CDC

MANUAL 11

SELF-STUDY COURSE 3013-G

Vector-Borne Disease Control

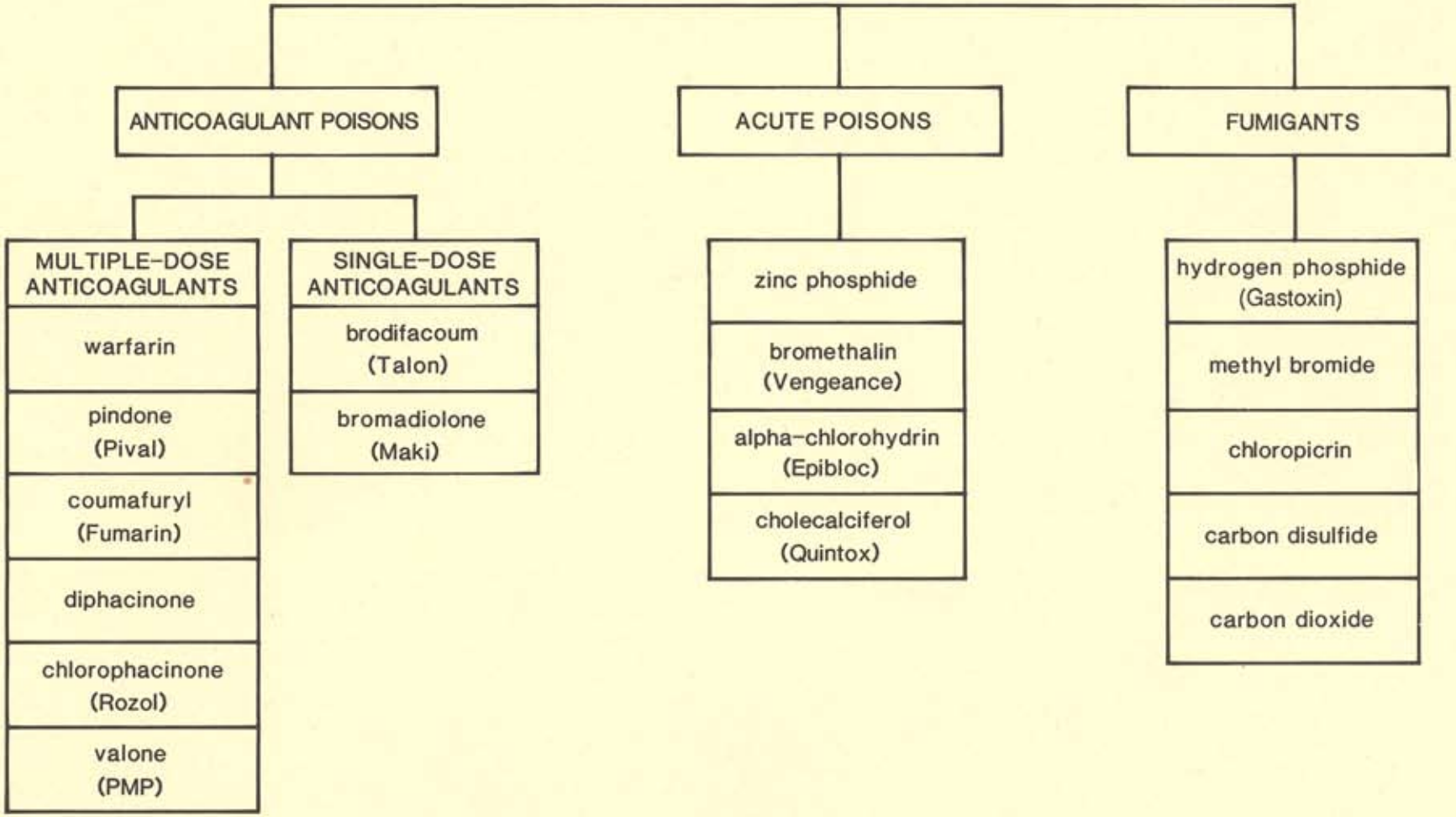
CONTROL OF COMMENSAL RATS & MICE

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES

SELF-STUDY

CHEMICAL CONTROL OF RODENTS

By
Harry D. Pratt



CONTROL OF COMMENSAL RATS AND MICE

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
CENTERS FOR DISEASE CONTROL AND PREVENTION

Controlling rat populations, not individual rats, is the key to a successful rodent-control program in a community.

The use of trade names and the names of supply or manufacturing firms is for identification purposes only and does not constitute endorsement by the Public Health Service or by the U.S. Department of Health and Human Services.

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RODENTS AND HUMAN WELFARE

Rats and mice have accompanied man to most of the areas of the world that he has settled. Historically, they have been responsible for more human illnesses and deaths than any other group of mammals. Man's indifference and carelessness in handling food and refuse have fostered populations of rats and mice in such close proximity to his home and work that they are commonly called "domestic" rodents *(9, 67, 80)*.

ECONOMIC IMPORTANCE

Rats in the human environment cause enormous economic loss. They consume or contaminate vast quantities of food and animal feed. They destroy other property as, for example, when they cause fires by gnawing the insulation from electric wires. It is estimated that 5 to 25 percent of fires of unknown origin on farms are caused by rats.

No reliable estimate of the rat population of the United States is available as a basis for calculating these losses, although the ratio of one rat for every person has frequently been quoted in the literature. If, in consideration of recent improvements in environmental sanitation and rodent control, this rough estimate used in the past is reduced by one-half, that is, to one rat for each two people, then the United States has some 100,000,000 rats. Each rat damages between $1 and $10 worth of food and other materials per year by gnawing and feeding, and contaminates 5 to 10 times more. Thus, rats may cost the United States between $100,000,000 and $1,000,000,000 annually in terms of direct economic losses *(15, 80)*.

RAT BITES

In addition to the annual dollar losses due to rats, there is also the intangible cost of rat-associated injury and illness. Rat bites create a serious health problem and are far more common than most people realize. In some of the larger cities, hundreds of rat bites are reported each year. Many cases are never reported.

Based upon available records, large metropolitan areas of the United States experience rat-bite at a rate as high as 10 per 100,000 persons per year. Prior to the initiation of the Federal Urban Rat Control Program in 1969, this amounted to 3,000 to 4,000 cases annually in the large cities alone, and the cases unreported from them and from the smaller cities and towns undoubtedly totaled several thousand more. Based on a rate of 10 cases of rat-bite per 100,000 persons, and an urban population of 140 million, Scott *(88)* estimated that there were 14,000 victims of domestic rat-bite in this country annually.

Helpless infants and defenseless adults (invalids, unconscious, and elderly persons) are particularly subject to attack by rats. Occasionally rat-bite wounds cause death. All rodent bites should be promptly and carefully cleaned and disinfected. Tetanus immunization or a booster shot is often recommended. However, since 1969, the Public Health Service has advised that

bites of rats and mice seldom, if ever, call for rabies prophylaxis. "This recommendation, based on the low rate of infection in wild rodents, is further supported by the fact that there has never been a case of human rabies in this country attributed to rodent exposure, even though rodent bites are common. An estimated 24,000 rodent bites (from domestic and wild rodents) per year are severe enough to require medical consultation" ***(105)***.

RODENT-BORNE DISEASES

Rats and mice are responsible for spread of a number of diseases, either directly, as by contamination of human food with their urine or feces, or indirectly, by way of rodent fleas and mites. Following are brief descriptions of the more common of these diseases.

RAT-BITE FEVER

Causative agent, *Streptobacillus moniliformis*

The bacteria that cause rat-bite fevers are found on the teeth and gums of many rats and are transferred from rat to man by the bite of the rat. The most frequently occurring rat-bite fever in the United States is called Haverhill fever. It is similar to rat-bite fever of the Orient called sodoku (caused by *Spirillum minus*) ***(8, 65, 101)***.

LEPTOSPIROSIS

(Weil's Disease)-Causative agent, *Leptospira spp.*, primarily *L. icterohemorrhagiae*

Leptospirosis is a mild to severe infection that is seldom fatal. Human cases of the disease result from direct or indirect contact with infected urine of rodents and of certain other animals. The spirochetes, which are found in water or on food, may enter through mucous membranes or minute cuts or abrasions of the skin. Thus, leptospirosis is often found in sailors, miners, sewer workers, fish or poultry dealers, and abbatoir workers. In Hawaii, Norway rats and house mice were found to have high *Leptospira* carrier rates ***(74)***.

In St. Louis, Missouri, cases of leptospirosis occurred in dogs and humans in areas where sewer rats had *L. icterohemorrhagiae* infections ***(36)***.

SALMONELLOSIS

Causative agent, *Salmonella spp.*

Salmonellosis, which is generally classed as food poisoning, is a common disease of worldwide distribution. It is an acute gastroenteritis produced by *Salmonella* bacteria of the group pathogenic for man and other animals. It is spread in various ways, one way being through food contaminated with rat and mouse feces containing *Salmonella* organisms ***(8, 15, 67, 80, 101)***.

TRICHINOSIS

Causative agent, *Trichinella spiralis*

Trichinosis results from an infestation of the intestines and muscles by larvae and cysts of *Trichinella spiralis*. Both man and rodents develop the disease from eating raw or insufficiently cooked pork infected with the organism. Research has indicated that rodents may play an important role in the spread of the disease to hogs that feed on uncooked garbage at open dumps, for hogs experimentally fed the trichina-infested feces of rats and mice readily become infected. In turn, the rodents at open dumps undoubtedly often feed on raw or insufficiently cooked pork scraps, which keeps the rodent-swine-man cycle of this disease going ***(4, 83)***.

MURINE TYPHUS FEVER

Causative agent, *Rickettsia typhi*

Murine typhus occurs in California and in the Southeastern and Gulf Coast States. Rats are the reservoir animals from which the disease reaches man by way of rat fleas. The oriental rat flea, *Xenopsylla cheopis*, is considered the most important vector of the disease. The causative organism enters the bloodstream when feces of infected fleas are scratched or rubbed into a flea-bite wound or other break in the skin. Murine typhus is similar to epidemic or louse-borne typhus, but the illness is much milder and the fatality rate in untreated cases is much lower ***(8, 15, 77, 80, 98)***.

PLAGUE

Causative agent, *Yersinia* (formerly *Pasteurella*) *pestis*

Plague is the "Black Death" that once killed millions of people in Europe, Asia, and Africa. No major urban outbreak of plague has occurred in the United States since 1924. However, a reservoir of the disease exists in wild rodents of the western states, where the bacteria are transmitted from one rodent to another and sometimes to man by the bite of rodent fleas. There is always the danger that domestic rodents will become infected, and that they, in turn, will carry the infection to human population centers. The disease is often fatal to the rat and the flea, and the death rate in untreated human cases is extremely high ***(6, 15, 16, 58, 64, 73, 78)***.

RICKETTSIALPOX

Causative agent, *Rickettsia akari*

Rickettsialpox is a mild nonfatal disease resembling chickenpox. It is transmitted from the house mouse to man by the bite of the house-mouse mite, *Liponyssoides* (formerly *Allodermanyssus*) *sanguineus.* In this country rickettsialpox has been reported from Boston, Mass., West Hartford, Conn., New York, N. Y., Cleveland, Ohio, and Philadelphia, Pa. ***(47, 63, 82)***.

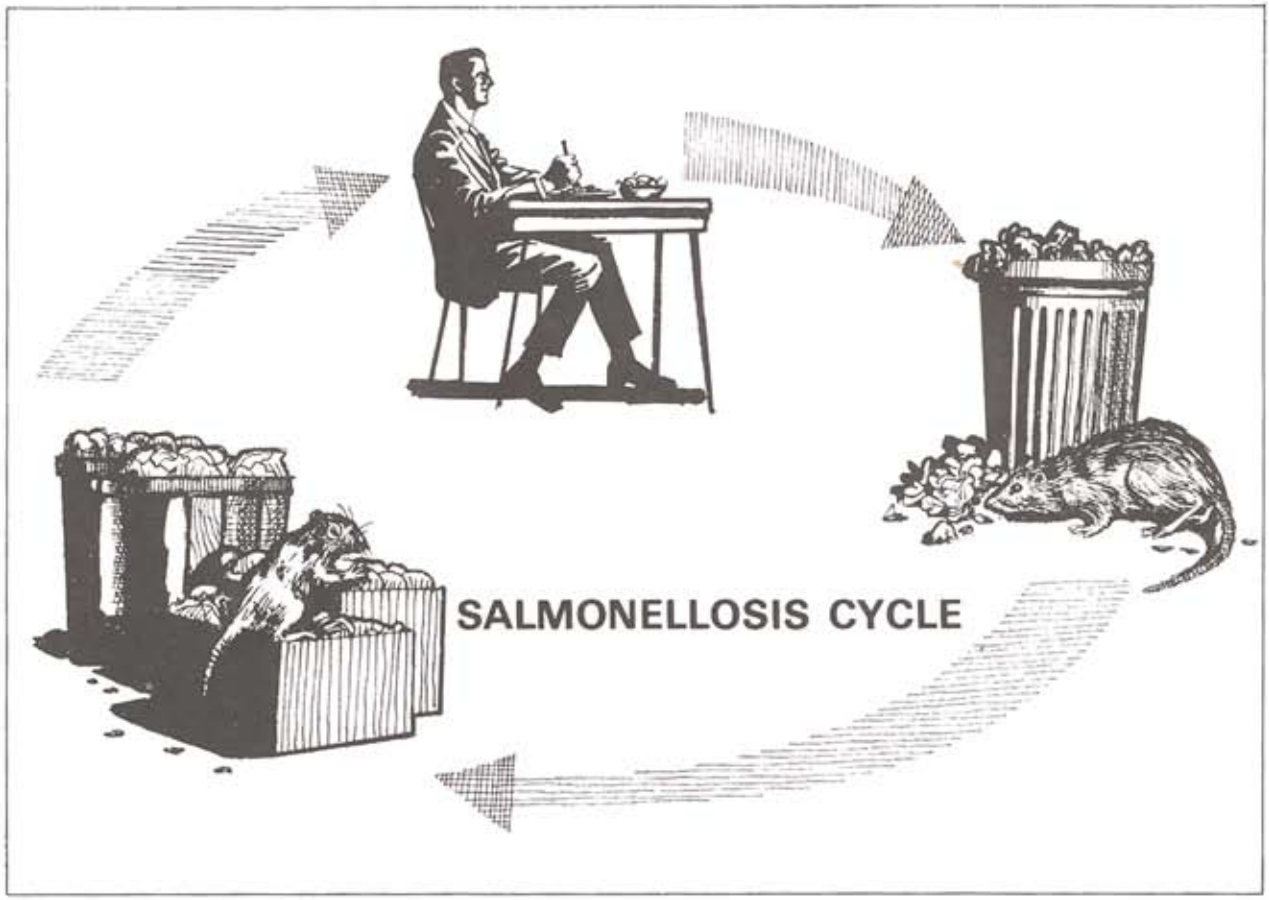
LYMPHOCYTIC CHORIOMENINGITIS

Causative agent, LCM virus.

Lymphocytic choriomeningitis (LCM) is a viral disease of mammals, especially house mice. Humans become infected by contact with the saliva, nasal secretions, urine, and feces of infected mice, usually in contaminated food or dust. In man the disease often resembles influenza, with recovery in a few days or weeks. Severe cases have many of the symptoms of encephalitis; a few end fatally ***(8, 101)***.

OTHER DISEASES

A number of other diseases of less frequent occurrence are associated with domestic rodents. Two of these are toxoplasmosis and listeriosis ***(8, 101)***.



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DESCRIPTION AND HABITS OF COMMENSAL RATS AND MICE

BIOLOGICAL FACTORS

The Norway rat, roof rat, and house mouse live in close association with man and have been carried by humans throughout the world. They are often called "domestic rodents," although this label implies that man raises them like livestock. In recent years many authorities refer to them as "commensal rodents," which refers to the fact that "these animals live at man's expense, eating his foods, living in his house, and sharing with man their diseases, without contributing anything beneficial to the relationship." *(15)*.

All rodents are best characterized by their single pair of incisor teeth on each jaw and by the absence of canine teeth. Commensal rodents in the Old World family Muridae, often called "murine rodents," have tails with fine scales and few hairs, whereas many of the American rodents, such as the field mice, wood rats, squirrels, and chipmunks, have hairy or bushy tails *(20, 44, 72)*.

NORWAY RAT

The Norway rat (*Rattus norvegicus*), predominantly a burrowing rodent, is the most common and the largest of the commensal rats. It is distributed throughout the temperate regions of the world, including the United States. Common names for the species are the brown rat, house rat, barn rat, sewer rat, and wharf rat.

Body: heavy, stocky.

Body weight: 7 to 18 ounces (200 to 500 grams), adults average about a pound (450 grams).

Length of head and body: 7 to 10 inches (180 to 255 mm).

Tail: length 6 to 8 1/2 inches (150 to 215 mm); shorter than head plus body, bicolored, dark above, pale below.

Total length: 13 to 18 1/2 inches (325 to 460 mm).

Fur: coarse, usually brownish or reddish-gray above, whitish on belly with gray underfur. Entirely black individuals occur in the United States.

Nose: blunt.

Ear: small, close-set, with fine hairs, appears half buried in fur, does not reach eyes. Rarely over 3/4 inch (20 mm) long.

Eye: small.

Teats in female: 12; 3 anterior (pectoral) and 3 posterior (pelvic) pairs.

Droppings: large, up to 3/4 inch (20 mm) long, capsule shaped, often with blunt ends.

Sexual maturity: reached in 2 to 3 months after birth.

Gestation period: averages 22 days.

Young: often 8 to 12 per litter.

Number of litters: about 4 to 7 per year.

Number weaned: about 20 per female.

Length of life: average about 1 year.

Harborage: outdoors — in burrows in the ground and under foundations of buildings, particularly barns, chicken houses, and animal quarters, in rubbish and garbage dumps, and in sewers; indoors - between floor and ceilings and in walls, in enclosed spaces of cabinets, shelving, and appliances, in piles of rubbish, and in other spaces concealed from view.

Range: 100 to 150 feet (30 to 50 meters).

Food: garbage, meat, fish, vegetable, fruit, and cereal baits are well accepted; daily requirement, 3/4 to 1 ounce (22 to 30 grams) of dry food, more of moist food.

Water: daily requirement, 1/2 to 1 ounce (15 to 30 ml).

ROOF RAT

The roof rat *(Rattus rattus)* is somewhat smaller than the Norway rat and is a more agile climber. In the United States its range is almost entirely confined to the South, to the Pacific coast, and to Hawaii. It is abundant in the tropical and subtropical regions of the world but is rare or absent in the colder regions.

Body: slender, graceful.

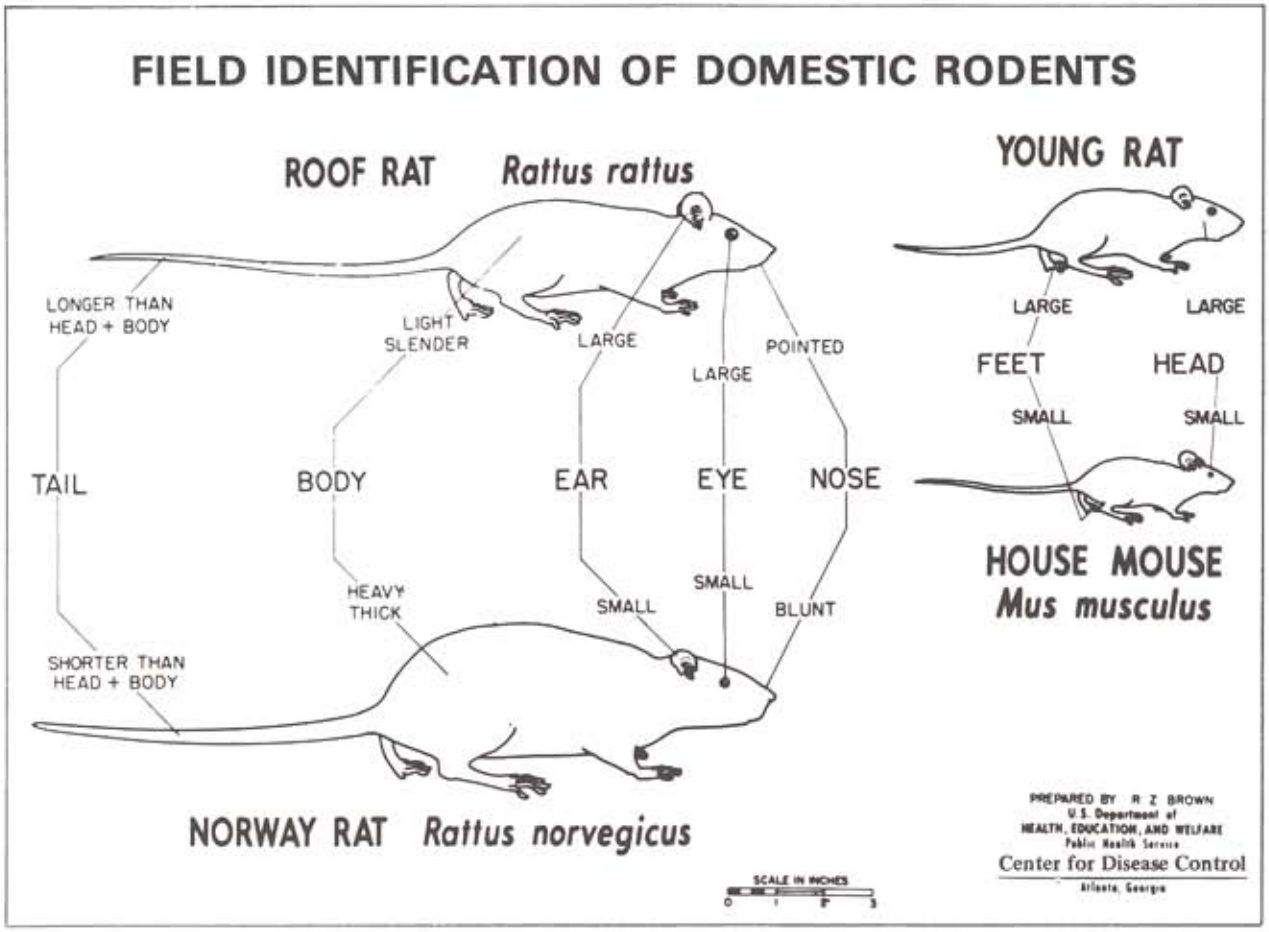
Body weight: 4 to 12 ounces (110 to 340 grams), adults average 1/2 to 2/3 pound (225 to 300 grams).

