Maintenance of Rattlesnakes in Captivity

by James B. Murphy
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Front Cover: An adult Mexican Lancehead Rattlesnake *(Crotalus polystictus).* Photograph by Joseph T. Collins.

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TO OUR PARENTS AND MARTHA F. MURPHY
WHO TOLERATED AND ENCOURAGED OUR
INTEREST IN VENOMOUS CREATURES.

PREFACE

Beginning in November 1966, a multifaceted approach for the investigation of rattlesnakes (genera *Crotalus* and *Sistrurus*) and other pit vipers was initiated at the Dallas Zoo by using a combination of field and captive observations. Our observations concerning the ecology and natural history of wild rattlesnakes were utilized as a basis in order to successfully maintain captive specimens. Further, many of the behavioral components found in rattlesnakes were not readily observable in the field but could be seen in captivity. As our studies continued, it became apparent that the continuation of a captive colony of rattlesnakes, roughly numbering 50 taxa and 125 individuals, required specialized techniques. To that end, we searched the literature dealing with reptilian husbandry, especially concerning rattlesnakes. In addition, we consulted with colleagues who had successfully maintained these ophidians. Since reproductive and captive propagation was a consideration, we tried to develop a format with that objective in mind.

The results of our studies are contained in this account and a companion volume which deals with the ecology and natural history of 45 taxa of Mexican rattlesnakes. This present account is divided into two parts; the first covers successful husbandry techniques, and the second surveys organisms causing pathogenicity, recommendations for treatment and appropriate medical procedures. It is obvious that many of these techniques can be applied on a larger scale to the captive maintenance of a considerable number of reptile species besides rattlesnakes.

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Dallas Zoo
Dallas, Texas
April 1978

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MAINTENANCE IN CAPTIVITY

The number of published accounts relating to the maintenance of various species of rattlesnakes is rather limited. Klauber (1956) related some of the experimentation done at the San Diego Zoo with certain species of rattlesnakes in order to keep them successfully in captivity. Kauffeld (1943a, 1953a, 1965, 1969, 1969a) mentioned techniques developed at the Staten Island Zoo which were used to maintain the large collection of rattlesnakes at that institution.

Some species of rattlesnakes adapt readily to captivity and longevity records over 10 years are not uncommon (see Perkins, 1954; Shaw, 1957, 1962; Kauffeld, 1965). It has been our experience that certain montane species of rattlesnakes, i.e., *Crotalus transversus*, which are found in specific habitat niches, seem to adapt less easily to a captive state. Other forms, such as *C. triseriatus*, which have invaded a number of habitat types, appear hardier in captivity.

General Maintenance

Quarantine procedures for incoming specimens must be strictly followed. Care must be taken to prevent cross contamination, and any diseased snakes should always be serviced after the healthy specimens have been attended (Frye, 1974b). Upon arrival, the snakes may be soaked in a prophylactic solution of tetracycline (1 tsp/gal H_2O) for 24 hours, but the value of this procedure has not been established (Marcus, 1971).

Cage sanitation can be accomplished by the use of a quaternary ammonium disinfectant (Murphy, 1973b, 1975). O'Connor (1966-1967) warned against the use of coal tar, phenol compounds, pine oil and compounds of heavy metals.

Routine examination for the presence of parasites and other disorders should be undertaken.

Generally, the use of cedar shavings, crushed corncob products, peat moss, sand, or other fine material is inadvisable for cage substrate. Gravel or newsprint, depending on the purpose required, provide suitable and sanitary alternatives. Contrary to the findings of Klauber (1956), we have had greater success maintaining most rattlesnakes singly in relatively small cages.

Specific Requirements

Temperature.—Reptilian thermoregulation can be accomplished, to a large extent, by physiological thermoregulation (Benedict, 1932) and behavioral thermoregulation (Cowles and Bogert, 1944; Colbert *et al.*, 1946; Bogert, 1949, 1959; Dawson, 1960; Brattstrom, 1965). Benedict (1932) tested *Crotalus atrox* in order to evaluate the production of metabolic heat (body weight and surface area) and its relationship to body temperature, but the substrate temperatures were ignored (Brattstrom, 1965). As the body temperature drops, the ability of an ectotherm to produce heat physiologically to maintain that body temperature drops. The thermal significance of metabolic heat production is probably minimal, due in part to the large surface area as opposed to the relatively small body mass. Of greater significance is the regulation of body temperature by behavioral means (Cloudsley-Thompson, 1971). For crotalid snakes, Brattstrom (1965) characterized the behavioral thermoregulatory pattern as diurnal, primarily thigmothermic with occasional basking, crepuscular and nocturnal patterns developing as hot seasons begin.

The normal activity range, through an analysis of internal body temperatures, refers to the range of activity between the voluntary minimum and voluntary maximum (Cowles and Bogert, 1944). Klauber (1956) felt that the voluntary minimum for rattlesnakes could generally be around 16°C for desert species and slightly higher for other forms. The voluntary maximum was about 37°C, possibly a degree or so higher in desert forms (Klauber, 1956). According to Klauber (1956), the normal activity range for Nearctic rattlesnakes was between 26.5°C and 32°C, and centered around 29.5°C. Brattstrom (1965) summarized the body temperatures of 56 temperature records of rattlesnakes which showed a range of 17.5°-34.5°C: mean 29.7°. Pough (1966) reported the mean temperatures of 26.5°C (21.9°-29.8°) for *Crotalus scutulatus* and 25.7°C (22.4°-29.8°) for *C. atrox*.

