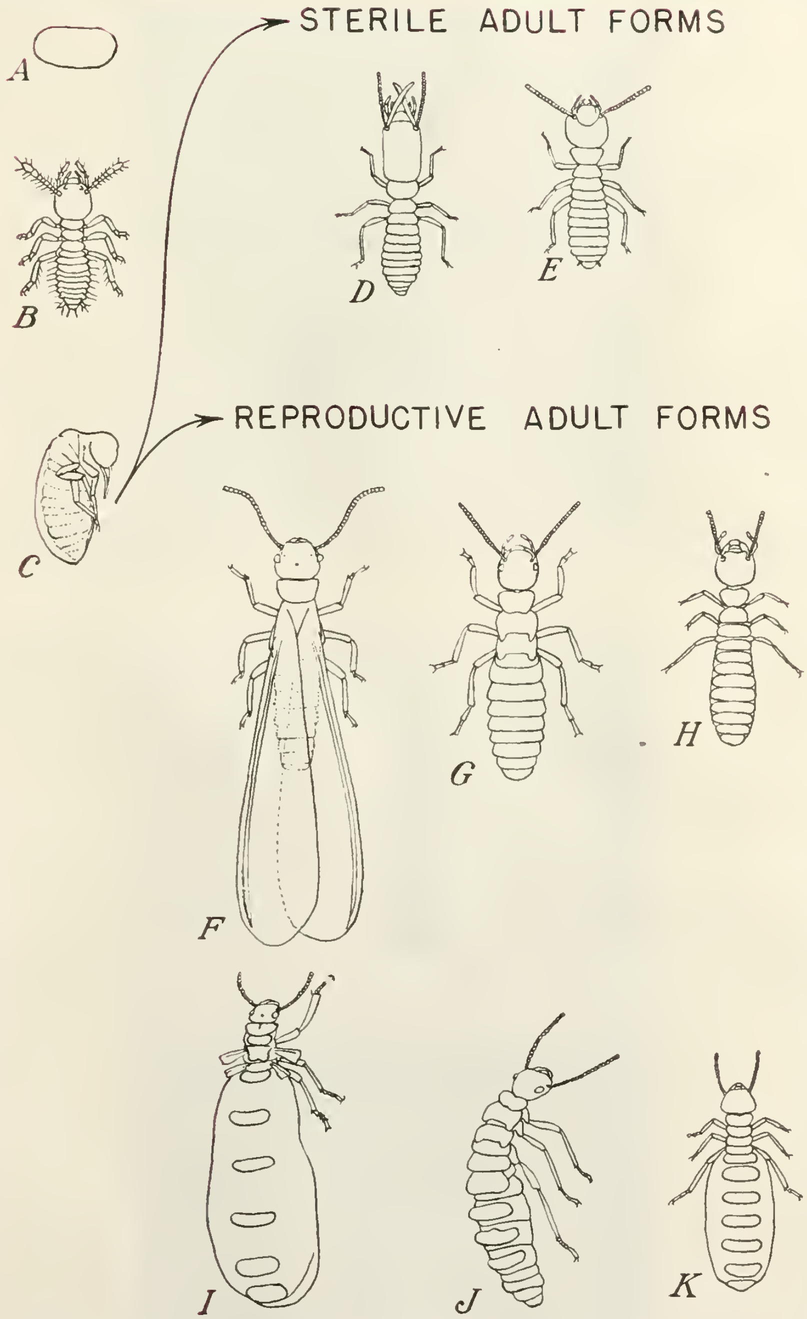


FIGURE I.—Diagram showing the relationships of the stages and forms of our common subterranean termite *Reticulitermes, flavipes*: *A*, Egg; *B*, recently hatched nymph; *C*, immature nymph in quiescent or resting stage; *D*, soldier; *E*, worker; *F*, sexual winged adult; *G*, sexual adult with wing pads; *H*, workerlike wingless sexual adult; *I*, *J*, and *K*, enlarged egg-laying females or queens, corresponding to *F*, *G*, and *H*, respectively. *D* and *E* are sterile adult forms; *F*, *G*, *H*, *I*, *J*, and *K* are fertile or reproductive adult forms. (The enlargements are approximately as follows: *A*, ×16; *B*, ×13½; *C*, ×10; *D*, ×4½; *E*, ×5½; *F*, ×6; *G*, ×4½; *H*, ×5; *I*, ×2½; *J*, ×2½; *K*, ×3.)