Length of head and body: 6 1/2 to 8 inches (165 to 205 mm).

Tail: length, 7 1/2 to 10 inches (190 to 255 mm). Longer than head plus body, uniformly colored.

Total length: 14 to 18 inches (350 to 450 mm).

Fur: fine body hair and long, prominent, guard hairs. Three color phases have been recognized in the past: the black rat *(Rattus rattus rattus)*, which is black to slate-gray; the Alexandrine rat *(Rattus rattus alexandrinus)*, which is brownish above and grayish-



white below; and the fruit rat *(Rattus rattus frugivorus)*, which is brownish above and white-to lemon-yellow below. All three subspecies interbreed and different color variants sometimes occur in the same litter. Therefore, many authorities consider the domestic forms all one species ***(49, 87)***.

Nose: pointed.

Ear: large, prominent, hairless, stands out from fur, can be pulled over eye. Generally more than 3/4 inch (20 mm) long.

Eye: large.

Teats in female: 10; 2 anterior (pectoral) and 3 posterior (pelvic) pairs.

Droppings: medium size, up to 1/2 inch (13 mm) long, sausage- or banana-shaped, ends often pointed.

Sexual maturity: reached in 2 to 3 months after birth.

Gestation period: averages 22 days.

Young: often 6 to 8 per litter.

Number of litters: often 4 to 6 per year.

Number weaned: about 20 young per female.

Length of life: average about 1 year.

Harborage: above ground-level; indoors - in attics, between floors and ceilings and in walls, and in enclosed spaces of cabinets and shelving; outdoors - in trees and dense vine growth.

Range: often 100 to 150 feet (30 to 50 meters)

Food: vegetables, fruits, and cereal grains preferred; daily requirement, 1/2 to 1 ounce (15 to 30 grams) of dry food, more of moist food.

Water: daily requirement, up to 1 ounce (30 ml).

HOUSE MOUSE

The house mouse *(Mus musculus)* is abundant throughout the United States. It is found throughout the world.

Body: slender, graceful.

Body weight: 1/2 to 3/4 ounce (14 to 21 grams).

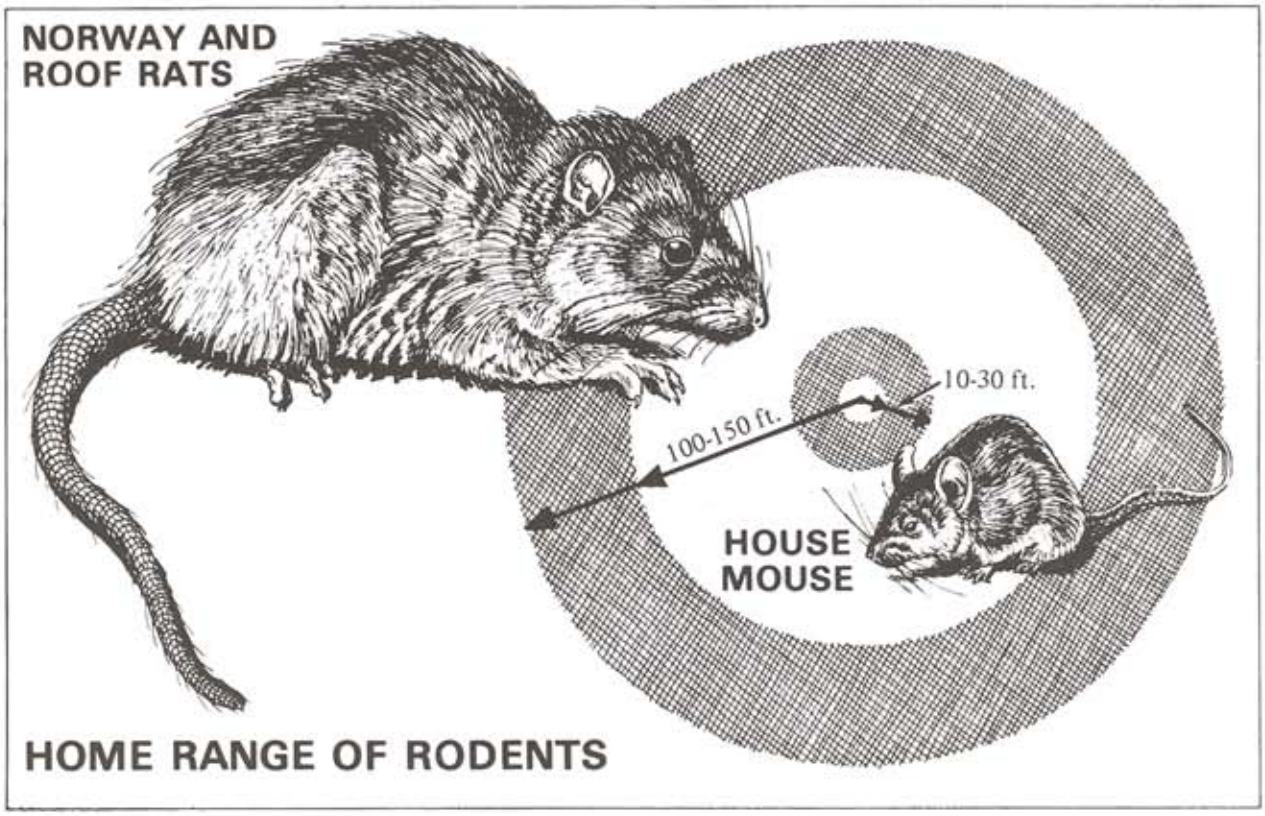
Length of head and body: 2 1/2 to 3 1/2 inches (65 to 90 mm).

Tail: 3 to 4 inches (75 to 100 mm). Equal to, or a little longer than, head plus body, uniformly grayish.

Total length: 5 1/2 to 7 1/2 inches (140 to 190 mm).
Fur: fine, brownish-gray on back, gray on belly.
Nose: pointed.
Ear: large, prominent, with some hairs, can be pulled over eye. Usually about 1/2 inch (13 mm) long.
Eye: large.
Teats in female: 10; 3 anterior (pectoral) and 2 posterior (pelvic) pairs.
Droppings: small, up to 1/4 inch (7 mm) long, rod- or spindle-shaped.
Sexual maturity: reached in 1 1/2 to 2 months after birth.
Gestation period: averages 19 days.
Young: often 5 to 6 per litter.
Number of litters: as many as 8 per year.
Number weaned: about 30 to 35 per female.
Length of life: average less than 1 year.
Harborage: indoors, in any convenient space between walls, in cabinets, in other furniture, or in stored goods; outdoors, in weeds, rubbish, or grasslands.
Range: 10 to 30 feet (3 to 10 meters).
Food: cereal grains preferred, but most types of edible materials; the mouse is a nibbler; daily requirement, 1/10 ounce (3 grams) of dry food, more of moist food.
Water: daily requirements, 3/10 ounce (9 ml); however, the mouse can live and grow in a dry habitat, as a sack of grain in a warehouse without free water, and utilize the metabolic water in food.

SENSES, AGILITY, AND REACTIONS OF RODENTS

Touch: well-developed in highly sensitive whiskers, or vibrissae, and in certain guard (tactile) hairs. Rats and mice prefer to run along sidewalls, between things, or in runways where they can keep their whiskers in contact with vertical or side surfaces.
Vision: not as well developed as in man. Rodents are color blind, so distinctive coloring of poison baits does not reduce their acceptance by rats and mice. Their vision is adapted to dim light. They can distinguish between shapes of objects and discern movement at distances up to 30, sometimes as much as 45, feet.
Smell: keen. Rodents apparently like the odors of most foods eaten by man. They are used to the odor of man; his odor on baits and traps does not repel them.
Taste: well-developed. Rats and mice will eat most foods that man will eat and prefer fresh food to spoiled food. Norway rats often eat bitter poison baits containing red squill which roof rats and mice refuse. Mice eat strychnine-poisoned grain that rats



HOME RANGE OF RODENTS

usually refuse. Rats associate sickness caused by poison bait with the bait and not with the poison *(80)*. Norway rats can detect minute amounts of warfarin contaminants (250 parts per billion) in poison baits *(12, 16, 80)*.

Hearing: keen. They can locate the source of a noise within 6 inches. Loud noises cause rodents to attempt escape from a building. Many attempts have been made to produce ultrasonic devices which would drive rodents from buildings. Brooks *(15)* has summarized much of the research in this field as follows: "Ultrasound will not drive rodents from buildings or areas, will not keep them from their usual food supplies, and cannot be generated intensely enough to kill rodents in their colonies. Ultrasound has several disadvantages: it is expensive, it is directional and produces "sound shadows" where rodents are not affected, and its intensity is rapidly diminished by air and thus of limited range."

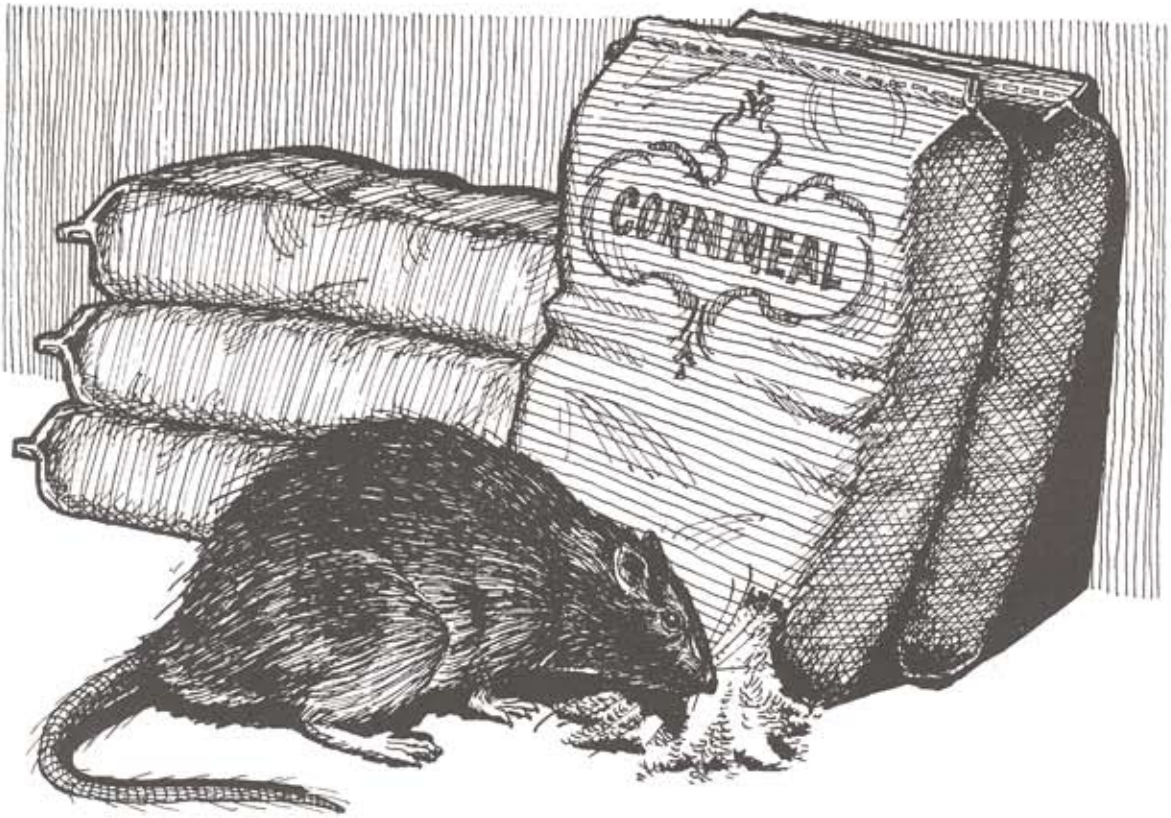
Balance: excellent. A falling rodent always lands on its feet. The roof rat maintains its balance while walking on suspended wires, using its long tail as a balancer.

Reaction to Strange Objects: Rats may avoid a new sound or a strange object in their environment for three or more days, particularly if their associates are alarmed by it. Other objects are readily accepted by them examples: (food, garbage). As rodent population pressures build, the rats frequently exhibit "chain-fright reaction" to disturbances. Mice are very curious and check their habitat constantly. Two recently-developed traps, the Ketch-All and Tin Cat, are effective because of the curiosity of these animals. When curious mice investigate these unbaited traps, they trip a treadle, or tilt a tunnel tube, and are caught alive in the holding compartment. Other mice are attracted to these traps by the squeaking mice (see p. 36).

Climbing: Roof rats and house mice are good climbers, and the Norway rat can climb quite well when necessary (see under Ratproofing, p. 40)

Jumping and Reaching: Rats can jump nearly 2 feet vertically, 3 feet with a running start. They can jump 4 feet horizontally, and 8 feet horizontally from an elevation that is 15 feet above the finish point. Rats can reach about 13 inches *(23)*.

Swimming: Rodent are good swimmers. They are able to swim up through floor drains and toilet bowl traps.



RECOGNIZING RAT AND MOUSE SIGNS

Rats and mice are usually nocturnal and secretive and are rarely seen during the day except when infestations are heavy. Therefore, it is necessary to properly interpret signs that indicate their presence to plan control work. These signs are found along walls, under piles of rubbish, and behind or under boxes, boards, and thick vegetation. From the rodent signs, one can tell the species present, and whether there is a current or old, heavy or light, infestation *(7, 9, 67, 72, 80)*.

DROPPINGS

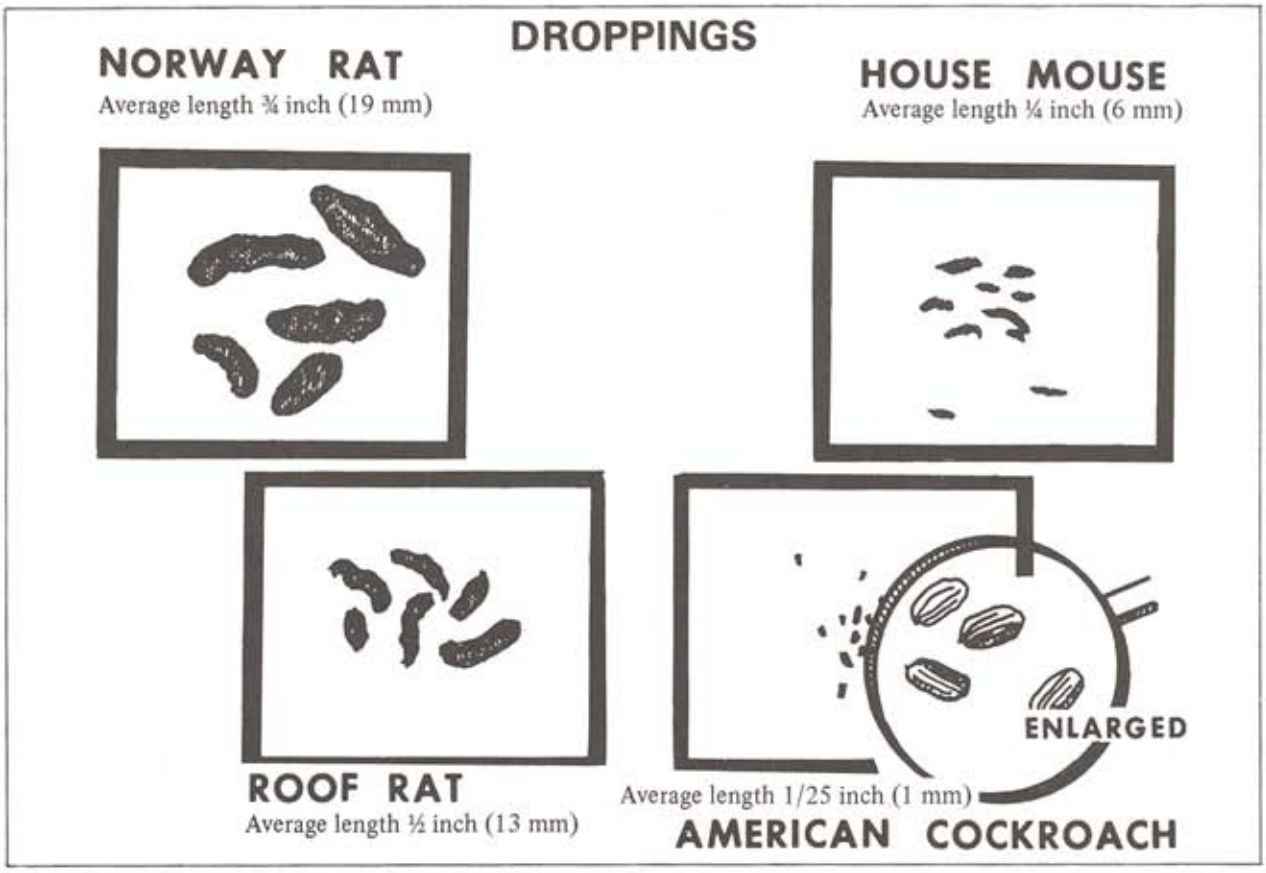
Fresh droppings of feces are usually, moist, soft, shiny, and dark, but in a few days they become dry and hard. Old droppings are dull and grayish, crumble when pressed with a stick, and are often moldy or covered with fungi. When examined under magnification, hairs are usually visible in rodent droppings. Cockroach droppings never contain hairs.

RUNWAYS

Rats habitually use the same runways between food, water, and harborage. Because of the keenly developed sense of touch in their vibrissae (whiskers) and in specialized hairs along the body, rats prefer continual body contact with at least one vertical surface, such as a fence or wall. Outdoors these runways are narrow pathways of beaten earth swept clear of debris. Indoors, greasy runways are found along walls, steps, and rafters marked additionally by urine, feces, and sex hormones. Undisturbed cobwebs and dust in a runway indicate that it is not in use.

RUBMARKS

Along regularly traveled runways, a dark, greasy mark forms from contact by the rodent's body. Fresh marks are soft and will smear if rubbed. As the grease



ages, it dries and gathers dust and will flake off when scratched with a fingernail. The rubmarks of the Norway rat are most commonly found along runways near ground or floor level, while those made by the roof rat are most commonly seen overhead as swing marks beneath beams or often at the point where they connect to the walls. Mice do not leave detectable rubmarks unless an infestation is heavy.

BURROWS

The Norway rat prefers burrows for nesting and harborage; the roof rat burrows only occasionally. Burrows are found in earth banks, along walls, under rubbish or concrete slabs, and in similar places. If a burrow is in use, its entrance will be free of cobwebs and dust. Fresh rub marks on hardpacked soil at the opening indicate a well established and presently used burrow. The presence of fresh fragments of food or freshly dug earth at the burrow entrances also indicates current use by rats. Burrows are seldom far from a source of food and water.

GNAWINGS

The incisor teeth of rats grow at a rate of 4 to 6 inches a year, so these rodents must do some gnawing each day in order to keep their teeth short enough to use. Rats gnaw to gain entrance and to obtain food. When gnawings in wood are fresh, they are light colored and show distinct tooth, marks. Small chips of wood or other materials indicate recent gnawing. With age, wood gnawings become dark and smooth from weathering and from frequent contact with the rodent's body *(67, 80)*.

TRACKS

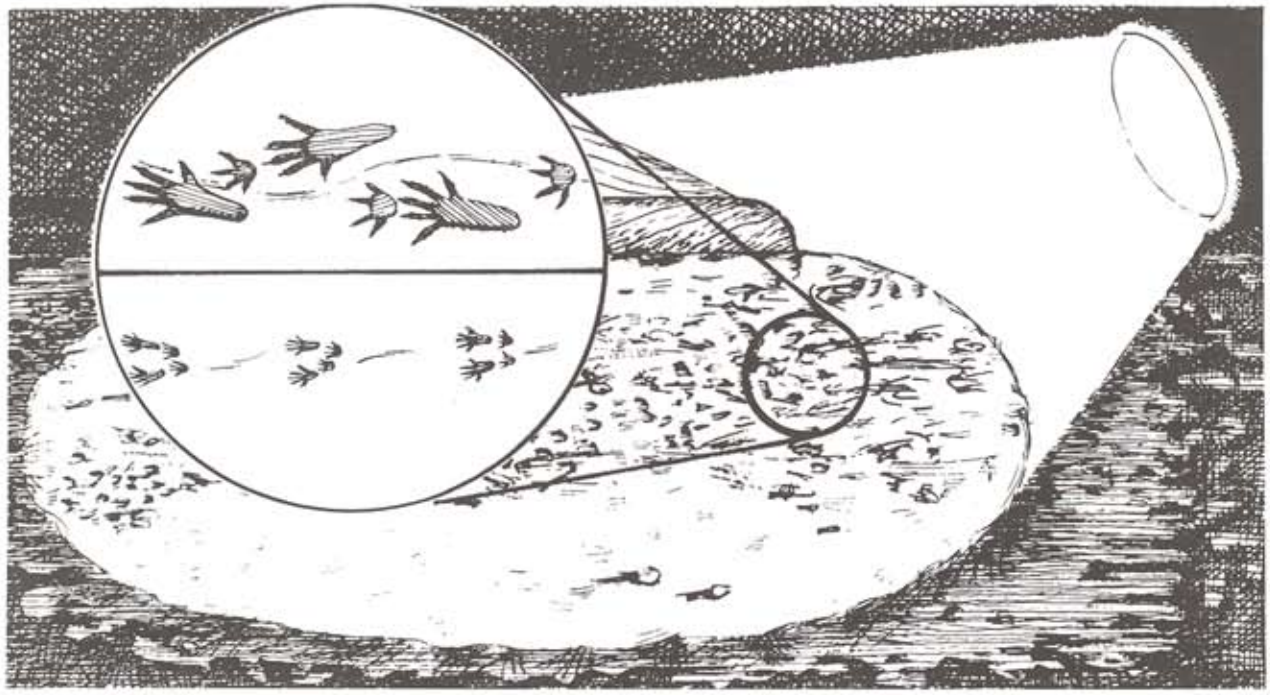
Fresh tracks are sharp and distinct, whereas old tracks are covered with dust and are therefore less distinct. The tracks of the 5-toed rear paws are more commonly observed than are those of the 4-toed front paws, but both may be present. Smooth tracking patches of any dust material, such as flour or talc, placed along runways are of value in checking for rodent activity. To see tracks in the dust; the inspector should hold a flashlight at an acute angle that causes the tracks to cast distinct shadows. Tail marks, too, are often visible in dust or tracking patches *(44)*.