Basking is utilized by rattlesnakes to increase the body temperature when the air temperature is below 24°C, the ground is cool, and the sun is in evidence. The lower limit of basking behavior seems to be around 13°C (Klauber, 1956).

Cowles and Bogert (1944) recorded the body temperature of *C. atrox* and found that the range is between 21.0° to 34.0°C: mean 27.4°. The minimum voluntary temperature was 18.0°C and the critical maximum was 39°C. The same authors (1944) reported the temperature range 17.5°-31.5°C (critical maximum 41.6°C) for the sidewinder *Crotalus cerastes,* and 31°-32°C as a thermal preference. Mosauer and Lazier (1933) found that *C. cerastes* and *C. atrox* were killed by exposure to the October California sun in 7-10 min. Their body temperature registered 46.5°-47°C and the surface of the sand was 55.5°C.

Brattstrom (1965) found that specimens of *Crotalus cerastes* had body temperatures ranging from 20.6°-33.5°C (mean 26.2°), *C. mitchellii* ranging from 26.3°-31.8°C (mean 30.3), *C. scutulatus* ranging from 22.2°-34.0°C (mean 30.3°), *C viridis* ranging from 21.0°-34.1°C (mean 28.9°), *C. pricei* ranging from 18.0°-23.8°C (mean 21.1°), *C. ruber* with a mean of 24.0°C from one specimen, and *C. willardi* with a mean of 30.0°C from one specimen.

Lowe and Norris (1954) recorded the temperature of one *Crotalus enyo* at a mean 29.7°C. Fitch and Glading (1947) reported a temperature range of 27°-32°C for northern Pacific rattlesnakes.

When reptiles are placed in a thermal gradiant, they tend to concentrate in an area to select a preferred body temperature (nomenclature after Licht, *et al.*, 1966) which may be somewhat similar to the eccritic temperature or the selected temperature in the field. Brattstrom (1965) tested *Crotalus viridis helleri* in a thermal gradiant and found body temperatures ranged from 27.6°-30.8°C (mean 29.4°) which closely approximated the mean temperature level recorded in free-ranging *C. viridis* subspecies. A specimen of *C. ruber*, also tested in the thermal gradiant, appeared to prefer a lower temperature of 24.0°C.

Although congeneric species may vary widely, in terms of distribution and habitat selection, the thermal requirements from species to species may fall within a rather closely limited range. Conversely, different genera may have rather variable thermal preferences, despite a similar habitat or distribution (Cloudsley-Thompson, 1971). Generally, diurnally active forms can survive at higher temperatures than nocturnal species (Miller and Stebbins, 1964).

Coloration has a minimal effect on the ability of the rattlesnake integument to absorb radiation, but is related to procrypsis (Dammann, 1961). Thermoregulation is mainly controlled by substratum temperatures.

Recommendations for the temperature range for maintenance of rattlesnakes in captivity varies from 18°-32°C (Lederer, 1936; Lueth, 1941; Allen and Neill, 1950; Klauber, 1956; Kauffeld, 1965, 1969). Generally, 27°C seems to be a satisfactory maintenance temperature for most rattlesnake species (Klauber, 1956; Kauffeld, 1969). A method for heating reptile terraria has been reported (Logan, 1972).

The necessity for a clearly defined diel temperature cycle in captivity is poorly understood, particularly for montane forms of rattlesnakes. Two specimens of *Crotalus polystictus* were maintained for 9 months in a thermal situation which reached a level of 29°C during the day, and dropped to as low as 10°C at night. The snakes maintained excellent body weight and fed regularly.

The relationship between the elicitation of reproductive cycles and hibernation periods in captive reptiles, including rattlesnakes, is not well known (see Peaker, 1969). Certain species of rattlesnakes can be successfully hibernated in environmental chambers (Radcliffe, *et al.*, 1974). Aldridge (1975) found that seasonal testes development was dependent on high temperatures in *Crotalus viridis* and photoperiod had no apparent effect on the seminiferous tubule size or interstitial cell size.

Water.—Desert reptiles, by burrowing or utilizing burrows, are able not only to thermoregulate effectively, but also to maintain water economy (Schmidt-Nielsen and Dawson, 1964). Water loss in *Crotalus* was 0.176 mg/g/hr and ratio of loss from lungs to loss from skin was 70:30 in rattlesnakes (Cloudsley-Thompson, 1971). Water is reabsorbed in the cloaca and large intestine (Klauber, 1956; Jungueira, *et al.*, 1966).