From Farmers' Bull. 1472.

Plate IV

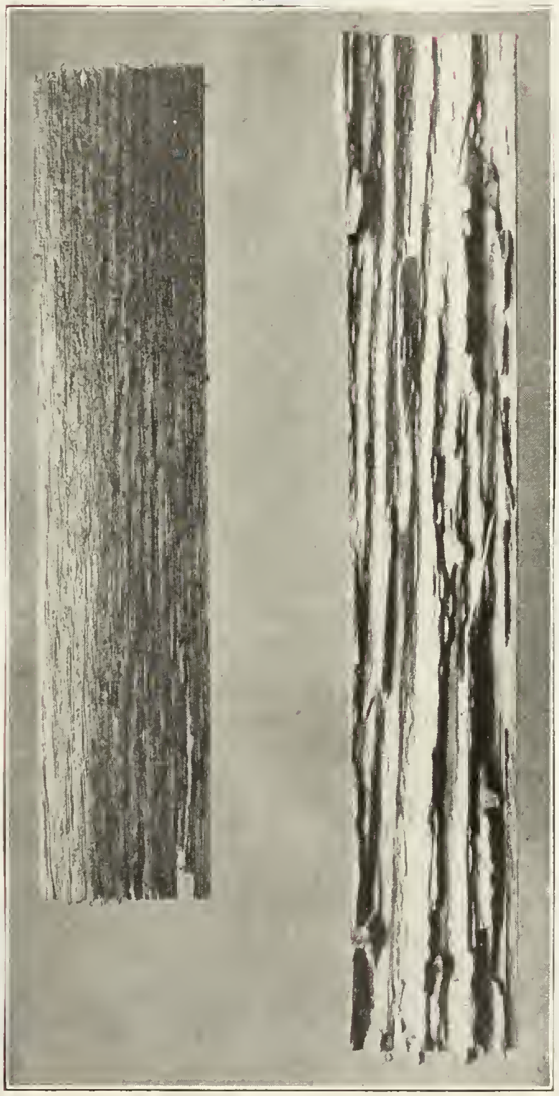


FIGURE I.—Damage to oak flooring done by the common eastern subterranean termite *Reticulitermes flavipes.* Note that damage is not apparent on the upper surface.

FIGURE 2.—Tube of coarse yarn from bale of cotton on floor of building infested by subterranean termites, Greenville, S.C.

Plate V

FIGURE 1.—Interior view of portion of whitewashed brick foundation wall of building, below ground level, showing shelter tubes of our common subterranean termite *Reticulitermes* sp., penetrating the disintegrated lime mortar. These termites came through the earth banked up against the exterior wall To remedy this condition the exterior wall will have to be faced with concrete for some distance below the ground level.

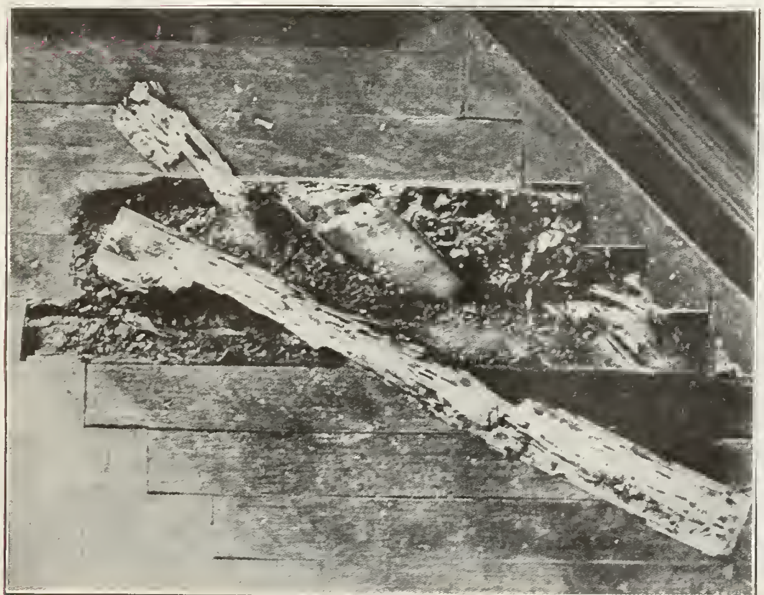


FIGURE 2.—Quartered-oak flooring damaged by the subterranean termite *Reticulitermes flavipes* in an infested building, Washington, D.C., 1915.