SOUND

Rodents are often detected by hearing rats or mice gnawing or scurrying in attics, walls, or other parts or buildings. Frequently these infestations are first recognized by persons as they lie in bed.

SMELL

The odor of dead rodents, rodent droppings and urine often leads to careful investigation and discovery of infestations of rats and mice.



CONTROL OF RODENT POPULATIONS

BASIC PRINCIPLES

Controlling rat populations, not individual rats, is the key to a successful rodent-control program in a community. Examples of populations are the rats within a city block, those in a sewer, the rats infesting a farm, or those living in or around a feed mill. At any given time, each city block has a certain capacity to support rats. This capacity is related to the availability of food, harborage, living space and other vital rodent requirements. The rat population in a block cannot long be greater than this capacity. Permanent reduction of one or more vital factors (food, water, or harborage) in the block will result in a permanent reduction in the rodent population *(84)*.

POPULATION FORCES

Forces that determine the size of a rodent population at a given time are: reproduction, mortality, and movements into or out of an area. Reproduction increases a population, mortality decreases it, and movements can do either. Rats breed during the entire year, with peaks in spring and fall. Winter is the best time to conduct a poisoning campaign on a rat population, since breeding is then at a minimum. The next best time is summer, then fall. In field tests, populations reduced by poisoning in the winter took 12 months to return to their former levels; those poisoned in summer took only 6 months.

POPULATION CHANGES

As rat and mouse populations increase in size, the mortality rate also increases until a state of equilibrium, is reached. Increased competition due to population pressure increases the mortality and movements of rodents. Movements into or out of an area are less important in determining the size of rat populations than either reproduction or mortality. Rodents often migrate much greater distances than the limits of their normal home range (rats 100 to 150 feet, mice 10 to 30 feet) as, for example, their annual movement from fields to buildings in the fall and then back to the fields in the spring; and their migrations when their usual sources of food are cut off, or when they are flooded out or burned out.

LIMITING FACTORS

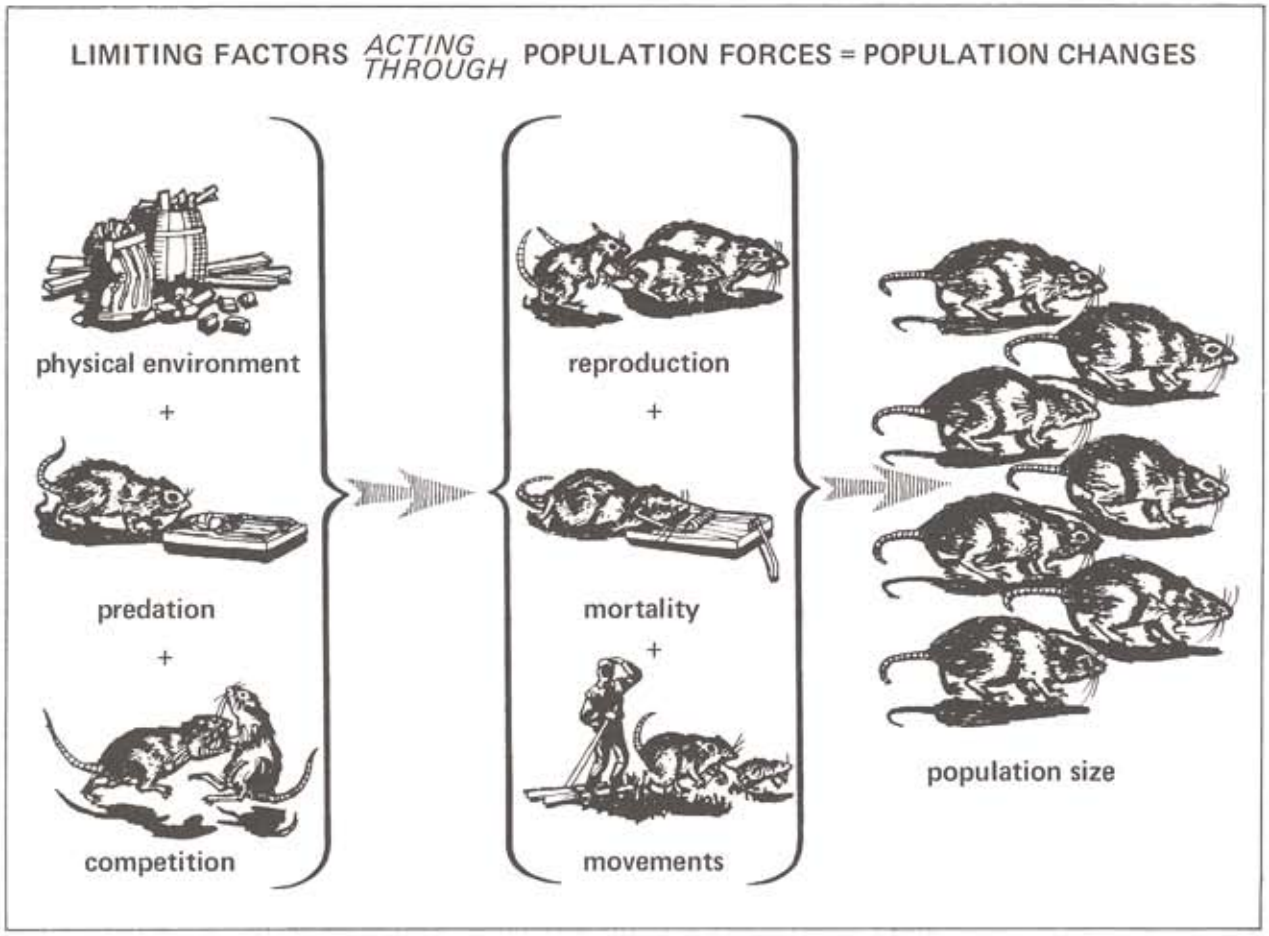
The factors that establish a balance among reproduction, mortality and movement of rodents are: the physical environment, predation and parasitism, and competition.

The physical environment is comprised of three main elements: food and water, harborage, and climate. Improperly handled foods, garbage, and field crops are the major sources of rodent food. (Favorite foods and harborage for rodents are listed on pages 5 to 7 under ("Description and Habits of Commensal Rats and Mice.") Climate directly affects the number of rodents that survive outdoors but has little or no effect on those living in heated buildings. A given environment can support only a certain number of animals. Generally speaking, areas with warm, moist climates support more, while those with dry, cold climates support fewer. *Man can reduce rodent populations and keep them low by permanently eliminating their food, water, or harborage.*

The effect of predators and parasites in reducing rodent populations appears to be temporary. This includes the predatory activities of man, dogs, cats, foxes, rats, birds, snakes and other foes, and the parasitic activities of bacteria, rickettsia, spirochetes, protozoa, viruses and worms.

Competition, whether between members of the species or between two or more species, is one of the most important factors limiting rat populations. Norway rats compete intensely with roof rats and have replaced them over large areas, particularly in many cities where both once were found. Competition among members of the same species is very closely associated with the social organization of a population. Definite social orders, or hierarchies, exist among rats and among mice. These social orders are determined largely by fighting, and the most aggressive animals in a population are dominant. Others are killed or are forced to move, and those that move may suffer even higher mortality from predators and resident rodents in the new areas. The strife caused by increased population pressure lowers the rate of reproduction, increases the mortality rate, and decreases the population. In summary, the most lasting control can be achieved by

permanent alterations of the physical environment of rats and mice. Man should so change the environment as to cause increased competition and predation, thereby lowering the capacity of the environment to support rats and mice. Environmental sanitation is thus the first and foremost requirement for permanent rodent control *(9, 15, 16, 19, 26, 27, 62, 67, 80, 81, 84)*.



SANITATION FOR RAT AND MOUSE CONTROL

Poor storage of refuse (garbage and rubbish) and of food in the home and in business establishments invites rats to infest blocks and neighborhoods. Rat and mouse populations are controlled by the storage of all refuse in rodent-proof containers, the satisfactory collection and disposal of refuse, and the proper storage of usable materials. Structural harborage, such as small protected enclosures under cabinets, shelves, and stairs, should be eliminated. Permanent removal of harborage and sources of food will eliminate existing rat and mouse populations *(84)*.

STORAGE OF REFUSE

Placing garbage and refuse in paper or plastic bags before putting it in the refuse container:

1. Reduces fly breeding
2. Confines odors
3. Prevents garbage from sticking or freezing to the sides of the container, thus avoiding damage to cans (from bumping to loosen garbage)
4. Reduces cleaning frequency
5. Adds to the useful life of the container.

Refuse storage facilities should include enough containers to hold all garbage and rubbish that normally accumulates between collection days. A good refuse container is:

1. Rust-resistant
2. Water-tight
3. Tightly covered
4. Easy to clean
5. Provided with two handles or a bail
6. Rat- and damage-resistant
7. Heavy duty
8. Made with a recessed bottom

Recommended container capacity:

For garbage only	5-12 gallons
For combined garbage and rubbish	20-32 gallons

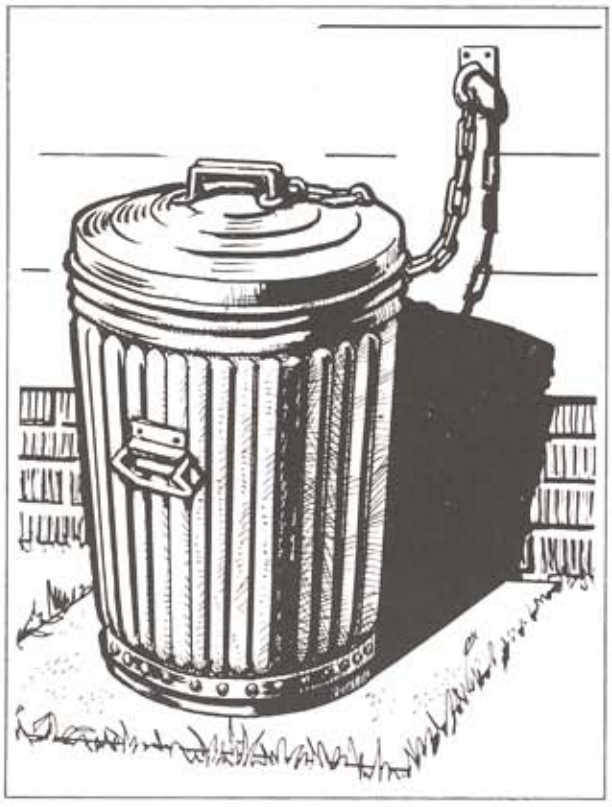
Fifty-five gallon drums should not be used as refuse containers. When filled, they are too heavy and too clumsy to handle, and usually they have no lids or the lids are unsatisfactory.

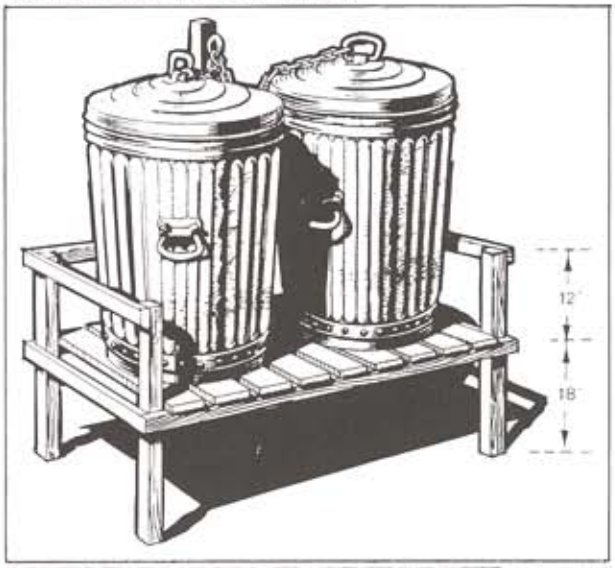
Concrete slabs improve the appearance of storage facilities but are effective only if refuse spillage is scrupulously avoided and containers are tightly closed at all times except when being filled or emptied.

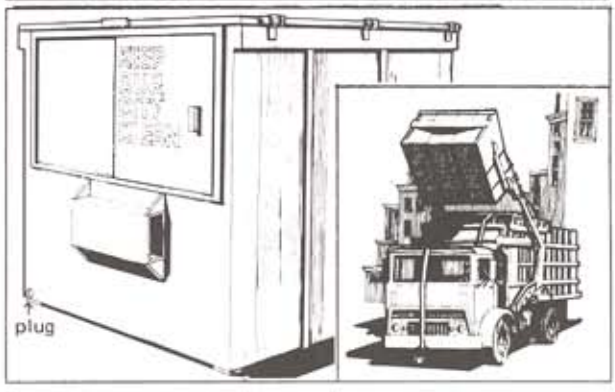
Storage on the premises can be greatly improved by providing and maintaining proper storage racks or stands for refuse containers. Sketch plans for satisfactory racks of various designs and materials can usually be obtained from local or state agencies. Types of holders that have proved adequate include: (a) single steel post with hooks to which the refuse cans are hung by the handle or bail, and sometimes with a stirrup to support the bottom of the container, (b) a pipe rack either of threaded or welded construction, (c) a rack made of steel bars such as those used in reinforcing concrete, of angle iron, welded together, and (d) single 1- or 2-can racks built of wood.

Bottoms of storage racks are made of equally spaced slats of selected materials and should hold the containers at least 18 inches off the ground. This elevation reduces corrosion of containers, permits regular cleaning underneath, reduces rat harborage under the rack, and minimizes the possibility of cans being overturned. Chains attaching container lids to the racks prevent loss of lids and minimize damage. Painting improves rack appearance and longevity.

Bulk Storage Containers are usually quite satisfactory at apartment buildings, housing projects, or business establishments. Commercial firms produce bulk containers of various sizes that are efficient and serviceable. Most bulk storage containers are designed to be emptied mechanically at the storage site into compactor-type collection vehicles capable of holding the contents of a number of bulk storage units. Many bulk containers have a drain hole to facilitate cleaning. These drain holes, often 2 to 3 inches in diameter, should be fitted with a removable hardware-cloth screen to prevent entry of rats and mice, or, preferably, the plug should be replaced after each cleaning. Otherwise, rats can enter such bulk containers through drain holes, thus converting a rat-proof container into a feeding station for rodents *(84)*.







STORAGE OF USABLE MATERIALS

Proper storage of usable materials reduces the food and harborage available to rodents to a minimum. All packaged bulk foodstuffs should be stacked 12 to 18 inches off the floor. Unless used promptly, foods removed from commercial packaging should be stored in covered glass or metal containers. All food scraps left after meals should be collected and packed in a covered refuse container.

Sweeping floors at frequent intervals removes rodent food and permits ready detection of fresh rodent signs. In food-handling locations, a white band 6 inches wide painted along the floor next to the wall speeds the discovery of rodent droppings, rodent tracks, and other signs indicating the presence of rats and mice.

Thorough inspections should be made regularly to detect any new evidence of rodent infestation. Remember effective and permanent control of rats and mice can be attained only through a **continuous sanitation program.**

COLLECTION OF REFUSE

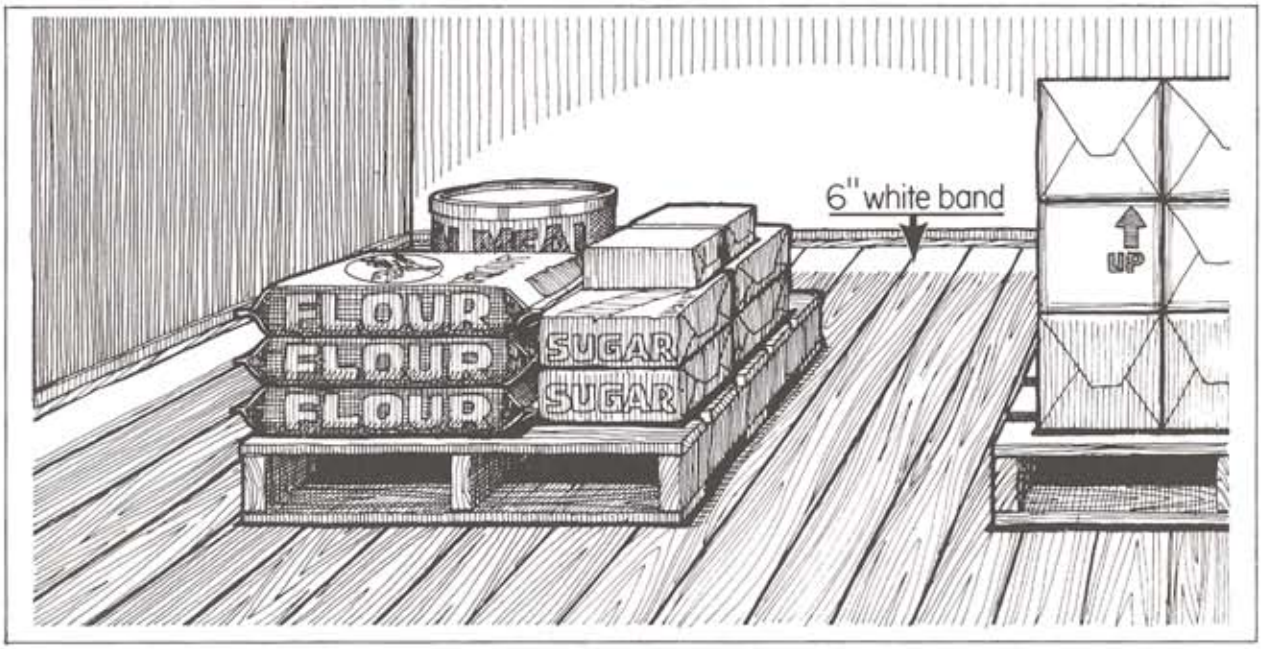
Good refuse storage practices are dependent upon adequate refuse collection service. Twice-weekly collection of residential garbage, or of combined garbage and rubbish, is recommended to prevent the overloading of household storage facilities, which provides exposed food for rats and a breeding medium for flies. Daily collection of refuse is recommended for business sections.

Compactor-type trucks are the equipment of choice for collection because they handle bigger loads, prevent contents from blowing or spilling out, are leakproof, and have low loading heights *(84)*.

DISPOSAL OF REFUSE

Open refuse dumps and areas where hogs are fed on garbage are major producers of flies and rats, and the rats may migrate from these unsatisfactory disposal sites to adjacent cities and farms. When the rats' daily source of food at such a site is cut off, as by a snowstorm or a refuse-collectors strike, great numbers of the rodents will migrate elsewhere. Unfortunately, many cities have insanitary rat-infested dumps. Until a sanitary method of disposal is instituted, it is often necessary to poison rats periodically to reduce the population and to prevent migrations (see page 19).

The sanitary landfill and incinerator methods of refuse disposal can be operated so that conditions favorable to rat production do not develop. At a prop-



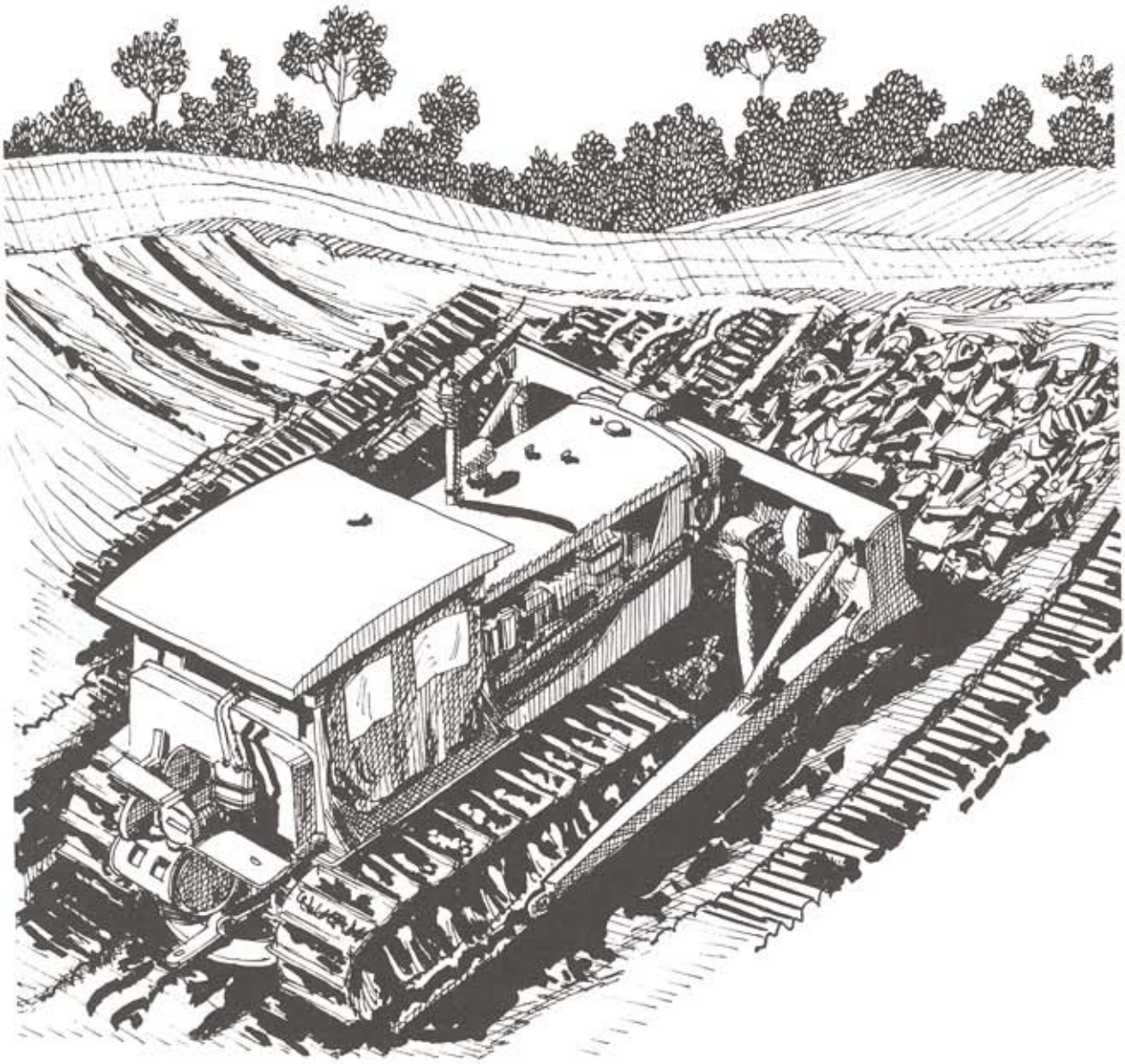
erly operated sanitary landfill, garbage and rubbish are compacted and covered with earth daily. Local officials must demonstrate continuing interest in and support of a model operation by providing adequate financing, by visiting it frequently, and by making it a showplace for the public and visiting officials. Modern incinerators operating at high temperatures completely burn combined refuse, thus leaving a residue that does not furnish food for rats *(19, 35, 80, 84)*.