Although rattlesnakes can be kept for long periods of time in captivity without drinking (Klauber, 1956), it is important to provide captive rattlesnakes with water. Ashley and Burchfield (1966) found that snakes were attracted to fresh water and were stimulated to drink; they recommended changing the water daily. New-born snakes are particularly susceptible to dehydration, so fresh water must be made available to them. Certain arid-dwelling forms, i.e., *Crotalus mitchellii stephensi*, appear to decline quickly if the relative humidity reaches an inordinately high level through evaporation in the water dish, so it seems expedient to offer water weekly for a short period and remove the water dish at other times.

Kauffeld (1969) warned that consistent regurgitations may be due to the imbibing of water after feeding, thus it may be best to remove the source of water for a few days after feeding.

Feeding.—There have been a number of references to the feeding of snakes, including rattlesnakes, in captivity. The following authors have discussed various methods of feeding: Ashley and Burchfield, 1966; Backhaus, 1963; Burchfield, 1975a, 1975b, 1975c; Ditmars, 1912; Falck, 1940; Fautin, 1946; Fitch and Twining, 1946; Kauffeld, 1943, 1953a, 1969; Klauber, 1956; Klingelhöffer, 1955; Loewen, 1947; Nietzke, 1969, 1972; Storer and Wilson, 1932; Thomas, 1934; Vogel, 1964; Wiley, 1929.

The use of freshly killed food for feeding snakes has been widely recommended (Fautin, 1946; Kauffeld, 1943, 1953a, 1969; Klauber, 1956; Loewen, 1947). A pair of endoscopic forceps can be used to present the food item. With some individual snakes, a feeding response can be elicited only after the snake is provoked to strike defensively. With other specimens, slight movement of the prey with forceps can stimulate feeding. Care must be taken to present the lateral aspect of the prey, since some newly acquired snakes strike only if they are able to secure a hold in the shoulder region of the prey item. The defensive reaction of the snake should be constantly monitored, for the balance between defensiveness and interest can be used as an indication in order to induce successful feeding. Often, the slow withdrawal of the prey item with forceps can elicit feeding. Pressing the body of the snake with the food item often causes an immediate defensive strike, whereupon the prey item should be dropped and the snake left undisturbed.

Trimming the whiskers and removing the skin from the nose of the rodent prey will often stimulate feeding (Ashley and Burchfield, 1966). By grasping the nape of the neck of the rodent and pulling sharply by the tail, the effects of *rigor mortis* in producing unnaturally contorted prey items will be minimized.

Since some snakes are apt to be nocturnal feeders, the prey item should be left in the cage overnight.

Although some authors suggest that the use of live food is ineffectual (Kauffeld, 1953a), the loreal pits of rattlesnakes, as temperature differential receptors (Noble and Schmidt, 1937) aid in the detection of live prey. Some rattlesnakes will feed only upon live prey. For some of the smaller montane rattlesnakes, the use of newborn mice has been unsuccessful, whereas small furred mice (weight 7.5g) are readily eaten. Rodents (as prey items) can cause considerable damage to a snake if they are not killed quickly. They should be removed if they are uneaten after 30 minutes. Often a diffidently feeding rattlesnake can be provoked to strike and feed if the rodent is dipped in water prior to being offered to the snake. The rodent will begin to preen and usually ignores the snake, whereupon the snake will be stimulated to strike.

Some of the smaller montane rattlesnakes, and the young of larger species, feed readily on small lizards, and in a few cases refuse to feed on anything but lizards. Lizard genera such as *Uta, Sceloporus*, *Anolis* and *Cnemidophorus* provide suitable prey items. Kauffeld (1953a) insured a steady supply of lizards by freezing them in water and thawing them when needed. In general, it is advisable to substitute newborn mice in place of lizards as quickly as possible for juvenile rattlesnakes.

Klauber (1956) summarized the food records of many species of rattlesnakes, and individual food preferences may be obtained by consulting this reference.

Certain poorly feeding rattlesnake species, particularly the montane forms, respond to a small flat rock placed in the enclosure which appears to offer them added security. The snake's position on the rock above the prey item seems to elicit a feeding response. In addition, a fine mist of water sprayed prior to feeding may stimulate a snake to feed.

Most forced feeding recommendations are haphazard and dangerous to snakes due to stress and undue handling. A variation of the immobilization tube technique (Murphy, 1971) proposed by Radcliffe (1975) works well and safely in assistance feeding. A freshly killed food item is placed in one end of the tube with the snout of the prey touching the rostral area of the snake. The snake's jaws are gently opened, the nose of the food item is placed therein, and the snake is forced to move forward through the tube. The prey item is manipulated, by virtue of the snake's forward movement and esophagal undulations, into the gullet and eventually swallowed.

One technique suggested by Lowe (1943) which has been mentioned as a stimulant to feeding in rattlesnakes requires the use of a box with a suitably cut entrance hole with some nesting material and newborn rodents placed inside.

According to Klauber (1956), small rattlesnakes should be fed weekly, subadults biweekly and older adults monthly, depending on the obesity of the specimens.

Regurgitations, particularly as the result of debilitation, can occasionally be prevented if the abdomen of the food item is slit.