Figure 3. A Shoe Victim
Termites made it unfit
for rainy weather.

Plate VI

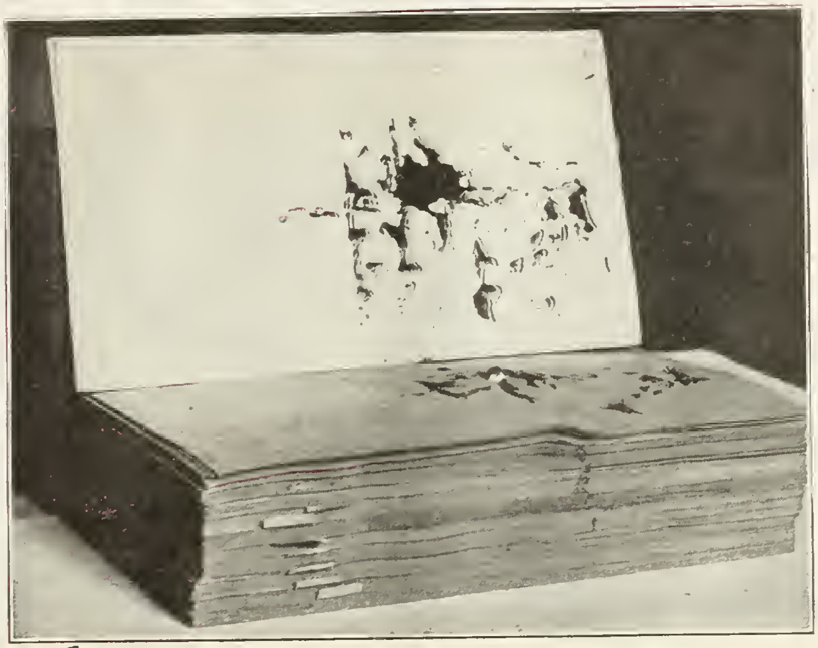


FIGURE I.—Revenue stamps damaged by the subterranean termite *Reticulitermes flavipes* on infested flooring in the Bureau of Engraving and Printing, Washington, D.C., 1921.

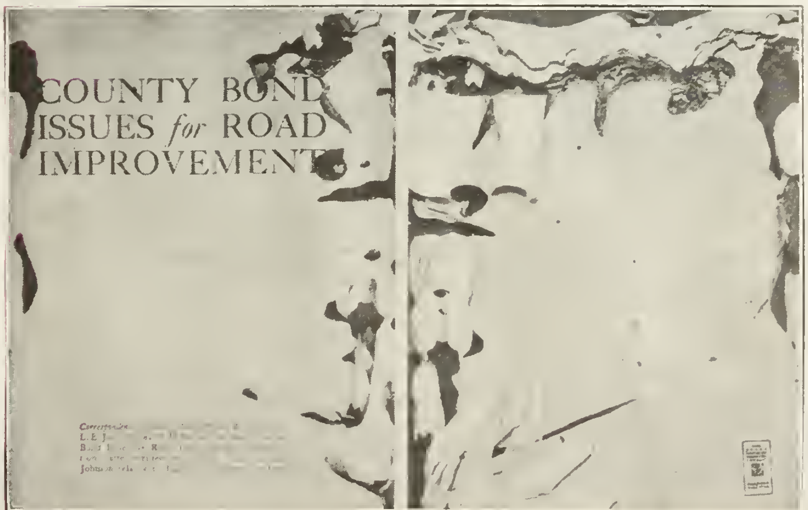
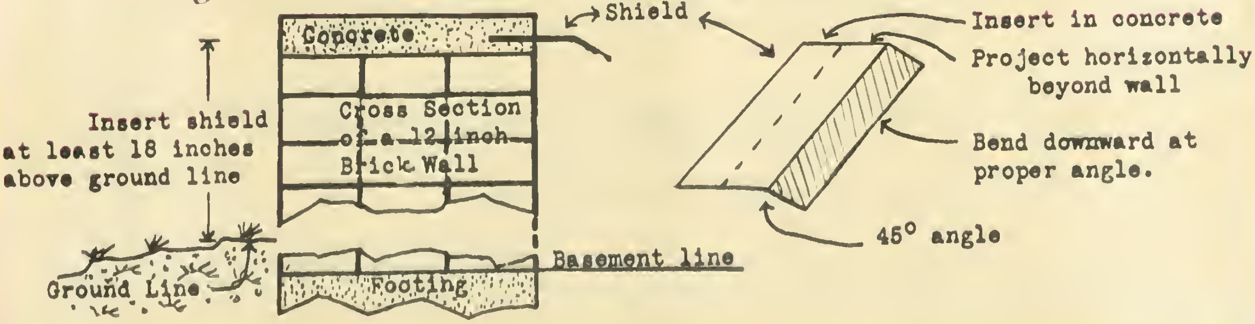