Where sewer systems are adequate, electric garbage grinders provide sanitary disposal of garbage. However, this leaves other rubbish such as cans and bottles, which must be collected regularly *(84)*.

Research has shown that composting municipal wastes is feasible and that it can meet public health requirements for sanitary disposal. Costs of composting are higher than sanitary landfill costs but are lower than incinerator costs. Compost permits the salvage of some noncompostible materials such as metals and rags, and produces an end product, humus, that can be sold as a soil-conditioner supplement to fertilizers. However, composting should be considered primarily as a method of sanitary refuse disposal rather than as a source of income or a method of satisfying an agricultural need. Despite considerable investment and the application of advanced techniques, no largescale composting plant has operated at a profit for a long enough time to be considered a financial success *(13, 84)*.

REFUSE AND SEWER RATS

Rats often enter sewers at outlets and through manholes, catch basins, broken pipes, or drains. They nest in the ground at or near such locations. In the sewers, the rats feed on floating or stranded organic matter at the bottom or sides of pipes, especially during periods of low sewage flow. The problem is usually greatest in areas where storm and sanitary sewers are combined. The domestic sewage of an average community furnishes ample food to maintain a sizable rat population. The problem of rats in sewers will probably become greater in this country as more garbage grinders are used, and the food content of inadequate sewers increases *(5, 15, 81, 84)*.



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RODENT KILLING

RELATION TO OTHER CONTROL PROCEDURES

In the community rodent-control program, rodent killing is an important adjunct to improvements in sanitation and other environmental factors. However, timing is of great importance; and control through killing alone does not endure. For these reasons, killing methods can be applied most effectively:

1. Before sanitation or cleanup programs are begun-to prevent mass movement and spread of rodents.
2. After dusting with 5 percent carbaryl (Sevin) or other recommended insecticide for flea control-to suppress plague and murine typhus while reducing rodent populations.
3. After ratproofing work-to eradicate rodents in buildings.
4. Early in community programs-to stimulate public interest in rodent control.

Rat killing without environmental improvements, particularly good sanitation, is inefficient because:

1. Rats and mice rapidly restore their original population level through their high birth rate. The reduced competition promotes more frequent survival of the young.
2. A continuous killing program is necessary, which is costly in terms of labor and materials.
3. Continued use of most poisons can result in bait shyness

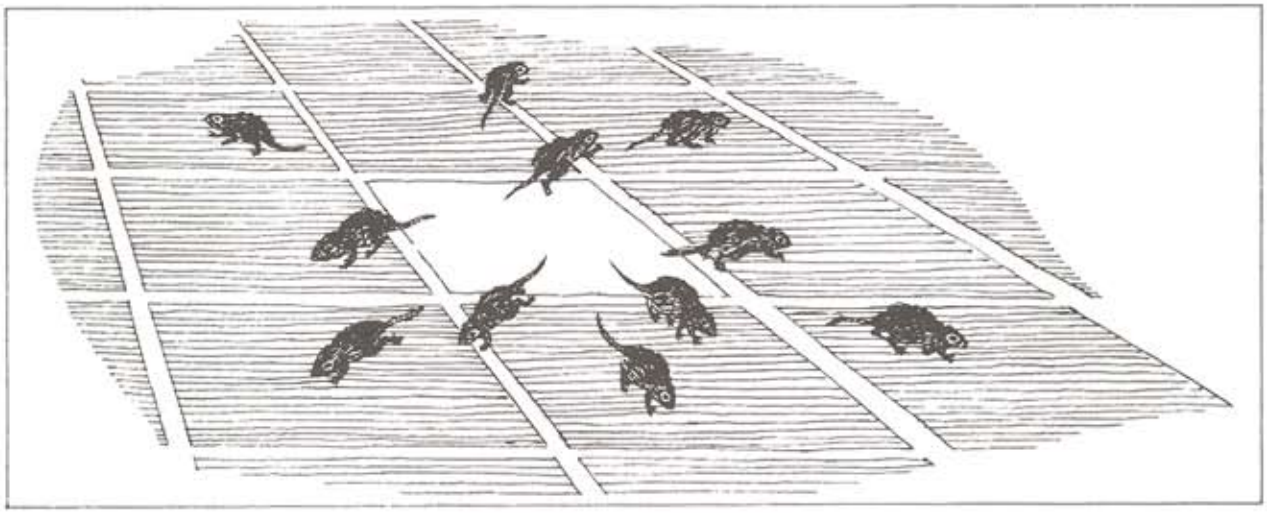
LEGAL ASPECTS

The Federal Environmental Pesticide Control Act (FEPCA) of 1972 (Public Law 92-156) became law on October 21, 1972. This legislation is usually referred to as the "amended FIFRA." It revised the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947.

This new law extends federal registration and regulation to all pesticides, including those manufactured, distributed, or used within a single state. It requires the correct application of pesticides to ensure greater protection of man and the environment. It prohibits the use of any registered pesticide in a manner inconsistent with its labeling. It specifies that all pesticides must be classified for "general use or restricted use." *(67, 71)*.

General Use Pesticides are those that will not ordinarily cause unreasonable adverse effects either on the user or the environment when used in accordance with the label instructions. These products include such rodenticides as the ready-to-use anticoagulants sold over the counter for the general public that are only slightly hazardous to the user or the environment.

Restricted use pesticides are those that may cause adverse effects on the environment or the applicator unless applied by, or under the supervision of, competent persons who have shown ability to use products safely and effectively. Such persons will be certified through programs administered by the states in cooperation with EPA. EPA has published a list of "restricted use pesticides" including such acute roden-



ticides as zinc phosphide and most of the fumigants such a methyl bromide and Phostoxin. The "restricted use" products can be used only by, or under the supervision of, a certified applicator ***(67, 71)***.

The amended FIFRA requires that persons who apply restricted-use pesticides, either pass an examination and thus qualify for certification, or work under the supervision of a certified applicator. The certification examination will be given by a state agency. In preparing for this examination, the U.S. Department of Agriculture and the U.S. Environmental Protection Agency have published a core manual on general standards entitled *Applying Pesticides Correctly* ***(71)***. All persons who apply restricted use pesticides will be expected to understand the information in this core manual.

In addition, commercial pest control applicators will be expected to pass an examination in Category 7, Industrial, Institutional, Structural, and Health-Related Pest Control.

Persons applying restricted-use pesticides on public health programs – whether funded with local, state, or federal funds – will be expected to pass an examination in Category 8 – Public Health Pest Control, or to work under the supervision of a person who has passed such an examination. Manuals and courses for commercial pest control operation have already been prepared. Manuals for persons who wish to be certified in Categories 7 and 8 have been prepared by government agencies.

PESTICIDE APPLICATORS SHOULD CONSULT EITHER A STATE REGULATORY AGENCY, OR SOME OTHER APPROPRIATE AUTHORITY, BEFORE APPLYING ANY RODENTICIDE, IF USE OF THAT PRODUCT COULD POSSIBLY BE IN QUESTION. EVERY PERSON WHO APPLIES PESTICIDES SHOULD ENSURE THAT THESE MATERIALS ARE USED IN STRICT COMPLIANCE WITH THE LABEL AND LOCAL, STATE, AND FEDERAL REGULATIONS.

POISONS AND BAITS

The anticoagulants are the rodenticides recommended for use by health departments and the public. These poisons, available commercially, are the ones with which the untrained individual is the least likely to experience difficulties.

Rodenticides are divided into three categories (see inside front cover). They are categorized according to their mode of action as anticoagulants, acute poisons, and fumigants. Anticoagulants, as warfarin and chlorophacinone, cause the blood to lose its ability to clot (or coagulate) usually three to seven days after the rodent eats the poison and the animal gradually bleeds to death. Acute poisons, as zinc phosphide, are fatal to the rodent from an hour, to a day or more, following feeding. Fumigants, as hydrogen phosphide and methyl bromide, kill as gases ***(9, 15, 16, 48, 67, 72, 80)***.

Anticoagulants prevent the conversion of vitamin K in the liver and subsequent formation of blood-clotting proteins in the blood. The blood loses its ability to coagulate, hence the name of these chemicals. There is leakage of blood from the capillaries throughout the body. The rodents literally bleed to death. Probably 90 to 95 percent of the chemical control of domestic rodents in the United States is done with the anticoagulants, either multiple-dose or single-dose.

MULTIPLE-DOSE ANTICOAGULANTS

Multiple-dose anticoagulants began to be marketed about 1950. These toxicants must be ingested for several consecutive days before the rodent dies. This multiple-dose feature provides a margin of safety for a child or animal that accidentally may eat a large amount of anticoagulant at one time. In addition if accidental poisoning should occur following repeated feedings, it can be effectively countered with treatments of vitamin K_1 or transfusions of whole blood.

For nearly forty years the multiple-dose anticoagulants have been the rodenticides of choice in the United States because they are economical, easy to apply, stable, relatively safe to use around man and his animals, are acceptable to rodents, and do not cause bait shyness. These anticoagulants cause internal hemorrhages, so the rodents slowly bleed to death. Even when weakened, the rodents do not appear to associate their weakened condition with the food supply. They return again and again to feed on anticoagulant-treated baits. So the problem of bait shyness commonly associated with the acute poisons is largely overcome. Anticoagulant baits should be made available to rat populations for a period of two weeks or more. Nonfatal doses of acute poisons, such as red squill and strychnine formerly used, are often painful, whereas the anticoagulants apparently cause no pain.

The multiple-dose anticoagulants are divided into two series, the hydroxycoumarins and the indandiones, as shown below:

Common name (Example)	Trade name (Example)	Chemical name
Hyroxycoumarin Series		
coumafuryl	Fumarin	3-(alpha-acetonylfurfuryl)-4-hydroxycoumarin
warfarin	Warfarin	3-(alpha-acetonylbenzyl)-4-hydroxycoumarin
Indandione Series		
chloro-phacinone	Rozol	2-(p-chlorophenyl)-phenylacetyl -1,3-indandione
diphacinone	Diphacin	2-diphenylacetyl-1,3 indandione
pindone	Pival	2-pivalyl-1,3-indandione
valone	PMP	2-isovaleryl-1,3-indandione

The multiple-dose anticoagulants are available in many forms such as solid and liquid concentrates, ready to use meal baits, water baits, bait blocks, pellets, place packs, and tracking powders ***(15, 16, 40, 41, 42, 43, 67, 72, 80, 96)***.

Anticoagulant concentrates are generally available in powder form which is mixed at a ratio of 1 part concentrate to 19 parts of bait (1:19) to make 20 parts of the proper field strength poison bait. Warfarin, fumarin, and Pival are sold as 0.5% concentrates which are mixed at the 1:19 ratio to make the field strength 0.025% bait. Diphacinone and chlorophacinone are sold as 0.1% concentrates which are mixed at the 1:19 ratio to make the field strength 0.005% bait. Pival is also marketed as a 2% concentrate that is mixed at a 1:79 ratio to make the final field strength 0.025% bait. Chlorophacinone (RoZol) is sold as a mineral oil concentrate. One quart of this concentrate is mixed with 100 pounds of bait to make the field strength 0.005% bait ***(15, 16, 80, 96)***.

The anticoagulant concentrates can be mixed in a variety of simple, inexpensive baits such as yellow corn meal, rolled oats, or a combination of the two. Advantages of these materials are low cost, good acceptance by rodents, and good keeping qualities.

Four mixtures which have worked well in rodent control projects are included below:

1. CORNMEAL BAIT FORMULA

MATERIALS	PARTS BY WEIGHT	AMOUNT	AMOUNT
Anticoagulant (0.5% warfarin, Pival, or fumarin; 0.1% diphacinone)	1 part	1 lb.	5 lbs.
Yellow Cornmeal	19 parts	19lbs.	95 lbs.
Total	20 parts	20lbs.	100 lbs.

Where rodents do not accept this formula, replace some of the corn meal with various mixtures of oatmeal, oat groats, coarse rolled oats, or cracked corn and granulated sugar. A small amount, of vegetable oil can be added as a binder and attractant. Charcoal can be added as a discoloring agent.

2. MIXED BAIT FORMULA

MATERIALS	PARTS BY WEIGHT	AMOUNT	AMOUNT
Anticoagulant (0.5% warfarin, Pival, or fumarin; 0.1% diphacinone)	1 part	1 lb.	5 lbs.
Yellow cornmeal	6 parts	6 lbs.	30 lbs.
Oat groats or coarse rolled oats	5 parts	5 lbs.	25 lbs.
Chicken scratch feed (cracked corn)	7 parts	7 lbs.	35 lbs.
Confectioner's sugar	1 part	1 lb.	5 lbs.
Vegetable oil	1 part	1 lb.	5 lbs.
Total	21 parts	21 lbs.	105 lbs.

Since mice eat only a small amount at a time, the chances of their ingesting sufficient poison can be increased by using relatively high proportions of anticoagulant in the bait, as 1 part of anticoagulant to 9 parts of corn meal. Sugar can be added as an attractant.

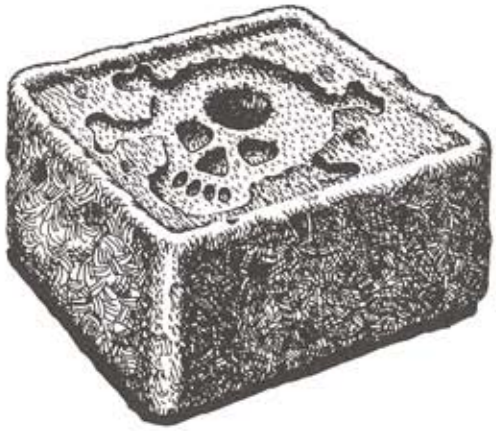
SOME CHARACTERISTICS OF

	POISONS	Lethal Dose (Mg/Kg)	Percent used in Bait	Degree of Effectiveness	Acceptance	Reacceptance	Cumulative	Tolerance Developed	Odor	Taste
FIRST GENERATION ANTICOAGULANTS	ANTICOAGULANTS Warfarin Fumarin Pival	1[1]	0.025	Good	Good	Good	Yes	No	None	Slight
	ANTICOAGULANT Diphacinone Chlorophacinone	0.5[1]	0.005	Good	Good	Good	Yes	No	None	Slight
SECOND GENERATION ANTICOAGULANTS	ANTICOAGULANT brodifacoum (Talon)	0.27 Norway Roof 0.40 Mice	0.005	Good	Good	Good	Yes	No	None	Slight
	ANTICOAGULANT bromadiolone (Maki, Contrac)	1.13	0.005	Good	Good	Good	Yes	No	None	Slight
ACUTE POISONS	ALPHA-CHLOROHYDRIN (Epibloc)	200	1.0	Good	Good	Good	No	No	None	Slight
	BROMETHALIN (Vengeance)	2.2 N 6.6 R 6.7 M	0.01	Good	Good	Good	No	No	Slight	Slight
	CHOLECALCIFEROL (Quintox)	43.5	0.075	Good	Good	Good	Yes	No	None	None
	ZINC PHOSPHIDE	40	1.0	Good	Good	Fair	No	No	Strong	Strong

1. More or less. Total dose accumulated over 5 days or more.

COMMON RODENTICIDES

Chemical Deterioration in Baits	Solubility		Type of Bait Mixtures			ACTION (Cause of Death)	Relation to Humans and to Other Animals			ANTIDOTES
	Water	Oil	Dry	Fresh	Water		Secondary Poisoning	Absorbed thru Skin	Degree of Hazard in Use	
None	Yes	Yes	Yes	No	Yes	Inhibits clotting of blood; causes internal hemorrhages.	Rare	No	Slight	Vitamin K and transfusions of whole blood.
None	No	Yes	Yes	No	No	Inhibits clotting of blood; causes internal hemorrhages.	Rare	No	Slight	Vitamin K and transfusions of whole blood.
None	No	No	Yes	No	No	Inhibits clotting of blood; causes internal hemorrhages.	Rare	No	Slight	Vitamin K and transfusions of whole blood.
None	No	No	Yes	No	No	Inhibits clotting of blood; causes internal hemorrhages.	Rare	No	Slight	Vitamin K and transfusions of whole blood.
None to Slight	Yes	No	Yes	Yes	Yes	Nephro-hepato- and neurotoxic	No	No	Slight	None
None	No	Yes	Yes	No	No	Metabolic decoupler loss of nerve transmission; paralysis	No	No	Slight	Limit absorption by emesis or gastric lavage. Fine charcoal
None	No	Yes	Yes	No	No	Mobilizes stores of calcium; causes overdose of calcium in blood (Hypercalcemia)	Some	No	Medium	Calcitonin is effective in lowering serum calcium level
Fast	No	Yes	Yes	Yes	No	Heart paralysis; gastrointestinal and liver damage	Rare	No	Medium	Copper sulfate before emetic; cathartic and water. Avoid fats and oils (as milk)



3. MOUSE CONTROL BAIT FORMULA

MATERIALS	PARTS BY WEIGHT	AMOUNT	AMOUNT
Anticoagulant (0.5% warfarin, Pival, or fumarin; 0.1% diphacinone)	1 part	1 lb.	10 lbs.
Corn meal	9 parts	9 lbs.	90 lbs.
Total	10 parts	10 lbs.	100 lbs.

With the liquid anticoagulant concentrate chlorophacinone (RoZol), the following formula has worked well (80).

4. CHLOROPHACINONE (RoZol) BAIT FORMULA

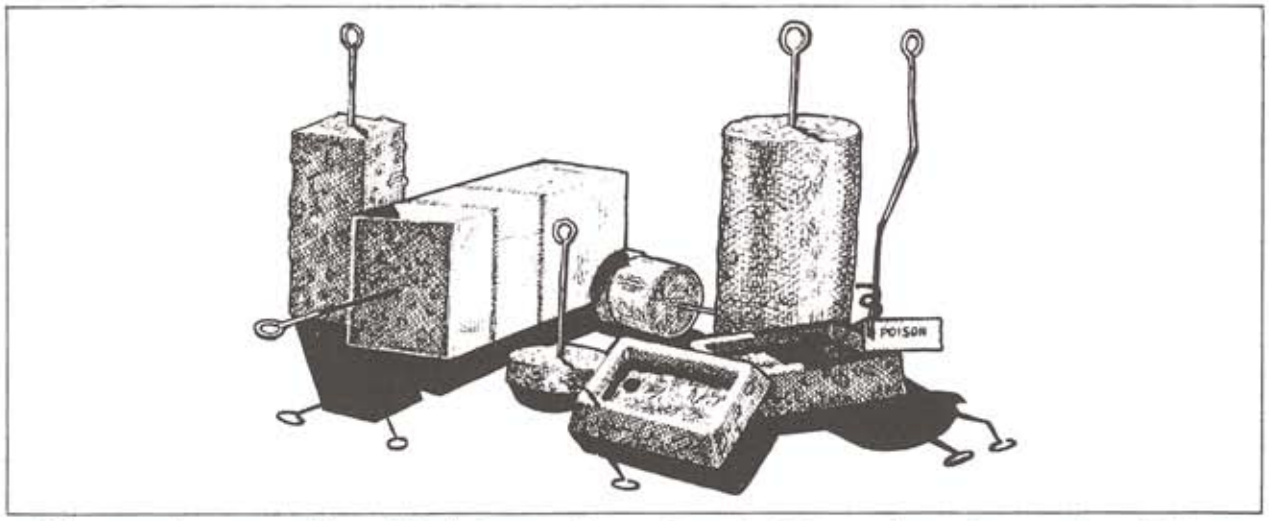
MATERIALS	AMOUNT	AMOUNT
Chlorophacinone (RoZol)	8 oz.	32 oz. (1 quart)
Oat groats	7½ lbs.	30 lbs.
Yellow corn meal	7½ lbs.	30 lbs.
Cracked corn	9 lbs.	36 lbs.
Confectioner's sugar	1 lb.	4 lbs.
Total	25½ lbs.	102 lbs.

Ready-to-use anticoagulant baits usually contain 0.025% warfarin, fumarin, or Pival; 0.005% diphacinone or chlorophacinone (RoZol); or 0.55% PMP. In one experiment artificial flavors such as butter-vanilla, roast beef, maple, or coconut were used to increase the bait's attractiveness to rodents *(80)*. Apple, meat, fish, or cheese flavors are used in commercial products. These ready-to-use baits are usually put into cardboard or plastic trays, bait stations, or other convenient holders, which are placed carefully to keep them out of the reach of children or pets.

Anticoagulant water baits are made by mixing sodium or calcium salts of the anticoagulants in water. They are usually dispensed in bait stations similar to chicken watering fountains. Liquid anticoagulants are often used in dry attics, in warehouses in which all water sources can be restricted, and in some bait stations with adequate space for both liquid and dry baits. In such warm, dry situations, the combined use of liquid and dry anticoagulant in a bait dispenser surrounded by anticoagulant tracking powder is more effective in killing house mice than either rodenticide formulation alone.