Stress.—Cowles and Phelan (1958) found that certain rattlesnakes possess an olfactory chemoreceptive alerting mechanism which enables them to recognize potential predators and enemies. Physiological changes induced by fear were recorded with an electrocardiograph, and showed that odors from kingsnakes *(Lampropeltis)* and human beings evoked strong responses. In addition, the sight of human beings and vibrations, even of low intensity, caused marked changes in heart rate. Some easily excitable species (i.e. *Crotalus polystictus*) respond nervously to very slight vibrations. The deleterious effects of captivity can be minimized by isolating rattlesnakes from fear-inducing stimuli through placement of cages in quiet surroundings, elimination of ophiophagus enemies and so forth. In the case of newly captured snakes, any disturbances caused by the captor is apt to disrupt the feeding process. Clarke and Marx (1960) found that the heart rate of *C. r. ruber* increased when an observer entered or left the room during the observational period.

DISEASES, INFECTIONS AND TREATMENTS

The "Maladaption Syndrome," according to Cowan (1968) accounted for many of the pathological conditions which afflicted captive reptiles, due in part to stress and, in some cases, a refusal to feed. Tissues tend to lose structural integrity, and various diseases begin to appear, such as ulcerative stomatitis, necrosis and ulceration of the enteric mucosa, increased effects of parasitism and overall debilitation. Ulcers become infected, both with pathogenic bacteria and nonpathogenic organisms and abscesses, disseminated sepsis and vegetative endocarditis can occur.

Cowan (1968) felt that members of the North American snake family Crotalidae which do not adapt readily to captivity may undergo apparently spontaneous focal necrosis in the pancreas, followed by poorly controlled regeneration, thereby producing hyperplastic, distorted adenomatous masses. The normal acini and islets are destroyed and interstitial fibrosis occurs. The pancreas may be enlarged and, histologically, the situation seems similar to adenocarcinoma.

The presence of bacteria and their products in the blood (septicemia) can affect captive reptiles (Marcus, 1971). Necropsy reveals microscopic evidence of bacteremia and discolored hyperemic organs (Page, 1966). Entry of bacterial pathogens can be precipitated by the sucking activities of mites, principally *Ophionyssus*, ulcerations, impactions, wounds and other injuries. Page (1966) mentioned *Aeromonas hydrophila* and *Pseudomonas aeruginosa* as the primary pathogens. Marcus (1971) suggested that isolation of afflicted reptiles, disinfection of the enclosures and elimination of mite vectors can reduce septicemia in some instances.

For a list of the various drug actions and interactions consult (Szabuniewicz, *et al.*, 1973). In order to understand the mechanisms of microbial action and the combination and choices of antimicrobial drugs, refer to Aronson and Kirk (1968) and to Kagan (1970). Injection sites should be midway between the vertebral column and ventral scutes at mid-body. Alternate sides for small dosages and split dosages on either side for larger amounts (Murphy, 1975).

Tuberculosis.—The organisms of the genus *Mycobacterium* are acid fast, slender rods which are aerobic and can be pathogenic to reptiles. Tuberculosis affecting rattlesnakes has been mentioned by Book (1945), Glidden (1936) and Klauber (1956). Cowan (1968) found lesions in the liver and lungs of garter snakes caused by *M. thamnopheos*. The tubercles were discreet white or grayish nodules (2mm in diameter) and were well defined, cellular, with central necrosis histologically. The predominant cells were large and singly nucleated.

Ulcerative stomatitis.—"Mouth rot" or ulcerative (or necrotic) stomatitis is characterized by an inflammation of the gingiva of the upper and lower dental arcades (Wallach, 1969). The infection is further manifested by a large amount of yellow-gray exudate and secondary osteomyelitis. Terminal pneumonia and gastroenteritis can follow. Occasionally, distention of the corneospectacular space may be apparent (Marcus, 1971).

Klingelhöffer (1955) mentioned two forms of mouth rot—an acute or mucous form which contributes to the death of the snake in a few days, and a chronic or caseous form where the snake survives for several months and may recover.

Heywood (1968) and Camin (1948) found that the mite *Ophionyssus natricis* was responsible for the transmission of the organism *Aeromonas hydrophila* and the resulting infection caused reptilian deaths. Glidden (1936) felt that the infection was caused by a species of *Staphylococcus*. Burtscher (1932) listed *Pseudomonas fl. liquefaciens* as the possible causative agent. Reichenbach-Klinke and Elkan (1965) mentioned *P. liquefaciens*, *Pasteurella* spp. and *Proteus* spp. Page (1961) stated that *Aeromonas* spp. Strain SA-5 was responsible for ulcerative enteritis in kingsnakes and that the organism was transmitted through the activities of mites or by direct contact (Page, 1966).

Ledbetter and Kutscher (1969) found that swabs of the fangs of rattlesnakes when cultured yielded *Aerobacter*, *Proteus*, *Pseudomonas*, four *Salmonella* strains and clostridia.

Aeromonas hydrophila is highly proteolic at temperatures less than 20°C and two biochemical types, both causing disease symptoms (gas forming Voges-Proskauer positive; non-gas forming Voges-Proskauer negative), have been recognized (Page, 1962). Both types are considered to be *A. hydrophila* following the designation of Ewing, *et al.* (1961).