FIGURE 2.—Correspondence and advertisement regarding issue of county bonds; damaged by subterranean termites infesting the building in Virginia in which they were stored.

Plate VII

Figure 1.— Proper Installation of Metal Termite Shield



From Form E-338 (Revised).

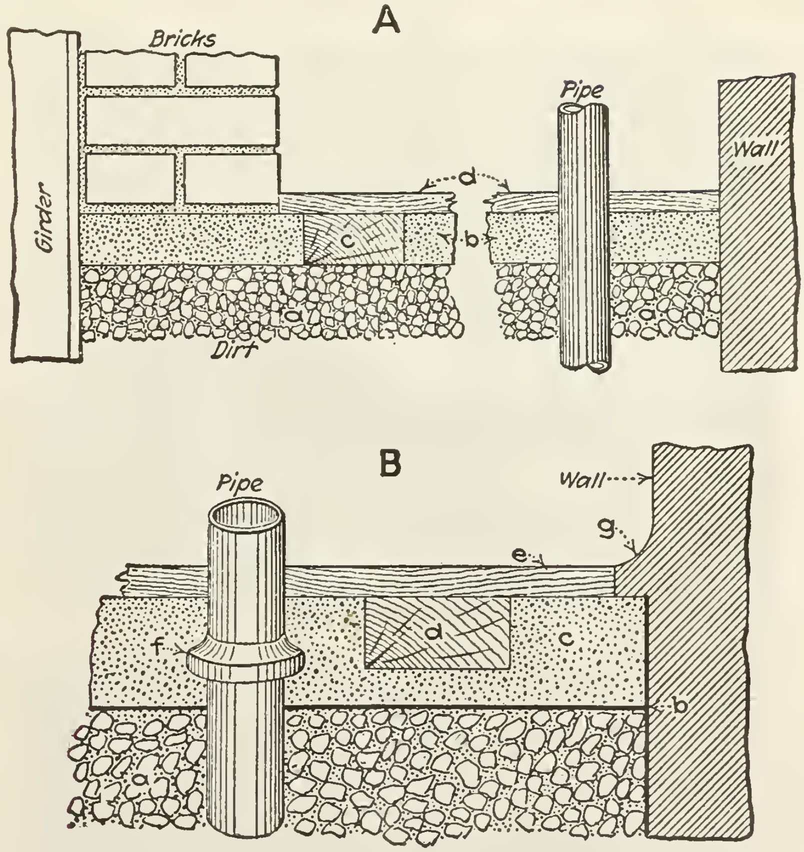


FIGURE 2.—*A*, Improperly constructed concrete flooring: *a*, Gravel or cinders loosely cemented with coarse concrete, 3 inches thick, but with many crevices and holes; *b*, solid, dense concrete, 2 inches thick; *c*, 2- by 4-inch untreated wood sleeper set in moist concrete over the grout; *d*, ⅞-inch pine flooring nailed to sleepers. *B*, Properly constructed concrete flooring: *a*, Gravel or cinders loosely cemented with coarse concrete, but with many crevices and holes; *b*, coal-tar pitch waterproofing ⅛ inch thick; *c*, dense concrete, 3 inches thick; *d*, 2- by 4-inch treated wood sleeper set in a groove in concrete which insulates it from termites in the earth; *e*, ⅞-inch flooring nailed on sleepers; *f*, metal collar around pipe which runs down through the concrete (this collar should be soldered to the pipe and embedded in the concrete); *g*, shoulder of concrete at point of wall and concrete floor to avoid a right-angle connection and consequent cracking.

From Farmers' Bull. No. 1472

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