Anticoagulant bait blocks include rodenticide mixed with bait and the resulting mixture stirred into melted paraffin which is then allowed to harden into blocks. Many of the commercial blocks contain whole grain yellow corn meal, or scratch feed mixed with the rodenticide and synthetic flavors, as meat, fish, or apple. The flavors are thought to increase the bait's attractiveness to rodents. Research by Brooks and his associates *(15, 80)* indicates that grain in paraffin blocks can absorb moisture and swell, particularly when used in sewers. Such swelling cracks and breaks the blocks. Peanut meal, as a replacement for the grain in the bait material prevents this swelling and breakdown of the bait blocks.

Many of the smaller bait blocks weigh about two ounces and are used for mouse control. Larger ones



weigh a pound or more and have holes in them so that they can be wired to iron rod steps or nails in the walls of sewers. In Rochester, New York, bait blocks of waste vegetable shortening (chicken-frying grease), paraffin, the liquid anticoagulant chlorophacinone (RoZol) gave excellent control of sewer rats *(80)*. Bait blocks are more expensive than cereal-type anticoagulant baits but have certain advantages over these dry formulations: the bait is not scattered and wasted by the rodents; it does not become moldy in damp situations; and if the blocks are wired in place, the bait is not washed away by high water in the sewers.

Anticoagulant pellets are made by molding cereal or grain formulations of anticoagulants into pellets. Pellets are less likely to be scattered and wasted by the rodent than loose formulations of grain or cereal. They can be poured down rodent burrows where they will be out of reach of children or pets, and they can be used in out-of-the-way places between rafters or in voids in walls. Some pellets are treated with special chemicals to make them mold- and weather-resistant.

Anticoagulant place packs contain a grain or cereal anticoagulant mixture in a plastic package, often with an attractive odor such as apple, peanut butter, meat or fish. These packages usually contain two to four ounces and are suitable for dropping down rodent burrows or into other rodent hiding places. Rodents pick up the place packs, carry or drag them into their burrows to eat the bait in safe harborage.

Anticoagulant tracking powders are toxic materials mixed into dusts, which are spread in patches where rodents are likely to walk through them. The rodenticidal dust adheres to the feet and to the body hair of the animal and is ingested as the rodent grooms itself. Several of the anticoagulants, such a 0.2% chlorophacinone (RoZol) and 2.18% PMP, have been formulated as tracking powders *(67, 96)*.

Making Paraffin Formulations. To poison rats in sewers and other humid areas paraffin-poison-bait blocks have been used effectively. Add up to 1½ pounds of melted paraffin to 2¾ pounds of grain (or peanut meal) and anticoagulant or zinc phosphide mixture (pages 21 and 28). Stir thoroughly and pour into containers, as paper cartons or cups, which can be torn away after the mixture has set. Bend a piece of wire so that it has a loop on both ends. Let one loop hang in the mixture as it solidifies. When the mixture has set, tear away the paper mold. Such preparations shed water, resist mildew and insect infestation, and keep the bait fresh for several weeks. Additional wire can be added to permit lowering the bait block into the sewer and securing it there.

Commercially made bait blocks varying from an ounce to a pound in size are available. Many of these have holes through which spikes can be driven to a surface, or wires can be attached, to use in sewers.

Some grains, as oats, and certain rodenticides, as Pival, are reported to be mildew-resistant. Also preservatives such as Dupont DDPD and 2,4,5-trichlorophenylacetate have been added to baits to extend their period of acceptability, but they also, reduce the taste acceptability to rodents. British workers have found no evidence that poisoning programs were improved through the use of mildew-inhibiting substances.

RESISTANCE TO ANTICOAGULANT RODENTICIDES IN RATS AND MICE

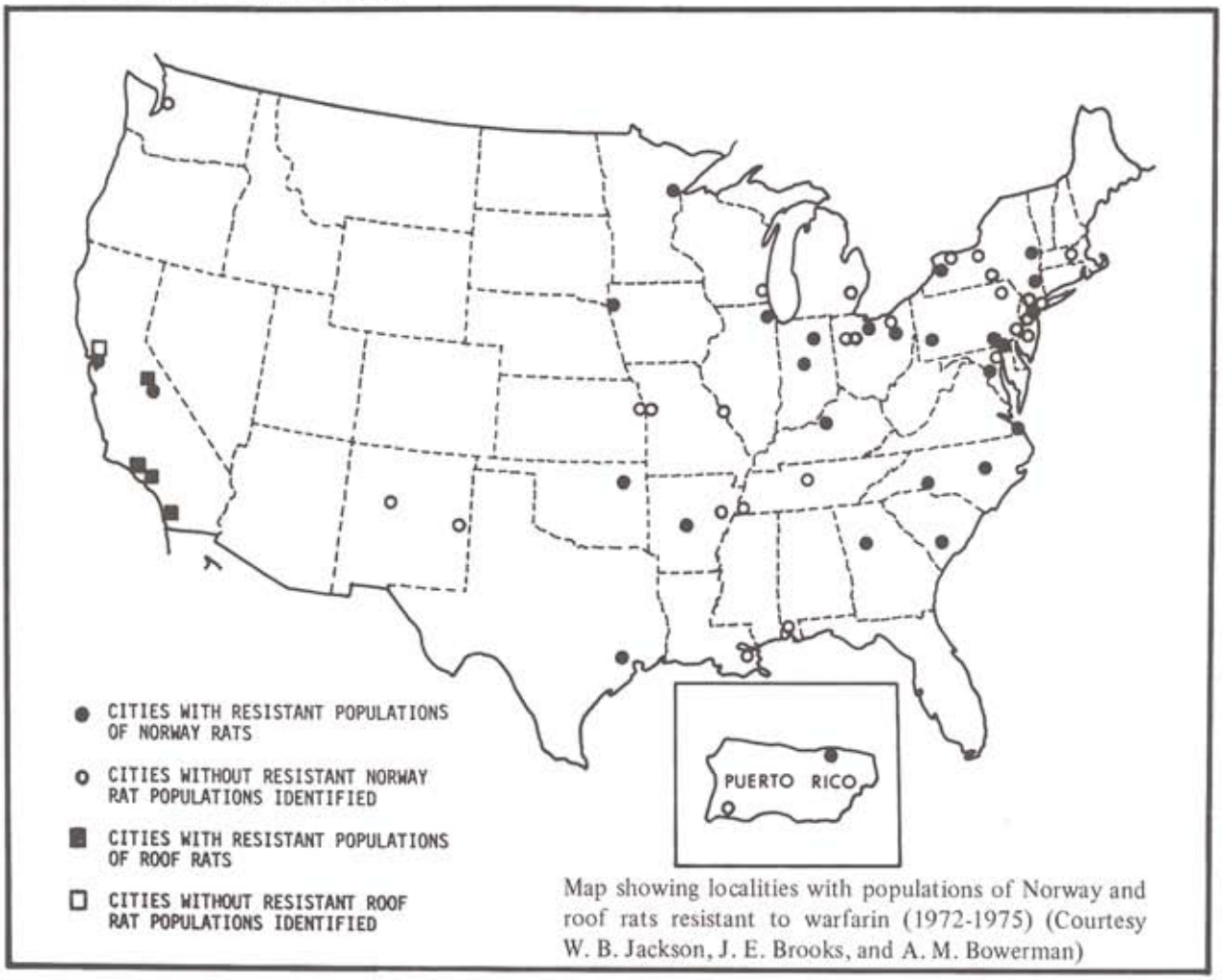
Anticoagulant rodenticides, such as warfarin, have been used since 1950. During the past 40 years the

anticoagulants have been the rodenticides of choice because of their effectiveness, reasonable cost, ease of application, good acceptance by rodents, safety to human beings and pets, and lack of bait shyness.

Resistance to anticoagulants in rats was first noted in Scotland in 1958. Later it was reported in a number of countries in Europe *(66, 72)*.

Anticoagulant resistance in Norway rats was reported in a rural area near Raleigh, North Carolina, in 1971 *(52)*. Later that year the U.S. Public Health Service authorized a country-wide survey to determine whether rats were resistant to anticoagulants in cities where the Urban Rat Control Program was being conducted. Arrangements were made to test five rats from many of these cities at two laboratories: the Environmental Studies Center, Bowling Green State University, Bowling Green, Ohio, and the Rodent Control Evaluation laboratory of the New York State Health Department, Troy, New York.

Live Norway rats were shipped to these laboratories, held for a few days, then fed a 0.005% warfarin and Purina chow diet for 6 days (1/5 the normal field concentration of the 0.025% bait) following procedures of the World Health Organization *(103)*. If the rats survived this 6-day feeding, and another 10 days on standard laboratory Purina chow, they were considered resistant. Roof rats were tested for a 12-day feeding period with warfarin baits containing 0.025% concentration. House mice were tested for 21 days with a 0.025% warfarin bait. The results of testing over 1200 Norway rats disclosed that a significant proportion (more than 5 percent) of the animals tested were resistant to warfarin in 18 areas and a lesser proportion in localized areas in many cities in the United States *(53, 54)*. A map showing cities with rat populations resistant to anticoagulant rodenticides has been furnished by Dr. W. B. Jackson, Mr. Joe Brooks, and Dr. A. M. Bowerman.



Map showing localities with populations of Norway and roof rats resistant to warfarin (1972-1975) (Courtesy W. B. Jackson, J. E. Brooks, and A. M. Bowerman)

Anticoagulants kill rats by interfering with the normal ability of the blood to clot. This causes internal bleeding. The exact mechanism is not known, but current research has pinpointed the use of vitamin K in the liver as the process affected by the anticoagulant. In normal rats, warfarin prevents the conversion of vitamin K and subsequent formation of blood-clotting proteins. The animals die of internal hemorrhages. In resistant rats, the chemical conversion of vitamin K is able to proceed, and the rats survive feeding on anticoagulant baits *(54, 55)*.

Scientists believe that the anticoagulants do not cause this resistance. They only reveal it. The potentialities for resistance are present in many populations of rodents. The anticoagulants act to kill off the most susceptible members of the population. There is inbreeding of the more resistant survivors until a significant percentage of the population survives after feeding on anticoagulant baits. The same general phenomena that led to the development of resistance to insecticides in cockroaches, flies, mosquitoes, bed bugs, and fleas have occurred in populations of rodents that have fed for years on anticoagulant rodenticides. These phenomena follow the broad concepts expressed by Charles Darwin more than a hundred years ago:

1. Overproduction in the rodent population
2. Great genetic variability among individual rodents
3. A struggle for existence
4. A survival of the fittest.

At present it is recommended that the use of anticoagulants be continued. Every 6 to 12 months **acute poisons, such as zinc phosphide and bromethalin, should be used to kill off as many as possible of the resistant rodents.** The use of aluminum phosphide for burrow gassing should also be considered in situations in which it is safe to use this chemical.

Roof rats and house mice that are resistant to anticoagulant rodenticides have been reported in Europe and in the United States *(55, 67, 72)*. Studies are being continued.

The development of resistance to anticoagulants in rodents emphasizes the need for improved environmental sanitation as the primary method of rodent control. Increased efforts should be made to clean up rodent food, such as waste foodstuffs, grain, and flour in food-handling establishments and warehouses. The homeowner should be encouraged to store edible foods in metal or glass containers, to use rodentproof garbage containers, and to reduce rodent harborage indoors and outdoors.

SINGLE-DOSE ANTICOAGULANTS

Single-dose anticoagulants, as brodifacoum (Talon) and bromadiolone (Maki and Contrac), began to be sold in the United States about 1980. These can be considered second generation anticoagulants with the ability to kill rodents after a single feeding *(48, 72)*. As with the first generation anticoagulants, such as warfarin, death does not occur until three or four days or longer after feeding on the single-dose anticoagulants, and the same antidotes, Vitamin K_1 or transfusions of whole blood can be used in case of accidental poisoning. The chemical formulae of the single-dose anticoagulants, brodifacoum and bromadiolone, are similar to those of multiple-dose anticoagulants, as warfarin, but differ in containing an atom of bromine *(96)*.

The single-dose anticoagulants are generally more expensive than the multiple-dose anticoagulants. However, the single-dose anticoagulants have achieved wide popularity in a short time because of their ability to control rodents after a single feeding and to kill warfarin-resistant rats and mice. These chemicals are marketed as meal baits, pellets for rats and micropellets for mice, and bait blocks *(79)*.

Resistance to warfarin and other first generation anticoagulants began to occur within a decade after their use. In the United States resistance to warfarin was documented in the 1970's by Jackson and coworkers *(53, 54, 67)* and world-wide by Meehan *(72)*. Similarly, resistance to the second generation anticoagulants has been reported in Europe. Within a decade of their widespread use, resistance began to appear to the second generation anticoagulants. The first signs of resistance to bromadiolone were noted in 1980 and 1982 in Europe *(66)*. There are also reports that rats and mice in England and mice in Canada required larger than usual intake of brodifacoum and bromadiolone to succumb *(72)*. In areas where chemical control of rodents is maintained constantly, it is recommended that use of first or second generation anticoagulants be alternated periodically with acute poisons, such as zinc phosphide or bromethalin, in order to delay as long as possible the development of resistance to the anticoagulants.

ACUTE POISONS

Four non-anticoagulant rodenticides are often used: zinc phosphide, bromethalin, cholecalciferol, and alpha-chlorohydrin.

Zinc phosphide has been used for many years as a bait or tracking powder. Important safety factors in its use are its dark gray color which makes it unattractive to adult humans, but perhaps not to children, and its strong garlic odor caused by the release of phosphine gas resulting from the reaction of zinc phosphide and moisture in the air, baits, or soil. Despite these characteristics Norway and roof rats and house mice seem to like the pungent odor and taste of this acute poison. Zinc phosphide reacts with stomach acids to liberate phosphine gas which enters the blood stream and causes liver, kidney, and heart damage, frequently ending in heart paralysis. Zinc phosphide is used at concentrations of 0.75 to 2 percent in grain, fruit, vegetable, fish, meat or pet food baits. It is also available in commercially prepared one percent zinc phosphide grain baits or pellets. However, its use should not be repeated at less than 6-months intervals since sublethal doses produce bait shyness.

Zinc phosphide is also used as a 10 percent tracking powder placed with a long handled spoon in protected bait stations or runways made of cardboard, wood, or metal. As little as a teaspoonful in a small runway is often sufficient to kill house mice that walk over tracking powder and take up a lethal dose as they preen themselves. Zinc phosphide tracking powder can also be blown into rat burrows or voids with a hand duster. Some animals that ingest a lethal dose die within an hour, others may not die until 24-36 hours later. Great care should be taken that the baits or tracking powders are not exposed to humans or pets, and that the tracking powder is not blown or tracked onto food or water *(9, 15, 16, 17, 22, 29, 40, 67, 72, 80, 96)*.

Cases of primary and secondary poisoning of domestic animals and wildlife exposed to zinc phosphidae have been reported *(15)* and of dogs to cholecalciferol. No secondary poisoning has been reported of animals that ate rodents killed with baits containing bromethalin or alpha-chlorohydrin.

Bromethalin (Vengeance) belongs in the diphenylamine group with a chemical formula $C_{14}H_7Br_3F_3N_3O_4$. It kills rodents by interfering with energy production in the body cells. This leads to buildup of fluid around the nerves, particularly the spinal column and brain, decreased nerve impulses, paralysis, and death. The eating of a single dose of the bait is usually lethal to the rodents, but death may be delayed for 2-4 days. This "Stop-Feed" reaction (after eating a single lethal dose) is important since smaller amounts of bromethalin need be exposed as compared with the anticoagulant rodenticides. Bromethalin is sold in 1/2-ounce bait packs, one-ounce packs, or bulk pellets *(50, 56, 90, 91)*.

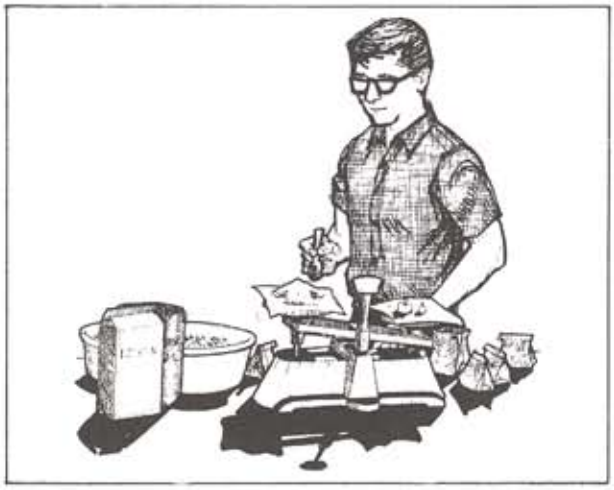
Cholecalciferol (Quintox), better known as Vitamin D_3, kills by mobilizing calcium from the bones so that the animal dies of hypercalcemia (too much calcium in the blood) and death from heart failure. Like bromethalin, cholecaliferol feeding stops after the ingestion of a single lethal dose, a "stop-feed" reaction, but death does not occur until 2-4 days later. This rodenticide is effective against both rats and mice that are resistant to the anticoagulants. It is available as a pelletized or meal rat and mouse bait and a mouse seed, in place packs or loose bait which may be placed in tamper-resistant bait stations *(70, 96)*.

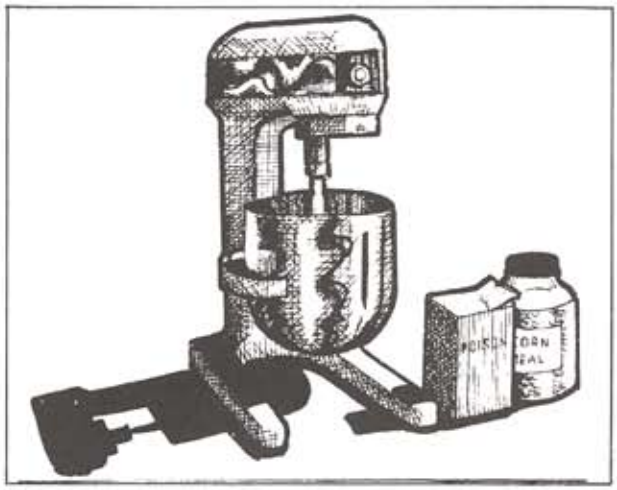
Alpha-chlorohydrin (Epibloc) is an acute rodenticide-sterilant that kills rats within a week after feeding. It differs from most rodenticides in that male rats ingesting a sublethal dose become permanently sterile. When a sterile male mates with a female, he does not produce offspring, but the female goes through false pregnancy that keeps her out of the mating cycle three times longer than usual. In some field trials, alpha-chlorohydrin has reduced rat populations by as much as 90 percent. Alpha-chlorohydrin has the chemical formula $HO\text{-}CH_2\text{-}CHOH\text{-}CH_2Cl$. It is sold as a 20 percent liquid concentrate and used as a 1% finished bait. Usually grain *(32, 72)*.

Many other rodenticides have been used in the past. Arsenic trioxide and barium carbonate have been replaced by newer, more effective toxicants. DDT, thallium sulfate, and strychnine have been banned by the government. Sodium fluoroacetate (1080) and Fluoroacetamide (1081) are very effective, fast-acting rodenticides. However, because of their toxicity to humans, lack of an antidote, their secondary effect on dogs, they should be used only in special situations by licensed applicators. Phosphorus paste, calcium cyanide, alpha-naphthathiourea (ANTU), and red squill are not generally available *(16, 79)*.

PREPARATION OF BAITS

Suggested materials for baits include: fresh, frozen, or canned meats, fish or pet food, bacon, yellow corn meal, cracked corn, hulled oats, rolled oats, apple, sweet potato, melon, tomato, peanut butter, butter, nutmeats, and (for mice) canary seed.





Fresh baits are most acceptable to rats and mice, so mix only enough for each day's needs. Larger amounts can be prepared and placed in a freezer until they are carried to the field.

A binder of molasses or vegetable, mineral, or fish oil is often used in cereal or dry baits to hold the poison and dry bait together, to aid in mixing, and to make the final product more attractive to rodents.

Mix bait only as directed: Read the label on the rodenticide container and follow all the directions for mixing. It is a violation of the "amended FIFRA" to use rodenticides containing more of the poison that that on the label. The EPA has published in the Federal Register a "Pesticide Enforcement Policy Statement" dealing with this subject *(67)*.

Mix baits well. Poor mixing results in non-uniform baits, poor kills, and speeds the development of bait shyness. Mechanical bait-mixing equipment is necessary if large quantities of bait are mixed routinely.

CAUTION: Clearly label poisons and poison-mixing equipment. Do not use bait-mixing equipment for any other purpose. Lock up poisons and mixing equipment when not in use. Treat all poisons with respect. Avoid inhaling powders or getting poisons on hands, clothes, or utensils from which they can reach the mouth. Wear rubber gloves when handling poisons. Always mix poisons in a well-ventilated place, particularly when mixing dry ingredients.

Mixing of Acute Poison Baits.

Zinc phosphide 1%	Amount
Zinc phosphide	4 oz.
Bait: ground fresh meat, Bacon, fresh or canned fish, cereal, grain. fresh fruits or vegetables or combinations of these	25 lbs.
Tartar emetic	1 1/2 oz.
Total	25 5/16 lbs.