Cooper (1973) found the organisms *Aeromonas, Proteus, Pseudomonas* sp., gram positive bacilli, and cocci in African snakes stricken with necrotic stomatitis. A streptomycin sulfate solution was sprayed directly on the diseased surface with a syringe and narrow needle (23-25 gauge) daily for five days. The concentration was altered (500mg up to 2-3g daily in 5ml distilled water) depending on the size and condition of the snake. Vitamin therapy with a multi-vitamin preparation injected systemically was also recommended.

Gray, *et al.* (1966a) found that the causative agent for necrotic enteritis was *Pseudomonas aeruginosa*, and the use of Aureomycin (chlortetracycline bisulfate) was instituted on a prophylactic basis with the highest margin of safety calculated to be 100mg/lb of body weight. Aureomycin (dosage 0.5g/gal of water) was given in the drinking water with a frequency of one dose daily for five days. Palestine vipers *(Vipera xanthina palestinae)* were highly susceptible to *P. aeruginosa* but Keydar, *et al.* (1971) discovered that Polymyxin (1-2mg per injection for a total dose of 10mg) was effective in eliminating disease symptoms.

A *Corynebacterium* organism of the group diphtheroid caused necrotic hemorrhagic lesions in the mouths of snakes and was infectious (Belluomini, 1965; Furlanetto, *et al.*, 1964). It was controlled by specific vaccination (Belluomini, 1965).

For the treatment of ulcerative stomatitis and submandibular abscesses in crotalid snakes, Bonilla and Seifert (1971) proposed the use of amphyl (o-Phenylphenol). Cotton swabs were soaked with amphyl and used for debridement and cleaning of lesions. In addition, the oral cavity was sprayed and this regimen was instituted with incoming specimens.

Kauffeld (1953b) recommended the use of 25% aqueous solution of Sulmet (sulfamethazine) but the efficacy of this treatment is questionable. O'Connor (1966-1967) asserted that the necrotic exudate should not be removed as this process leads to reinfection. Hunt (1957) mentioned the application of silver vitellin (25% silver-conjugated protein) in cases of ulcerative stomatitis. Burke (1972-1973) proposed using kanamycin or gentamycin in resistant cases.

Hinshaw and McNeil (1944, 1946) reported that captive rattlesnakes and other reptiles were dying from paracolon type 10 of *Salmonella*. The condition was characterized by small necrotic lesions of the liver and the organism was found in the heart, blood, kidney, liver, and lung. Salmonellosis is usually subclinical in reptiles, but enteritis or septicemia may be apparent (Marcus, 1971). Specific diagnosis can only be possible on the basis of positive bacteriologic cultures from the feces, cloacal swab or blood (Marcus, 1971). Ghoniem and Refai (1969) showed that *Crotalus ruber* was a reservoir for *Salmonella aqua.*

Edwards, *et al.* (1943) found that strains 183 and 184 were recovered from poults, while an identical culture, PL 27, was isolated from the liver of a rattlesnake. The liver exhibited extensive necrosis. Hinshaw and McNeil (1945) found no true *Salmonella* in nine rattlesnakes tested, but several strains of the Edwards, Cherry and Bruner paracolon types were isolated from the rattlesnakes.

Crotalus adamanteus snake serum agglutinated leptospiral serotypes *(L. ballum)* at low titre in the macroscopic agglutination test (White, 1963), *Sistrurus miliarius barbouri* was free of leptospiral agglutinins.

Enteretic and gastritic conditions occasionally occur which can be caused by a bacterial agent and are determined symptomatically by mucoid and discolored stools, hemorrhaging and regurgitation. Biosol (neomycin sulfate) is suggested because it does not lose its activity in the presence of gastro-intestinal secretions and enzymes. The dosage level is 10mg/kg of body weight IM, IV daily until the condition clears. However, this drug should not be given where the snake is severely dehydrated.

Bacterial flora.—Parrish, *et al.* (1956) sampled the bacterial flora of the mouths and venom glands of *Crotalus adamanteus, C. horridus* and *Agkistrodon piscivorus*, and the following organisms were reported: *Aerobacter aerogenes, Escherichia coli, Paracolon bacterium, Proteus vulgaris, P. aeruginosa*, unidentified enteric, *Corynebacterium* (diphtheroids) sp., *Clostridium* sp., *Micrococcus pyogenes*, var. *aureus* and *Streptococcus* sp.