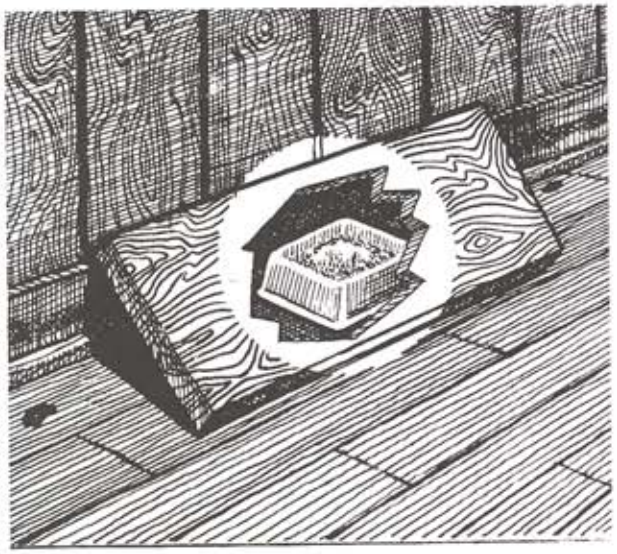
BAIT PLACEMENT

Anticoagulant Baits. Anticoagulants are not "one-shot" poisons, so they require a different method of use from other rodenticides (see page 20). The bait mixtures are frequently put into paper, metal, or plastic pie plates or into permanent bait stations. The number of pie plates or bait stations would vary with the size of the infestation. Small pie plates will hold 1/4 to 1/2 pound, whereas permanent bait stations often hold over a pound of bait mixture.

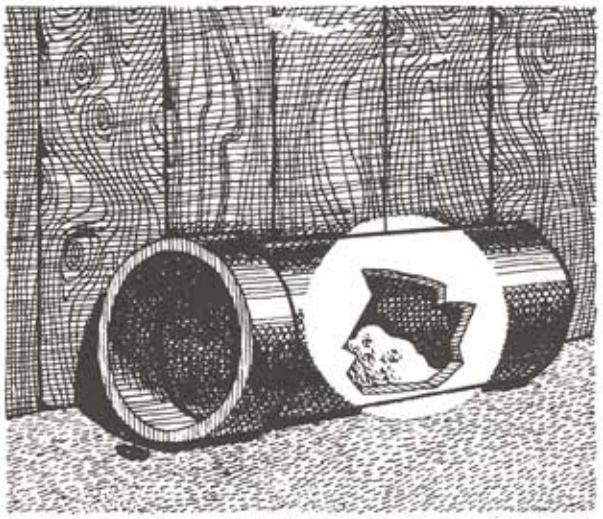
Be liberal in baiting. Bait stations are inspected at sufficiently regular intervals to ensure that baits remain wholesome and attractive and do not become infested with stored grain insects. For first generation anticoagulants to be fully effective, repeated doses must be consumed by every rodent for a period of 5 or more consecutive days. Anticoagulant bait mixtures are usually exposed for a minimum of 2 weeks; but, if

reinfestation is likely, a few bait stations maybe maintained on a permanent basis. Therefore, follow these instructions:

1. Protect animals other than domestic rodents, and shield baits from the weather, by putting the rodenticides under shelter or in bait boxes, under boards, or in pipes or cans.



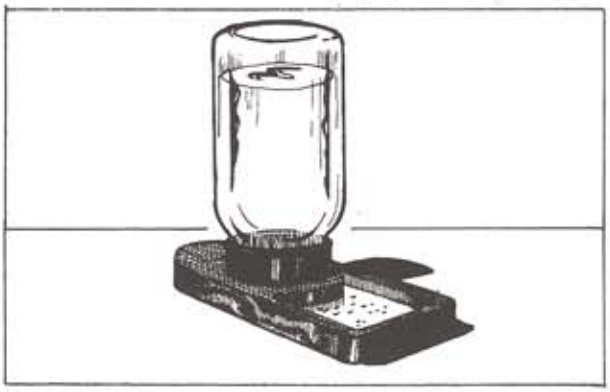
2. Record locations of all bait containers so that inspections can be made rapidly and the bait that has been consumed can be quickly replaced. (Note: Bait consumption is generally heavy right after initial placement, making daily inspection and replacement advisable for the first 3 days).
3. At each inspection, smooth the surface of the baits so that new signs of feeding will show readily.
4. Replace moldy, wet, caked, or insect-infested baits with fresh ones.



5. If a bait remains undisturbed for several successive inspections, move it to an area showing fresh rodent signs.

Use shallow bait containers fastened to the floor, or containers of sufficient weight to prevent rodents from either overturning them or dragging them to their burrows. A roofing tack driven through cardboard, plastic, or metal containers into the floor reduces spillage.

Poisoned Water. When poisoned water is used, place it only where other animals cannot get to it. Use containers that will not spill, such as glass caster cups or low metal or water-resistant paper cups. Chicken



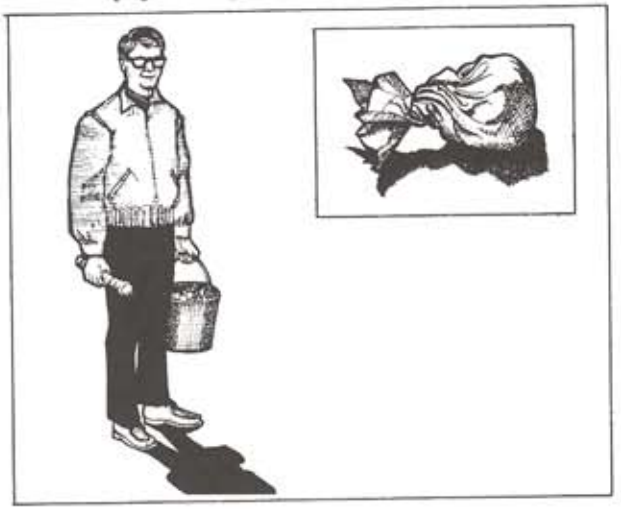
founts are satisfactory for permanent stations. *Note:* Water baits are most effective where other sources of water are limited or can be eliminated, as in feed mills or graneries. The use of anticoagulant dust placed around anticoagulant poison water stations is effective mouse control.

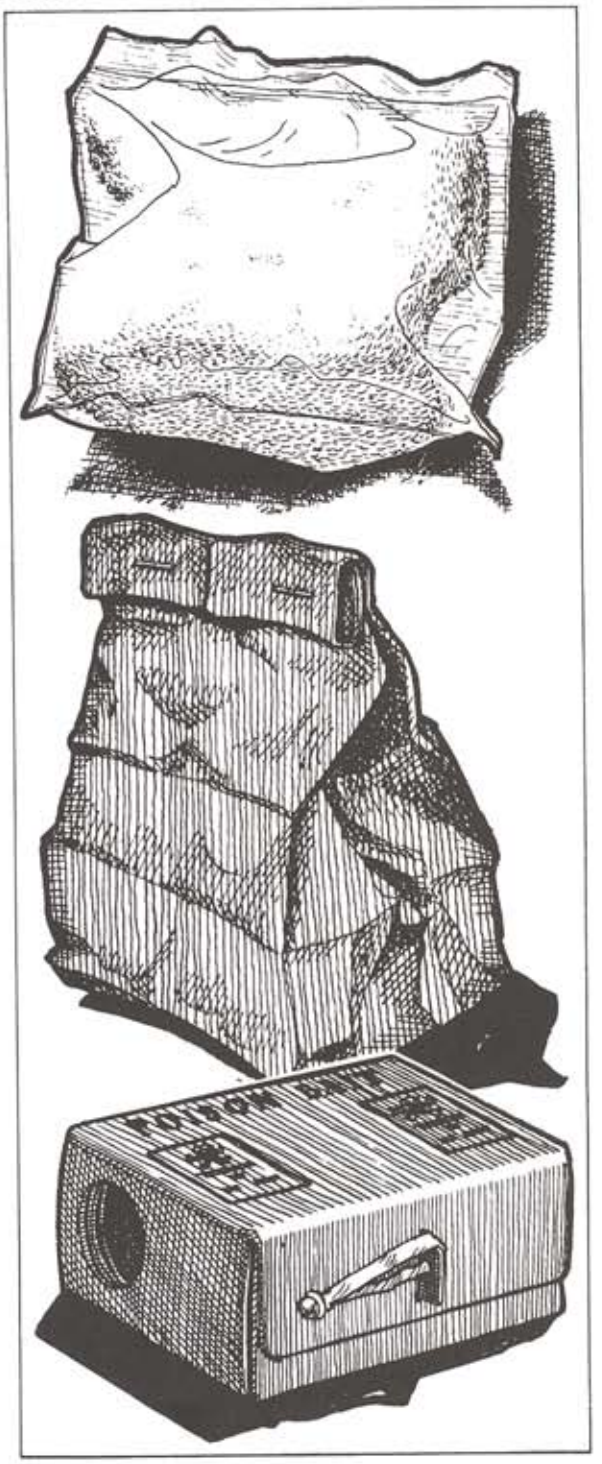
Single-Dose Poisons. Wrap one-shot poison baits in 4" x 4" paper squares to form "torpedoes" about the size of an extra large olive. One pound of such bait will make about 80 to 90 such torpedoes. These can be placed in secluded places. Rats prefer to carry their food to their harborage to eat.

If several types of baits such as meat, fish, or cereal are distributed at the same time, a different-colored paper wrapper should be used for each type, so the preferred bait quickly may be determined and used again.

Be generous with baits. Remember, rodents have a limited "home range," usually less than 150 feet for rats and 30 feet for mice. Too few baits, or poorly placed baits, may miss many rodents. Bait liberally where signs of rat activity are numerous and recent. In light or moderate infestations, torpedoes containing an acute poison, such as zinc phosphide, have given good control when applied at a minimum rate of 20 baits per private residence and 40 per small business establishment. As many as 100 to 200 baits may be required for premises with heavy rodent infestations. **Place baits in secluded areas out of the reach of children and pets.** Inspect and rebait as needed, using another poison and another bait material when the rats become shy of the original baits.

"Place Packs," which are bags of paper, moisture-resistant paper, or plastic, each containing about 1/4 pound of anticoagulant or acute poison bait mixture, can be placed in heavily infested sewers and into burrows and other inaccessible areas. Some operators pierce the bags in places to make the contents more accessible to rats. However, this makes it more difficult to determine the amount of bait consumed *(67)*.





PREBAITING

When acute poisons are to be used, prebaiting for several nights with unpoisoned baits is useful, particularly when rats show evidence of bait-shyness. However, it is too costly for large-scale use. The unpoisoned baits should be wrapped in papers of the same identifying colors as those used for the poisoned bait. Use of up to three kinds of bait – for examples, meat, fish, and grain – can increase bait acceptance, show which bait materials are preferred by the rodents, and indicate the number and locations of baits needed.

POISONING AT REFUSE DUMPS

Open refuse dumps with their continuously replenished supply of food and harborage suitable for rodents, are a special problem in rodent-control program (see page 15). Until sanitary disposal of refuse is instituted, poisoning may be the only effective means of controlling rats at these sites. Fifty to a hundred pounds, sometimes more, of poisoned bait may be required to bait the active faces of a heavily infested dump.

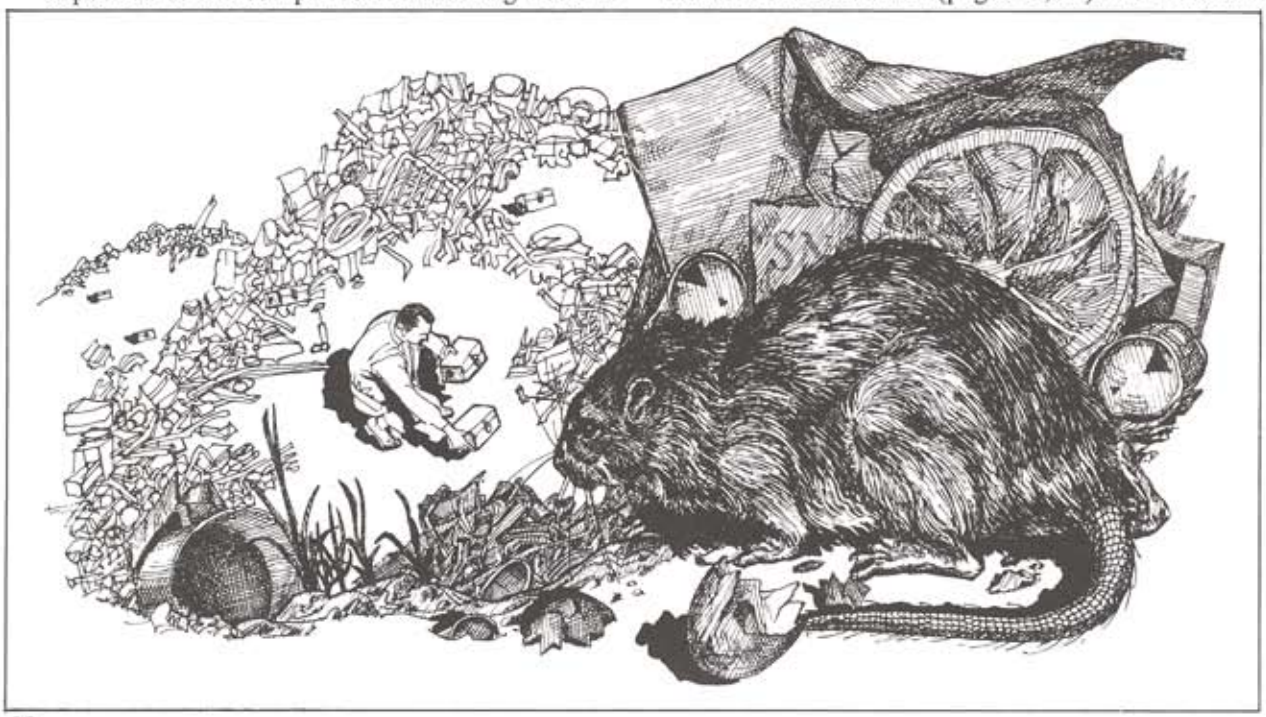
In converting an open dump to a sanitary landfill, the following procedures have been effective:

1. Close the dump and permit no additional loads of refuse or garbage to be placed in the area.
2. Wait about a day after the last load of refuse is deposited at the dump. Provide drinking water if none is available throughout the poisoning operation so that rats will not leave the dump.
3. Bait heavily with an acute poison for several nights. If rodent ectoparasites or cockroaches are a problem, power-dust the dump with a recommended insecticide.
4. On the day following the last night of acute poisoning, establish a number of anticoagulant rodenticide bait stations and service them regularly until all signs of rat feeding cease.
5. Level the dump and cover with earth to a depth of two feet after compaction.

POISONING IN SEWERS

In sewer systems, as at open dumps, rodents find harborage and a constantly replenished supply of food. An infested sewer, like an open dump, serves as a continuous source of reinfestation for adjacent neighborhoods. Unless and until permanent control of sewer rodents is achieved by major renovation or reconstruction of sewers, a poisoning program is the only effective means of control. Even so, results are short-lived and the sewers must be retreated periodically. Field trials suggest, however, that 2 to 4 treatments per year will give satisfactory control of rats in sewers.

The most satisfactory and effective formulations for use in humid sewers are the paraffin-poison-bait blocks described earlier (pages 24, 25). These contain



either an anticoagulant rodenticide or zinc phosphide as an acute poison. Wire the bait block to the iron-bar ladders in sewer man holes, or to nails driven into the sewer wall, to prevent the blocks from being washed away and to simplify retrieval of the bait for inspection.

CAUTION: Sewer manholes can serve as reservoirs of poisonous gases and carbon dioxide. A worker should never enter a manhole unless he has a rope tied as a lifeline around his body and helpers present to lift him to the surface, immediately, if necessary. In many situations, baits can be lowered into sewers and attached by wires to iron bar steps in entries, without actually entering the sewer.

TRACKING POWDERS

Dusts of zinc phosphide and anticoagulants, such as chlorophacinone (Rozol) or valone (PMP), have been used for many years as tracking powders. The dust must be fine enough to stick to the feet and fur of the rodents. Then, as they preen themselves, the rats and mice ingest a lethal dose of the poison. Tracking dusts can be blown into animal burrows or spaces within walls occupied by rodents, laid in runways or other areas frequented by rodents, or placed on the floor of bait boxes or around poison-water bait stations. Great care must be taken not to place tracking dusts in locations from which they can be blown or carried to contaminate foodstuffs, pet dishes, or animal feed or watering troughs *(9, 16, 67, 80)*.

REPELLENTS

Repellents are chemicals which repel rodents because of their odor or taste. In some enclosed situations, rodents, particularly house mice, are repelled by paradichlorobenzene and naphthalene. These are crystalline forms of chemicals that are used to protect woolens from clothes moths and carpet beetles. Two other materials have been incorporated into electric cables to prevent gnawing by rodents. These are Rotran R-55 produced by the Phillips Petroleum company and bioMet developed by M. and T. Chemicals. Rotran R-55 has been tested as an area repellent. When applied to rodent burrows, it sometimes causes the animals to abandon them *(96)*.

GASSING

Gassing of burrows is used as a supplementary measure for killing rodents. Most fumigants are restricted-use pesticides and should be used only by licensed operators or persons working under their direct supervision. Burrows should never be gassed if they are less than 20 feet from a building. The toxic gases could get into the structure and kill persons or pets.

Hydrogen phosphide (PH_3) has recently been given label clearance by the U.S. Environmental Protection Agency for fumigation of outdoor burrows of Norway and roof rats and house mice. Use Gastoxin ™ tablets approximately 4/5 inch in diameter, each of which weights three grams and releases one gram of hydrogen phosphide. Conduct the operations only on days when it is not raining and temperature is above 40° F., preferably 68° F. or higher. Open the resealable flask outdoors. Then, wearing dry gloves, place two to four tablets in each burrow opening. Stuff crumpled newspaper into the entrance to prevent soil from covering the tablets and slowing down the production of the gas. Then, shovel soil over the entrance and all other exit holes. The deadly hydrogen phosphide gas begins to be produced within hours from the reaction of the Gastoxin tablet and moisture in the air or ground. Hydrogen phosphide has a safety factor, a garlic or carbide-like odor that can be readily smelled by most humans in the range of 0.2 parts per million.

Chloropicrin (CCl_3N0_2) (tear gas) is sometimes used as a space fumigant in severely infested warehouses and other buildings. The liquid chloropicrin is poured over crumpled burlap sacks at a rate of one and one-half to two pounds of the liquid fumigant per 1000

square feet. Chloropicrin is also used as a burrow fumigant, mixed with motor oil and poured into rodent burrows, after which the exit holes are plugged with soil. The gas adheres tenaciously to soil particles and remains active in the burrows for a month or longer, not only killing the rats but repelling others that might otherwise take over the uninhabited burrow. An important safety factor in the use of chloropicrin is that very small concentrations are detectable by humans *(31, 79)*.

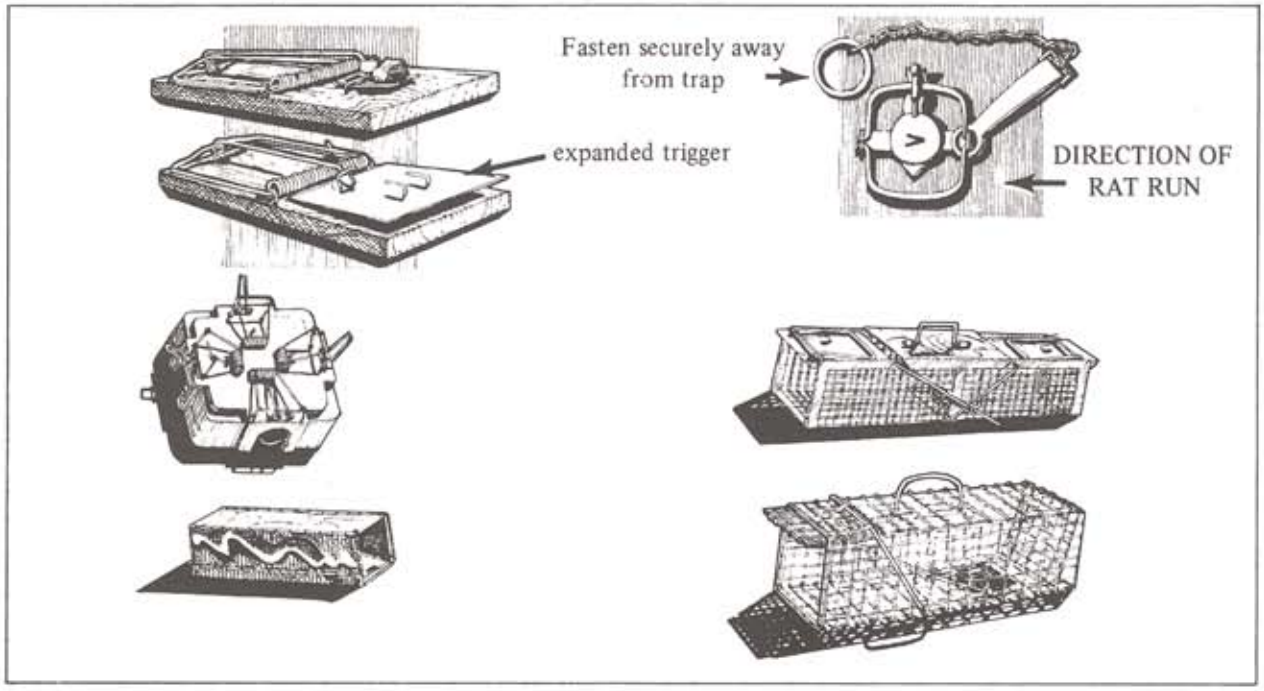
Carbon bisulfide (CS_2) is a volatile liquid which can be used for rat control. About 2 ounces (60 grams) of carbon bisulfide are applied to cotton batting, or other absorbent material, and placed deep within a burrow by a rod or pole. The opening is then closed with a shovelful of earth to retain in the burrow system the volatilized poison gas. Carbon bisulfide is very inflammable and is explosive. It is never used if there is danger of ignition by sparks or flames. Smoking is prohibited when working with this material.