Routine bacterial cultures from eight rattlesnake species at the Dallas Zoo have been performed, and the following organisms have been isolated from the heart blood, liver, lung, swelling from intercanthal area of head, lower colon and stool: *Pseudomonas aeruginosa* (lung, liver, lower colon), *Proteus mirabilis* (lower colon, heart blood), *Escherichia coli* (intercanthal area), *Arizona hinshawii* (lung), *Paracolobactrum coliforme* (heart blood, lower colon, liver), *Proteus rettgeri* (liver), and *Arizona* group (lung, liver). *Proteus mirabilis, Pseudomonas aeruginosa, Aeromonas hydrophila, Proteus morgani, Arizona hinshawii, Paracolobactrum coliforme, Salmonella bornum* (lactose positive), and *Arizona* group have been recovered from stool samples. In December 1970, an organism which was biochemically *Arizona hinshawii* was found in eight rattlesnake species *(Sistrurus ravus, Crotalus basiliscus, C. durissus, C. v. cerberus, C. willardi, C. cerastes, C. h. atricaudatus, C. ruber*) which died during a three week period. Symptomatology included gaping, inanition and anorexia, and convulsive seizures were exhibited prior to death. Routine antibiotic sensitivity tests (Kirby-Bauer Method: Bauer, *et al.*, 1966) demonstrated the organism's sensitivity to Chloromycetin (18mm), Polymyxin B (8mm), Kanamycin (13mm), Colymyin (11mm), Keflin (22mm), and Garamycin (16mm). Administration *in vivo* with chloramphenicol (15mg/kg) IM s.i.d. seemed to be effective in two instances.

Consult Glorioso, *et al.* (1974) for a taxonomic key for the isolation of bacterial pathogens.

Rattlesnakes are occasionally plagued with swellings on the head which involve the rostral area and may extend posteriorly to the frontal area. Bacterial cultures from this site were analyzed at the Dallas Zoo from four species; *Crotalus intermedius omiltemanus, C. mitchellii pyrrhus, C. molossus molossus, C. triseriatus aquilus.* The organisms discovered were as follows: *C. i. omiltemanus—Pseudomonas aeruginosa; C. m. pyrrhus—P. aeruginosa, Escherichia coli, Enterobacter aerogenes; C. m. molossus—P. aeruginosa, E. coli; C. t. aquilus—P. aeruginosa, Serratia marcescens,* coagulase-negative staphylococcus.

The final diagnosis for the *C. m. pyrrhus* was severe suppurative dermatitis; the tissues examined were scraps of skin and necrotic debris removed during debridement of a cutaneous wound. The lesion consisted of epithelial cysts filled with masses of necrotic debris, many colonies of bacteria and some necrotic granulocytes. In some segments of the material, numerous epithelioid cells and some granulation tissue was noted. Bacterial cultures (22° and 37°C) revealed the following organisms: *Corynebacterium xerosis,* few coagulase positive staphylococci, rare alpha *Streptococcus,* numerous *Pseudomonas aeruginosa* and moderate *Citrobacter freundii.* Sensitivity tests were undertaken and all organisms showed sensitivity to Gentamycin. Gentamycin sulfate (4mg/kg body wt. IM s.i.d. for five days) was administered, but no change was apparent.

Respiratory infections.—Rattlesnakes which are affected by respiratory distress and pneumonia generally manifest this condition through the following external symptoms: dyspnea, wheezing and sneezing, the oral and buccal cavity filled with clear, slightly viscous saliva which becomes purulent, cordlike yellow phlegm during later stages, weakness, inanition and lethargy, head held high for long intervals, and gaping (see Rothman and Rothman, 1960). MacCallum (1921) reported on an epidemic pneumonia affecting reptiles, including *Crotalus atrox.* The air cells found in the diverticula of the main bronchial cavity were filled with a blood stained exudate, and hemorrhaging was observed in the surrounding tissue. In *C. atrox,* cellular exudate filled the air cells, and this material contained leucocytes, red corpuscles, little fibrin and large numbers of an unidentified gram negative bacilli.

Cowan (1968) illustrated the reptilian inflammatory process in loose lung tissue as follows; dry and unaccompanied by liquifaction of necrotic material; dry, whitish and somewhat caseous pneumonic infiltrates, primarily monocytic exudates, and hyperplasia and metaplasia in the respiratory epithelium.

Zwart and Jensen (1969) reported that approximately 10% of the snakes investigated in earlier studies had respiratory infections caused by parasites, and nematodes were responsible for 30% of these cases.

When possible, bacteriologic cultures and sensitivity tests should be performed since *A. hydrophila* and other microorganisms have been implicated in reptilian pneumonia (Marcus, 1971).

A number of medications have been tested, and, in some cases, proposed for the elimination of reptilian respiratory infections, particularly Chloromycetin (O'Connor, 1966-1967), tetracycline and neomycin (Metzger, 1958), sulfanilamide (Holmes, 1954), penicillin and dihydrostreptomycin (Truit, 1962), Friar's Balsam (Noël-Hume and Noël-Hume, 1954), oil of eucalyptus and camphorated spirits (Kauffeld, 1969), penicillin, sulfathiazole, and tetracyclines (Rothman and Rothman, 1960).

Murphy (1973) recommended the macrolide antibiotic tylosin for the successful treatment of reptilian respiratory infections. Specimens of *Crotalus r. ruber* and *C. v. viridis* were treated with this drug (dosage level 25mg/kg of body weight IM daily until the condition cleared). Two *C. atrox*, one *C. v. concolor*, one *C. v. abyssus* and one *C. catalinensis* were also treated successfully (unpubl. observ.). Tylosin appeared to be the most effective drug for the treatment of reptilian respiratory infections.

Pathogenic fungi.—At the Dallas Zoo an adult *Crotalus polystictus* developed a small necrotic lesion which slowly increased in size and was located on the mid-dorsal line approximately 2/3 the length of the body. Immediately following exuviation, exudate would drain and gradual paralysis would develop posterior to the lesion. The snake became listless and refused to feed, so it was sacrificed on 18 October, 1974. *Penicillium* and *Aspergillus flumigatus* were recovered from the site of infection. The other organism recovered was *Sporotrichum*, which is known to form a necrotic ulcer on the skin surface. Subcutaneous nodules were also found at the site of the ulcer. Although treatment was not attempted, it might be advisable to excise the local lesion, or apply Nystatin or Amphotericin B. Intraesophageal administration of Potassium iodide or Amphotericin B (IV) might be warranted for the control of *Sporotrichum*.

Protozoa.—Zoo exhibits offer excellent conditions for the transmission of hemogregarine parasites and some mortality is to be expected under these circumstances (Hull and Camin, 1960). Rattlesnakes have been infected by the following hemogregarine protozoans: *Haemogregarina digueti* in *Crotalus atrox* (Roudabush and Coatney, 1937), *H. crotali* from *C. viridis* (Laveran, 1902) and *C. d. cascavella* (Pessôa, 1967), *H. digueti* in *Sistrurus ravus* (Phisalix, 1914), *H. romani* and *H. capsulata* in *C. d. terrificus*, and *C. d. collilineatus* (Pessôa, 1967), and an unidentified hemogregarine in *C. v. helleri* (Wood and Wood, 1936). Hull and Camin (1960) found *C. viridis* with intra-erythrocytic stages of hemogregarine parasites. The parisitaemia (number of infected erythrocytes per 100 erythrocytes) ranged in percentage from 0.1-33.8%.

Apparent congenital transmission of hemoparasites has been recorded (De Biasi, *et al.*, 1971, 1972). Young gametocytes, produced in the gravid female snake, appeared to be carried by the circulatory system to the uterine circulation where, after passing through the fetal membrane, they invaded the fetal erythrocytes. This occurred in the last stage of pregnancy. Although *Hepatozoon*, *Trypanosoma* and *Plasmodium* were found in the female snakes, only *Hepatozoon* seemed to invade the fetus. Additional information concerning *Hepatozoon* can be obtained by consulting Pessôa and De Biasi (1973). *Trypanosoma cascavelli* was reported from *Crotalus d. terrificus* (Pessôa and De Biasi, 1972). Pessôa, *et al.* (1974) found that *C. durissus* had an infection percentage of 11% for *Hepatozoon* and 1.5% for *Trypanosoma*. For diagnosis of trichomonads, direct fecal smears are necessary (Kiel, 1975). Filarial parasites, trypanosomes and haemosporidia can be detected with blood smears.

In those cases where pseudoneoplasms are produced due to helminth parasites and hemogregarines, Frye (1973) recommended excision, debridement and the use of an appropriate medication (povidone-impregnated gauze sponge, mild silver nitrate or 4% buffered formalin). Hemorrhage can be curtailed by pressure or pinpoint electrocautery, and the wound sutured with nonabsorbable material.

Methods for collecting and preparing protozoans and helminths have been described earlier (Murphy, 1973a, 1973b).

Amoebiasis.—Infections from various species of the protozoan parasite *Entamoeba* have been recorded as occurring in a number of reptiles (Fantham and Porter, 1953-1954; Hill and Neal, 1953-1954; Ippen, 1959; Graham-Jones, 1963) and rattlesnakes are probably also susceptible (Klauber, 1956; Donaldson, *et al.*, 1975). Snakes which were infected manifested indifference to food and showed weight loss after a two week period from the start of the infection. In addition, the feces sometimes showed blood-stained mucus. Early cases of this infection may be detected chemically with a guaiac test (Marcus, 1974). Geiman and Ratcliffe (1936) reported that the trophozoite of *Entamoeba invadens* produced lesions in the alimentary tract and liver and, in addition, encystation and quadrinucleate cyst formations were observed in the intestines and liver. Cowan (1968) further characterized the disease as being initiated in the intestinal tract with ulcerative formation in the colon and ileum. The amoebas spread to the liver and other organs via blood and lymph, and, as they moved into the blood stream from the lymphatic system, thrombic and inflammatory changes were present. Ratcliffe and Geiman (1934) mentioned that gastric ulceration was apparent, with the colon and lumen often filled with a friable grayish or blood-stained exudate. Coagulation necrosis was seen and the liver was affected along the route of the portal vein. On occasion, a preanal induration may be observed (Donaldson, *et al.*, 1975). The nutritional condition upon necropsy appeared to be satisfactory (Ippen, 1959). Since reptiles are often maintained in exhibit conditions where the substratum consists of damp sand or dirt, the possible transmission of protozoan parasites is increased (Hull and Camin, 1960) and care must be taken to isolate all infected individuals.

When snakes are maintained at high temperatures (35°-37°C), the viability of *E. invadens* diminishes (McConnachie, 1955; Meerovitch, 1961). *E. invadens* probably does not occur often in wild reptile populations (Meerovitch, 1958, 1961).