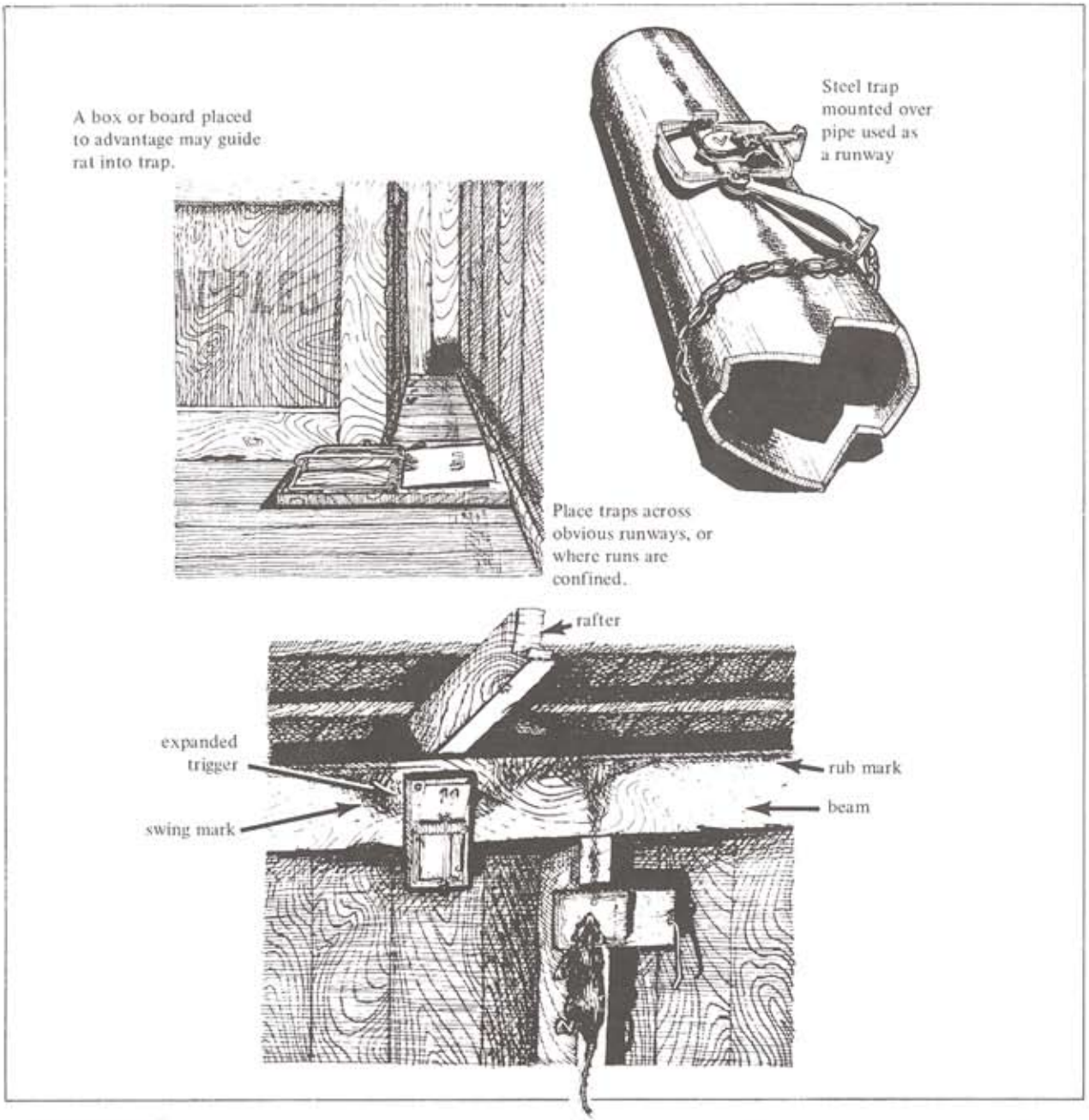
Methyl bromide (CH_3Br) is a volatile, colorless, odorless liquid. The heavier-than-air gas is formed from the liquid at temperatures above 38.5° F (3.6° C). The gas is highly toxic to animals and plants. Chloropicrin (tear gas) is often added to methyl bromide as a warning agent. The hazard associated with the outdoor use of methyl bromide for rodent control is slight if carried out by trained operators who take care not to get the liquid in their eyes or mouth, or on the skin. Methyl bromide does not present the fire hazard of carbon bisulfide. Methyl bromide canisters used in burrow fumigation have a valve and hose. The hose is inserted into the burrow and earth is packed around it. The valve on the canister is opened for 1 or 2 seconds to force ½ to 1 ounce (15 to 30 ml) of the liquid into the burrow where it volatilizes into the poisonous gas. Methyl bromide should not be used near the roots of grass or shrubs as it will kill the plants *(15, 16)*.

Carbon dioxide (CO_2) has been used to fumigate rat- and mice-infested refrigerated warehouses, where low temperatures must be maintained. Solid $C0_2$ (dry ice) is the most convenient and economical form of carbon dioxide to use. The ice is crushed and distributed throughout a room. An electric fan is used to disperse the gas. In such fumigations, the carbon dioxide is used at about 15% concentration for 24 hours. This requires approximately 30 pounds of dry ice per 1,000 cubic feet of space. Carbon dioxide fumigation should be considered in warehouses and other places where the odors or residues of other fumigants are undesirable *(15, 16)*.

OTHER KILLING METHODS

Flooding burrows can be effective in regions with tight clay soils. Water under pressure, as from a garden hose, can be used to drown rodents in their burrow or to drive them out so that they can be clubbed to death.





TRAPPING

SNAP, STEEL AND OTHER TRAPS

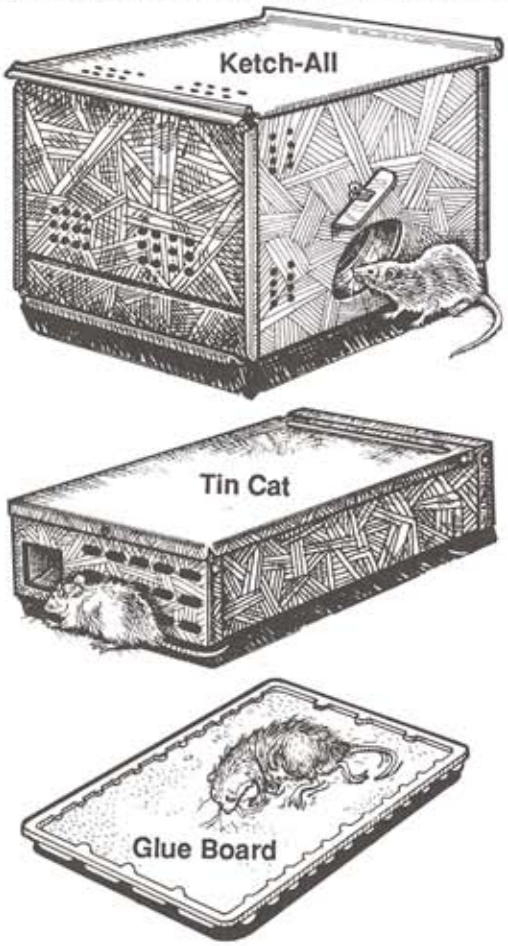
Traps are useful if poisons fail or poisoning activities are too risky, if the odor of unrecovered dead rodents would be a problem, or if live-trapped rodents are desired in order to collect rodent ectoparasites and blood samples for use in disease studies. For the latter purpose, steel traps or cage-type traps are used.

The snap trap is one of the most effective devices for killing rats and mice, particularly mice. An attractive bait should be fastened securely to the trigger. For rat control, the trigger can be expanded with cardboard or screen wire and used unbaited. Steel traps (Oneida-Victor #0 or equivalent) are effective for catching rats alive. Set the trap with the jaws open near or across the runway and fasten the chain securely so that the trapped animal will not drag the trap away. Cage or box traps are usually less convenient and are not as efficient as steel traps, but they catch the rodent uninjured. Placing cage traps in dark places, or covering them with material such as burlap bags, will increase catches. A "choker" type trap, properly set, may catch several mice per night.

Boiling or smoking traps to remove the human odor is not necessary. Rodents live so close to man that his odor is part of their everyday experience *(15)*.

MULTIPLE-CATCH MOUSE TRAPS

In commercial warehouses and food-preparation or food-handling establishments, where the use of rodenticides is not possible, automatic, multiple-catch mouse traps are often used. As their name implies, these traps are capable of catching up to 15 or more live mice in a single night. These traps are based on the fact that mice are very curious and constantly explore their habitats. The Ketch-All™ trap is wound up, mice enter the opening, depress a treadle, and are thrown into a holding compartment. In the Tin Cat™ trap, mice enter a tunnel-like tube, tilt it, and are tossed into the trap. The live, squeaking mice attract other mice into these traps. If the traps are serviced every day, the mice are drowned by dropping the loaded traps into a bucket of water. If the traps are left out for several days, often more mice are collected during the second or third day, after the trap has been marked with urine, than on the first day. Multiiple-catch traps are safe. No potentially hazardous baits are used. The mice are collected in the traps after they die, thereby reducing the potential for odor and/or fly problems which may result when bait-poisoned mice die in inaccessible places. Many USDA- and FDA- inspected plants do not allow rodenticides to be used inside. In the late 1980's approximately 400,000 multiple-catch traps were bought by the pest control, food, and pharmaceutical industries *(24, 93)*.



GLUEBOARDS

Glueboards are special traps made by spreading sticky material on cardboard, plastic, or other firm materials. Glueboards are also available commercially, sold in pairs like clamshells, a large size for rats, and a small size for mice. They are set in rodent runways, or baited with peanut butter, nutmeats, or other attractive foods. The rodents catch one foot in the glueboard, and later may get the other three feet and tail caught, as they struggle to free themselves before dying from exhaustion. Glueboards have achieved considerable popularity in warehouses, food-handling establishments, and other situations where it is not possible to use rodenticides *(37)*.

RELATED PROBLEMS

ECTOPARASITE CONTROL

Control of ectoparasites (fleas, lice, mites and ticks) is essential to prevent transfer of rodent diseases to man. Ectoparasites feed on the blood of their rodent

hosts and can thereby become infected. When the hosts are killed by trapping or poisoning, their ectoparasites sometimes, by chance, select a person as temporary host. If the ectoparasites are infected, they may transfer the disease-causing organisms to that person.

When disease is thought to be present in a population of rodents, ectoparasites should be killed before rodent killing measures are begun.

To treat a building or an area to kill ectoparasites:

1. Inspect for signs of rat or mouse activity, especially for rubmarks at the base of walls and for evidence of runways and burrows.
2. Treat all runways, burrow entrances and nests with 5% carbaryl (Sevin) dust or other recommended insecticide. Dust the vertical surfaces against which rodents may brush, using a dust gun or hand shaker. Anticoagulant rodenticides can be placed in the control area on the same day that insecticide dust is applied. The rodents must feed on the anticoagulant bait for several days before death occurs, allowing the insecticide sufficient time to kill the ectoparasites before the rodents die.

Rats that come in contact with the insecticide dust carry it on their feet and fur into their burrows and nests. This gives ectoparasite control in areas beyond the reach of normal dusting activities.

As determined in past extensive county-wide dusting programs, residential premises require about 2½ pounds (1.2 kilograms) of insecticide per treatment and business establishments require about 4 pounds (2 kilograms) per treatment ***(23)***.

In controlling plague or murine typhus, the modern approach is to dust with 5% carbaryl (Sevin) or other recommended insecticide to kill ectoparasites, particularly oriental rat fleas. The dusting operations should begin at those locations where the cases of plague or murine typhus were acquired, or are suspected of having been acquired. Treatments should then be extended to adjoining areas as needed. Outdoors, 4 or 5% malathion, or 5% carbaryl, dust can be used ***(80)***.

DEAD-RODENT ODORS

If possible, dead rodents should be removed. However, when they die in inaccessible places, the following measures may give partial or complete relief from offensive odors:

1. The use of fans will increase air circulation.
2. To mask unpleasant odors, such products as Bactine, Dutrol*, isobornyl acetate, Neutroleum Alpha, quarternary ammonium compounds, Styamine 1622, No-Dor-Zene, and Zephiran chloride can be used as an aerosol, a mist spray, or in a bowl or bottle with a cottonwick.
3. Oil of pine, oil of peppermint, oil of wintergreen, formalin, anise, or activated charcoal can also be used as masking agents or deodorants. For example, 10 drops of pine oil in a gallon of water can be applied with an atomizer or with a fine mist sprayer.
4. If the dead rodent can be located, as by fixing its position between partitions or walls, a pint water mixture of one of the masking agents listed in #2 above may be poured through a small hole bored into the wall a few inches above the floor level and as close to the dead rodent odor as possible. This treatment usually masks odors rapidly.

CARCASS DISPOSAL

The carcass of all rodents recovered from poisoning, trapping, or gassing operations should be buried or burned. Anyone who handles the dead rodents should wear rubber gloves.

*Dutrol is manufactured by Alpine Aromatics, Metuchen, N.J.; isobornyl acetate is manufactured by E.I. du Pont de Nemours, Wilmington, Del; Neutroleum Alpha, by Fritzche Bros., New York, N.T.; Styamine, by Rohm & Haas, Philadelphia, Pa., and No-Dor-Zene by Cline-Buckner.

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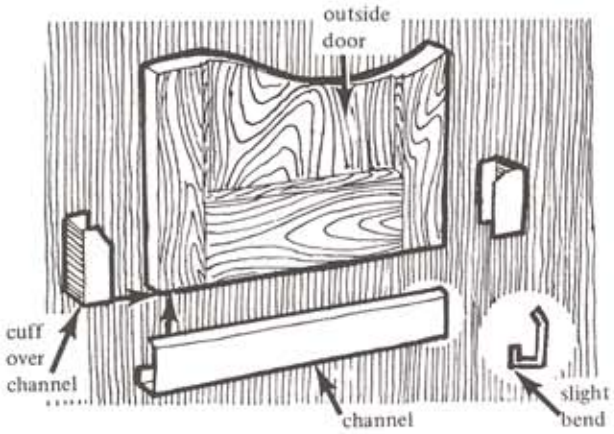
RATPROOFING

Ratproofing (or vent stoppage) consists of changing structural details to keep rodents out of buildings. Openings as small as a half inch square will admit young rats. Where only Norway rats are encountered, such openings as ground floor windows, sidewalk gratings, basement vents, utility pipe openings, and foundation walls are usually ratproofed; but if roof rats are found, wires, vertical pipes, and openings to upper floors and roofs should also be ratproofed. When only Norway rats are encountered, the stoppage work (to be most economical) is confined to the more likely points of entry and not to every possible entrance *(23, 89)*.

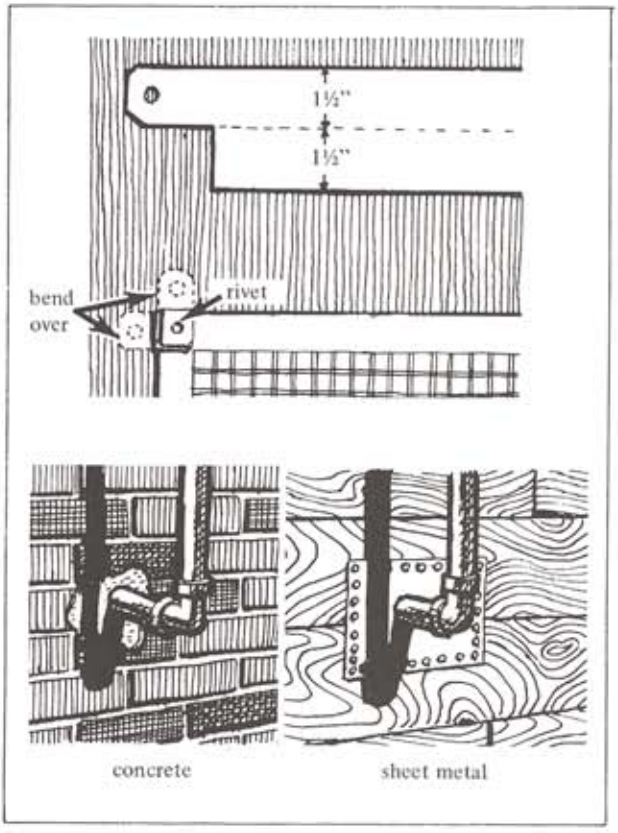
DEVICES

Most of the following discussion is concerned with the ratproofing of commercial businesses, particularly food-handling establishments. However, some of the items apply to private residences where rats are a problem, and particularly where roof rats are present in the South or on the Pacific coast *(23, 89)*.

1. The cuff and channel for wooden doors to side and back entrances prevent rats from gnawing under or around the doors. The front doors of most establishments are less exposed to rats and are generally protected with a kick plate. Wooden door jambs can be flashed with sheet metal to protect them from rat gnawing. Because open doors provide ready entry for rodents, both screen doors and wooden doors to food-handling establishments should be equipped with reliable self-closing devices.



2. Vents and windows can be made secure against rat entry by screening them with heavy wire mesh, preferably in a sheet metal frame. If desired, fly screening can be incorporated into the frame also. Wooden surfaces exposed to gnawing must be covered by the frame.
3. Metal guards of suitable construction should be placed around or over wires and pipes to prevent rats from using them to gain entrance into a building.
4. Openings around pipes or conduits should either be covered with sheet metal patches or filled with concrete or brick and mortar.
5. The use of concrete for basement floors and for foundations not only prevents rat entry but also increases the value of the property.
6. Floor drains, transoms, letter drops, and fan openings must receive stoppage consideration.



MATERIALS

1. 17-gauge 1/2-inch mesh galvanized hardware cloth for screening against rats; 19-gauge, 1/4-inch mesh for mice.
2. 18-gauge galvanized expanded metal for screening where exposed to damage is greater than normal.
3. 24- to 26-gauge galvanized sheet metal.
4. 1/8-inch brass or aluminum for kick plates.
5. Concrete, brick and mortar, glass, tile, and other building materials ***(23, 89, 92)***.

OTHER CONSIDERATIONS

As an adjunct to vent stoppage, buildings should be planned or modified to avoid dead spaces such as double walls, double floors, and enclosed areas under stairways.

Rubbish piles or other materials stacked against buildings should be removed. They provide the means by which rats and mice can bypass otherwise effective stoppage measures.

After buildings have been completely ratproofed, measures should be taken to eradicate the rodents that have been trapped within.

Inspections should be made at regular intervals to make sure that rats have not been reintroduced in incoming shipments and that the ratproofing work remains intact.

As a general guide in planning preventive measures, it will be assumed that *rats can do the following:*

1. Gain entrance through openings larger than 1/2-inch square.
2. Walk horizontal wires and climb vertical wires.
3. Climb the inside of vertical pipes 1 1/2 to 4 inches in diameter.
4. Climb the outside of vertical pipes with diameters up to 3 inches.
5. Climb the outside of vertical pipes and conduits of any size if within 3 inches of a wall.
6. Crawl horizontally on any type of pipe or conduit.
7. Jump vertically as much as 36 inches from a flat surface.
8. Jump horizontally 48 inches if on a flat surface.
9. Jump horizontally at least 8 feet from an elevation 15 feet above the finish point.
10. Reach about 13 inches.
11. Drop 50 feet without being killed ***(23)***.

NEW CONSTRUCTION

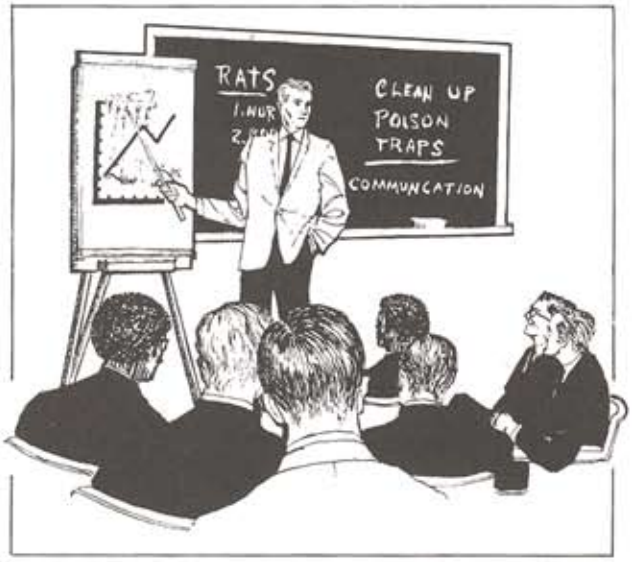
All new buildings should be designed that they are ratproof. Building codes of communities should be revised, if necessary, to require that new construction be ratproof. Codes should also specify that modifications and repairs be made to existing buildings to render them ratproof.

ORGANIZATION OF COMMUNITY RAT-CONTROL PROGRAMS

In any community, careful planning must precede inauguration of a rodent-control program. A properly designed program is essential in planning effective rodent-control. As a basis for planning, a survey must be made to determine the nature and extent of rodent infestation and causative conditions and to pinpoint the problem areas that in essence determine the type and size of program required. Survey results must be concisely summarized in a form suitable for presentation to local official. This might be a brief report supported by attractive maps and graphs, 2"x 2" color slides, video tapes and by any other materials or documents that illustrate the problem and emphasize the need for a rodent-control program.

Based on the survey results, tentative estimates of space, equipment, supplies, personnel, and other program requirements can then be made. Specific measurable, and realistic objectives directly related to problems found should be established for the program.

A work plan can then be formulated that includes such elements as citizen participation; community information, education and motivation; effective local administration; organization, and interagency coordination; development of and enforcement of adequate ordinances and codes; improvement of residential and accessory structures; refuse storage and premises sanitation; municipal services; and rat killing. This work plan should include an effective design for evaluation of the rodent control program. Evaluation is directly related to the objectives of the program and the more clearly and specifically these are stated, the more useful the appraisal results. When local officials have approved and budgeted the rodent-control program, complete details of plans, facilities and operations can be developed and implemented. After the program is operational, additional surveys should be made periodically to measure progress. Rat survey methods are described in detail in the publication "Urban Rat Surveys" *(28)*.



ORGANIZATIONAL STRUCTURE

A workable organizational structure for rodent control in a community develops somewhat as follows:

1. The health department of other local agency employs staff to control rats in blighted residential areas, in sewers, and in public buildings on a permanent basis. Some cities contract this work out to private firms.
2. Local health agencies or departments of public works provide inspection and enforcement services. In many communities these services now are inadequate or nonexistent, particularly in blighted areas, because of shortage of funds, equipment, and personnel.
3. Private pest-control firms contract to control rats in private business establishments and in residences.
4. State and Federal health agencies offer limited consultation, training and research in rodent control.

INFORMATION AND EDUCATION PROGRAM

The major element needed for a successful, long-lasting rodent-control program in a community is a strong, continuous educational program in environmental sanitation. It is essential that refuse (garbage and rubbish) handling facilities be improved, particularly in all blighted areas of the community, which almost invariably are the areas most heavily infested with rats. Proper storage of food and of refuse must be achieved neighborhood-by-neighborhood, block-by-block, residence-by-residence. Joint action of all concerned is essential.

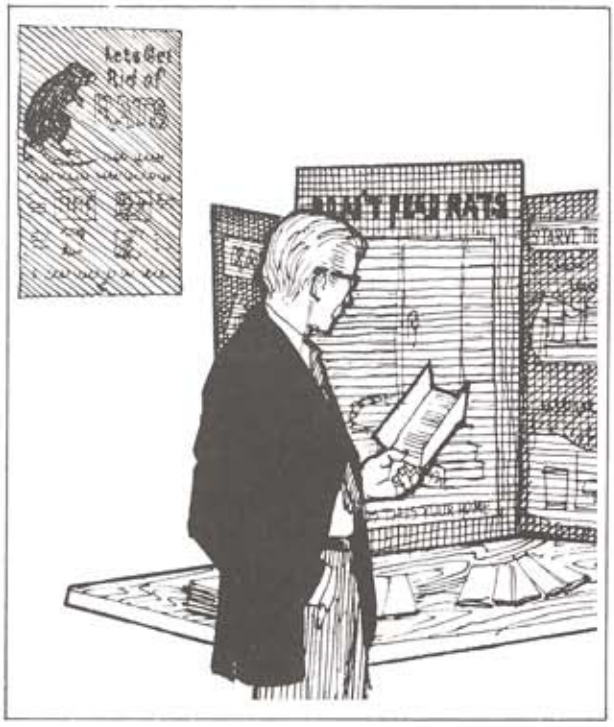
Before refuse storage can be satisfactory, the local government MUST provide adequate refuse collection service (twice weekly to residences and daily to businesses is recommended). If refuse collection is not frequent and regular, householders cannot be expected to store refuse properly. Ordinances and timely enforcement are needed for those who refuse to obey regulations. Carelessness and indifference of any of the people are formidable foes to a successful rodent-control program, particularly in blighted areas. These attitudes must be fought with a continuous educational effort and with consistent, fair, resolute law-enforcement activity on a continuing basis.

Each year, the essentials of rodent control should be taught in the schools to all students. Educational and promotional programs should be presented to community organizations such as Chambers of Commerce, Lions Clubs, Garden Clubs, and Rotary Clubs, and these groups should be invited to sponsor community projects to promote improvements.

For a rat-control program to be successful, educational and promotional work must reach the neighborhood or block levels. Oftentimes neighborhood garden or improvement clubs will assume leadership. In blighted areas, where the problem is greatest, resident block leaders must be found to spearhead needed improvements in their blocks on a continuous basis. In the neighborhood effort, Boy Scouts, Girl Scouts, and other youth groups are often of great help. Needless to say, the cooperation of all businesses and particularly those handling food, is vital to the success of a rat-control program.

Stimulating neighborhood meetings must be held periodically to gain and to maintain neighborhood and block enthusiasm and support. New ideas or "gimmicks" must occasionally be incorporated into motivational efforts to sustain citizen interest.

Publicity through mass media (newspapers, radio, television, exhibits, leaflets, etc) is helpful, particularly in the middle and high socio-economic areas. However, these media often do not reach the majority of the householders in blighted areas where the need is greatest. There, personal contact, usually door to door, is required.



SUMMARY

Rodents are filthy and destructive, and they spread disease-causing organisms. Their control requires; (a) environmental sanitation to eliminate food and harborage, (b) effective ratproofing, and (c) efficient killing programs. These control measures must be maintained on a continuous basis to keep rodent population at the minimum level.

Controlling rat populations, not individual rats, is the key to a successful rodent-control program in a community.

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SELECTED REFERENCES

1. Apperson, C. S., O. T. Sanders, and D. E. Kaukeinen. 1981. Laboratory and field trials of the rodenticide brodifacoum against warfarin-resistant Norway rats. Pesticide Science 12: 662-668.
2. Ashton, A. and W.B. Jackson. 1984. Anticoagulant resistance in the house mouse in North America. pp. 181-188. In: A. Dubock (ed.), Proc. Conf. on the Organization and Practice of Vertebrate Pest Control. ICI, Fernhurst, England.
3. Asia-Pacific Interchange. 1968. Proceedings—Rodents as Factors in Disease and Economic Loss. Institute for Technical Interchange, Center for Cultural and Technical Interchange between East and West, Honolulu, 285 pp.
4. Bailey, T. M. and P. M. Schantz. 1989. Trichinosis Surveillance, United States, 1986. CDC, MMWR, Surveillance Summaries 37, SS5: 1-8.
5. Barbahenn, K. R. 1970. Notes on the ecology of sewer rats in St. Louis. Proc. 4th Vert. Pest Conf.: 19-22.
6. Barnes, A. M. 1982. Surveillance and control of plague in the United States. Symp. Zool. Soc. London 50: 237-270.
7. Barnett, S. A. 1975. The Rat: A Study in Behavior. Univ. Chicago Press, Chicago. 288 pp.
8. Benenson, A. S. (ed.). 1985. Control of Communicable Diseases in Man. 14th ed. Am. Pub. Hlth Assoc., Washington. 485 pp.
9. Bennett, G. W., J. M. Owens, and R. M. Corrigan. 1988. Truman's Scientific Guide to Pest Control Operations. Edgell Communications, Duluth, Mn. 495 pp.
10. Berry, R. J. 1960. The natural history of the house mouse. Field Studies 3: 219-262.
11. Bjornson, B. F. and A. J. Brooks. 1962. Rat bait acceptance in sewers. Pest Control 30 (10): 24, 26, 30, 32.
12. Bowerman, A. M. and J. E. Brooks. 1972. What makes a palatable warfarin. Pest Control 40 (2): 22, 28, 29.
13. Breidenbach, A. 1971. Composting of Municipal Wastes in the United States. USEPA Pub (SW-47r), 103 pp.
14. Bronson, 1984. The adaptability of the house mouse. Scientific American 250 (3): 116-125.
15. Brooks, J. E. 1973. A review of commensal rodents and their control. CRC Critical Reviews in Environmental Control 3 (4): 405-453.
16. Brooks, J. E. and F. P. Rowe. 1987. Commensal Rodent Control. Wld. Hlth. Org., Vector Biology and Control Division, Geneva. WHO/VBC/87.949, 104 pp.
17. Brown, E. A. (ed.). 1989. 1989 Georgia Pest Control Handbook. Coop. Ext. Service, Univ. Georgia, Athens, Ga. 518 pp.
18. Brown, R. Z. 1953. Social behavior, reproduction, and populations changes in house mouse *(Mus musculus L.)*. Ecology Monographs 23: 217-240.
19. Brunner, D. R. and D. J. Keller. 1972. Sanitary Landfill: Design and Operation. USEPA Pub (SW-65ts): 59 pp.
20. Burt, W. H. and R. P. Grossenheider. 1976. A Field Guide to the Mammals of America North or Mexico. 3rd ed. Houghton Miflin Co., Boston 289 pp.
21. Calhoun, J. D. 1962. The Ecology and Sociology of the Norway Rat. USDHEW, PHS, Pub. No. 1008, Washington, 288 pp.
22. Chitty, D. and H. N. Southern. 1954. The Control of Rats and Mice. Vol. 1, 305 pp; Vol 2, 307-532 pp; Vol. 3, 225 pp. Clarendon Press, Oxford.
23. Communicable Disease Center. 1949. Rat-Borne Disease Prevention and Control. U. S. Fed. Sec. Agency, PHS, CDC, Atlanta. 292 pp.
24. Corrigan, R. M. 1988. Multiple-catch mouse traps: tips and trapping strategies. Pest Control Technology 16 (9): 45, 46, 50, 54, 56, 58.
25. Crowcroft, P. 1966. Mice All Over. Chicago Zoological Society, Brookfield, II,. 123 pp.
26. Davis, D. E. 1953. The characteristics of rat populations. Quart. Rev. Biology 28: 373-401.
27. David, D. E. and W. B. Jackson. 1981. Rat Control. pp. 221-277. *In:* T. H. Coaker (ed.). Advances in applied biology. Vol. 6. Academic Press, New York.
28. Davis, H., A. Casta, and G. Schantz. 1974. Urban rat surveys. USDHEW, PHS, CDC, Environmental Health Services Division, Atlanta, Ga. No. (CDC) 77-8344, 22 pp.
29. Drummond, R. C. 1972. Biology and control of domestic rodents. pp. 46-69. In: Vector Control in International Health, Wld. Hlth. Org. Geneva.
30. Dubock, A. C. and D. E. Kaukeinen. 1978. Brodifacoum (Talon™ rodenticide), a novel concept. Proc. 8th Vert. Pest Conf.: 127-137.
31. Ebeling, W. 1975. Urban Entomology. U. Cal. Press, Richmond, Ca. 695 pp.
32. Ericsson, R. J. 1982. Alpha-chlorohydrin in rodent control. Proc. 10th Vert. Pest. Conf.: 23-25, 6-9 (279).
33. FAO/WHO. 1973. Bibliography on Rodent Pest Biology and Control. 1950-1959. Food and Agriculture Organization of the United Nations, Rome, Parts I and II, 448 pp.
34. FAO/WHO. 1977. Rodent Pest Bibliography, 1970-1974. FAO Plant Protection Paper No. 7. Food and Agriculture Organization of the United Nations and World Health Organization, Rome. 832 pp.
35. Federal Register. 1988. Solid Waste disposal facility criteria; proposed rule. Federal Register 53: 33314-33342.
36. Feigin, R. D., L. A. Lobes, Jr., D. Anderson, and L. Pickering. 1973. Human leptospirosis from immunized dogs. Ann. Int. Med. 79 (6): 777-785.
37. Fitzwater, W. D. 1982. Bird Limes and rat glues—sticky situations. Proc. 10th Vert. Pest Conf.: 17-20.
38. Gratz, N. G. 1973. A. Critical review of currently used single-dose rodenticides. Bull. Wld. Hlth. Org. 48: 469-477.
39. Harmston, F. C. and C. T. Wright. 1960. Distribution and control of rats in five Rocky Mountain states. Pub. Hlth. Reports 75: 1077-1089.
40. Hayes, W. J., Jr. 1975. Toxicology of Pesticides. Williams and Wilkins Co., Baltimore, 580 pp.
41. Hayes, W. J., Jr. 1982. Pesticides Studied in Man. Williams and

Wilkins Co., Baltimore, 672 pp.
42. Hayes, W. J., Jr. and T. B. Gaines. 1950. Control of Norway rats with residual warfarin. Pub. Hlth. Reports 65: 1537-1553.
43. Hayes, W. J., Jr. and T. B. Gaines. 1959. Laboratory studies of five anticoagulant rodenticides. Pub. Hlth. Reports 74: 105-113.
44. Hoffmeister, D. F. and C. O. Mohr. 1957. Fieldbook of Illinois Mammals. Ill. Nat. Hist. Surv. Div., Manual No. 4, Urbana, Il. 233 pp.
45. Howard, W. E., W. W. Kilgore, and R. L. Duitt. 1967. Pest Control – Biological, Physical, and Selected Chemical Methods. Academic Press, New York.
46. Howard, W. E., R. E. Marsh. 1974. Rodent Control Manual. Pest Control 42(8): Supplement D-U.
47. Huebner, R. J., W. L. Jellison, and C. Armstrong. 1947. Rickettsialpox – a newly discovered rickettsial disease. Recovery of *Rickettsia akari* from a house mouse *(Mus Musculus)* Pub Hlth Reports 62: 777-780.
48. ICI Americas. 1982. A guide to urban rodent control featuring the use of Talon-G rodenticide. ICI Americas Inc., Goldsboro, N.C. 15 pp.
49. Jackson, W. B. 1982a. Norway rat and allies. pp 1077-1088 In: J. A. Chapman and C. A. Feldhammer, (eds.). Wild Mammals of North America. Biology, Management, and Economics. John Hopkins Univ. Press, Baltimore.
50. Jackson, W. B. 1982b. Bromethalin – a promising new rodenticide. Proc. 10th Vert. Pest Conf.: 10-16.
51. Jackson, W. B. 1984. Economic impact of commensal rodents in urban USA. pp. 303-314. In: Proc. Conf. on the Organization and Practice of Vert. Pest Control. ICI. Fernhurst, England.
52. Jackson, W. B., P. J. Spear, and C. G. Wright. 1971. Resistance of Norway rats to anticoagulant rodenticides confirmed in the United States. Pest Control 39 (9): 13, 14.
53. Jackson, W. B., J. E. Brooks, A. M. Bowerman, and D. E. Kaukeinen. 1975a. Anticoagulant resistance in Norway rats as found in U. S. cities. Pest Control 43 (4): 12, 14-16.
54. Jackson, W. B., J. E. Brooks, A. M. Bowerman, and D. E. Kaukeinen. 1975b Anticoagulant resistance in Norway rats as found in U.S. cities. Part II. Pest Control 43 (5): 14, 16, 18, 20, 22-24.
55. Jackson, W. B., A. D. Ashton, and E. Delventhal. 1988. Overview of anticoagulant resistance. pp. 381-388. In: J. W. Suttie (ed.). Current Advances in Vitamin K research. Elsevier Pub. Co.
56. Jackson, W. B., S. R. Spaulding, R. B. L. Van Lier, and B. A. Dreikorn. 1982. Bromethalin – a promising new rodenticide. Proc. 10th Vert. Pest. Conf.: 10-16.
57. Johnson, W. H. and B. F. Bjornson. 1964. Rodent Eradication and Poisoning Programs. USDHEW, PHS, CDC, Atlanta, Ga. 84 pp.
58. Kartman, L. 1970. Historical and ecological observations on plague in the United States. Trop. Geog. Med. 22: 257-275.
59. Kaukeinen, D. E. 1979. Field methods for census taking of commensal rodents in rodenticide evaluations. pp. 68-83. In: D. E. Kaukeinen (ed.) Vertebrate Pest Control and Management Materials. Amer. Testing and Materials, Philadelphia.
60. Kaukeinen, D. E. 1982. A review of the secondary poisoning hazard potential to wildlife from the use of anticoagulant rodenticides. Proc. 10th Vert. Pest Conf.: 151-158.
61. Kaukeinen, D. E. and M. Rampaud. 1986. A review of brodifacoum efficacy in the U. S. and worldwide. Proc. 12th Vert. Pest Conf.: 16-50.
62. Kennedy, F. D. 1981. The Urban Rat Control Program. PHS, CDC, Atlanta, 30 pp.
63. Lackman, D. B. 1963. A review of information on rickettsialpox. Clinical Pediatrics 2: 296-301.
64. Link, V. B. 1955. History of Plague in the United States. Pub. Health Monograph No. 26: 120 pp.
65. Lisella, F. S., R. L. Mullen, and E. P. Savage. 1967. A review of the ratbite problem in Tampa Florida. J. Environm. Health 29 (4): 322-328.
66. Lund, M. 1984. Resistance to the second-generation anticoagulant rodenticides. Proc. 11th Vert. Pest Confl: 89-94.
67. Mallis, A. 1982. Handbook of Pest Control. 6th ed. Franzak and Foster Co., Cleveland, OH. 1101 pp.
68. Marsh, R. E. and W. E. Howard. 1976. House mouse control manual. Part one. Pest Control 44 (8): 23, 24, 26, 29, 30, 32, 33, 62, 64.
69. Marsh, R. E., W. E. Howard, and W. B. Jackson. 1980. Bromadiolone: a new toxicant for rodent control. Pest Control 48 (8): 22, 24, 26.
70. Marshall, E. F. 1984. Cholecalciferol: a unique toxicant for rodent control. Proc. 11th Vert. Pest Conf.: 95-98.
71. McDonald, S. A. (ed.). 1988. Applying Pesticides Correctly. A Guide for Private and Commercial Applicators. U.S.D.A. and U.S.E.P.A., N.C. Agr. Exp. Ext. Service, Raleigh, N.C. 128 pp.
72. Meehan, A. P. 1984. Rats and Mice. Their Biology and Control. Rentokil Limited. East Grimstead, Sussex, England. 383 pp.
73. Miles, V., A. R. Kinney, and H. E. Stark. 1952. Flea-host relationships of associated Rattus and native wild rodents in the San Francisco Bay area of California with special reference to plague. Am. J. Trop. Med. Hyg. 6 (4): 752-760.
74. Minette, R. P. 1964. Leptospirosis in rodents and mongooses on the Island of Hawaii. Am. J. Trop. Med. Hyg. 13 (6): 826-832.
75. Mohr, C. O. 1951. Entomological background of the distribution of murine typhus and murine plague in the United States. Amer. J. Trop. Med. 31 (3): 355-372.
76. Moore, R. M., R. B. Zehner, J. I. Moulthrop, and R. I. Parker. 1977. Surveillance of animal-bite cases in the United States. 1971-1972. Arch. Environ. Hlth. 32: 267-270.
77. Morlan, H. B., B. C. Utterbach, and J. E. Dent. 1952. Domestic rats in relation to murine typhus control. Pub. Hlth. Monographs 5: 1-20.
78. Poland, J. D. and A. M. Barnes. 1979. pp. 515-558, 597. In: J. H. Steele (ed.) CRC Handbook Series in Zoonoses. Section A: Bacterial, Rickettsial, and Mycotic Diseases. CRC Press, Boca Raton, Fl.
79. Pratt, H. D., 1983. Rodenticides: what to use, where, when, and how. Pest Control 51 (10): 19, 20, 22-24.
80. Pratt, H. D., B. F. Bjornson, and K. S. Littig. 1976. Control of domestic rats and mice. Pub. No. 76-8141. USDHEW, PHS, CDC, Atlanta, Ga. 47 pp.
81. Pratt, H. D. and R. Z. Brown. 1976. Biological Factors in Domestic Rodent Control. USDHEW, PHS, CDC, Atlanta, Ga. (CDC) 76-8144, 30 pp.
82. Pratt, H. D., J. E. Lane, and F. C. Harmston. 1949. New locality records of *Allodermanyssus sanguineus*, vector of recket-

tsialpox. J. Econ. Entomol. 42: 414-415.
83. Robinson, H. A. and O. W. Olsen. 1960. The role of rats and mice in the transmission of the porkworm, Trichinella spiralis (Owens, 1835) Raillett 1895. J. Parasitol. 46(5): 589-597.
84. Salvato, J. A. 1982. Environmental Engineering and Sanitation. 3rd ed. John Wiley-Interscience, New York. 1163 pp.
85. Schein, M. W. and H. Orgain. 1953. A preliminary analysis of garbage as food for the Norway rat. Am. J. Trop. Med. Hyg. 2: 1117-1130.
86. Schoof, H. F. 1970. Zinc phosphide as a rodenticide. Pest Control 38 (5): 38, 42-44.
87. Schwarz, E. 1960. Classification, origin, and distribution of commensal rats. Bull. Wld. Hlth. Org. 23: 411-416.
88. Scott, H. G. 1965. Rat-bite: epidemiology and control. J. Environ. Health 27 (6): 900-909.
89. Scott, H. G. and M. R. Borom. 1965. Rodent-borne disease control through rodent stoppage. USDHEW, PHS, CDC, Atlanta, Ga. 34 pp.
90. Spaulding, S. R. 1987. Bromethalin—an alternative to anticoagulants. 1987 BCPC Monograph No. 37 Stored Products Pest Control: 137-147.
91. Spaulding, S. R. and W. B. Jackson. 1984. Field methodology for evaluating rodenticide efficiency. pp. 183-198. In: D. E. Kaukeinen (ed.). Vertebrate Pest Control and Management Materials. Am. Soc. Testing and Materials, Philadelphia.
92. Tarzwell, C. M., R. L. Stenburg, and H. P. Nicholson, and W. E. Lynn. 1953. The resistance of construction materials to penetration by rats. USDHEW, Pub. Hlth Monograph No. 11.
93. Temme, M. 1980. House mouse behavior in multiple-catch traps. Pest Control 48 (3): 16, 18, 19.
94. Thiermann, A. B. 1977. Incidence of leptospirosis in the Detroit rat population. Am. J. Trop. Med. Hyg. 25(5): 790-794.
95. Thiermann, A. B. and R. R. Frank. 1980. Human leptospirosis in Detroit and the role of rats as chronic carriers. Int. J. Zoonoses 7: 62-72.
96. Thomson, W. T. 1988. Agricultural chemicals. Book III. Fumigants, growth regulators, repellents, and rodenticides. Thomson Publications, Fresno, Ca. 210 pp.
97. Timm, R. M. (ed.). 1984. Prevention and Control of Wildlife Damage. Coop. Ext. Service, Univ. Nebraska, Lincoln. Looseleaf.
98. Traub, R., C. L. Wisseman, and A. Farhang-Azad. 1978. The ecology of murine typhus—a critical review. Trop. Diseases Bull 75: 237-317.
99. Troller, J. A. 1973. Sanitation in Food Processing. Academic Press, New York. 456 pp.
100. U.S. Fish and Wildlife Service. 1959. Characteristics of common rodenticides. Dept. of Interior, Leaflet WL-337, Washington, D.C.
101. Weber, W. J. 1982. Diseases transmitted by rats and mice. Thomson Publications, Fresno, Ca. 182 pp.
102. WHO/Vector Control. 1966. Seminar on rodents and rodent ectoparasites. Vector Biology and Control Division, Wld. Hlth Org., Geneva. WHOVBC/ 66.217. 222 pp.
103. World Health Organization. 1982. Instructions for determining susceptibility or resistance of rodents to anticoagulant rodenticides. Wld. Hlth. Org., Geneva. WHO/VBC/82.843. 9 pp.
104. WHO/FAO. 1971. Bibliography on Rodent Pest Biology and Control, 1960-1969. Parts I, II, III, IV. Wld. Hlth. Org., Geneva. VBC/71.9, 9a, 9b, 9c. 947 pp.
105. Winkler, W. G. 1972. Rodent rabies in the United States. J. Infect. Diseases 126: 565-567.

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