A number of treatments for the control of amoebiasis have been reported by previous workers (Backhaus, 1963; Dobbs, 1973; Donaldson, *et al.*, 1975; Fiennes, 1961; Frye, 1973; Gray, *et al.*, 1966b; Ratcliffe, 1961, 1966; Reichenbach-Klinke and Elkan, 1965; Wallach, 1969). Backhaus (1963) used antibiotic therapy (Aureomycin or Terramycin SF and Trigantol) and vitamin B_{12} in addition to Entero-Vioform (iodochlorhydroxyquin) and Resortren Comp. (chloquinate) (0.3g/kg of body weight) and the drug was used repeatedly in the case of a 37kg python (dosage 3g).

Entamide (diloxanide) and Fugillin (fumagillin) (500mg/kg of body weight) were used by Fiennes (1961; cited by Backhaus, 1963) and although Entamide was recommended because of a wider therapeutic index, the frequency and duration of treatment was not recorded. The antibiotic tetracycline hydrochloride has been suggested for the treatment of amoebiasis (Ratcliffe, 1961, 1966; Conant, 1971). Ratcliffe (1966) found that *Entamoeba invadens* was controlled with tetracycline hydrochloride using a dosage level ranging from 400-800mg per meter of snake. Lomotil (diphenoxylate hydrochloride), a parasympathomimetic drug, was proposed by Dobbs (1973) for the treatment of amoebiasis (dosage 1.25mg/kg of body weight orally—duration of treatment not given). Donaldson, *et al.* (1975) found that the treatment of amoebiasis was ineffectual with the use of tetracyclines. Flagyl (metronidazole) was recommended as the drug of choice administered with a stomach tube at the single dosage level of 275mg/kg. Gray, *et al.* (1966b) used Diodoquin (diiodohydroxyquin) as a retention enema for the treatment of a Komodo dragon (650mg/150cc of 0.9% saline given daily for 14 days for a 125 lb lizard) and Emetine hydrochloride USP (65mg daily IM for seven days for a 40 lb lizard).

Coccidiosis.—The transmission of coccidia by ectoparasites can lead to epizootics; quarantine of specimens and control of ectoparasites is important (Deakins, 1972-1973). Signs of infection may include hemolytic crisis, capillary sludging and thrombosis, desquamification of lung or intestine, and hepatocellular damage (Deakins, 1972-1973).

Fantham and Porter (1953-1954) felt that an intestinal and gall bladder infection in a timber rattlesnake, *Crotalus h. horridus*, was caused by the coccidean *Isospora naiae*, since schizonts and gametocytes were found in the intestinal mucus where there was epithelial destruction in the villi. Oocytes were also found in the bile. *Isospora dirumpens* has been reported in *Crotalus adamanteus* (Bovee, 1962). The presence of coccidia may be determined by fecal flotation.

Coccidiosis may be controlled with Bayrena (sulfamethoxydiazine) with a dosage level of 80mg/kg of body weight for the first day (Lehmann, 1972b), sodium sulfamethazine in the drinking water with the dosage level of 1 oz/1 gal for ten days (Wallach, 1969), and the use of sulfa compounds and amprolium (Dobbs, 1973) or sulfamerazine orally at 50mg/kg body weight (Kiel, 1975).

Helminths.—Although most trematodes have been reported from *Sistrurus miliarius*, due to its consumption of amphibian prey items, the flukes are generally not easily transmitted in captivity because of the molluscan intermediate host (Telford, 1971). Harwood (1932) reported the digenetic trematode *Renifer kansenis (= Ochetosoma kansense)* in *Sistrurus miliarius*. Hughes, *et al.* (1941, 1942), Byrd and Denton (1938), Nelson (1950), and Goodman (1951) found *Neorenifer glandularis (= Ochetosoma glandulare)* in *Sistrurus miliarius barbouri*. The genus *Neorenifer* has been found in the mouth, esophagus and intestinal tract of snakes. Flukes generally do not cause serious pathological problems and there is no satisfactory treatment other than manual removal from the mouth of the parasitized snake (Kiel, 1975). Presence of eggs can be determined by fecal sedimentation.

Cestodes.—Cestodes, particularly through heavy infestations, can cause possible nutritional imbalances, but the possibility of transmission in captivity is limited due to the requirement for invertebrate intermediate hosts. The genus *Mesocestoides* in the larval stage invades the hepatic tissue of the liver and causes extensive damage (Telford, 1971). Voge (1953) found *M. variabilis* in *Crotalus v. oreganus* where over 30 tetrathyridia were found in the intestinal mesenteries. Klauber (1956) mentioned *Proteocephalus* tapeworms from rattlesnakes taken in the vicinity of Tucson, Arizona, and Marr (1944) found tapeworms in *Crotalus atrox*. The genus *Oochoristica* has been found in rattlesnakes; *O. crotalicola* in

C. v. helleri and *C. cerastes laterorepens* (Alexander and Alexander, 1957), and *O. gracewileyae* in *C. atrox* (Loewen, 1940). Beyer (1898) mentioned a flatworn found in a rattlesnake. Additional information can be obtained from Wardle and McLeod (1952), and Yamaguti (1959). Infections can be diagnosed by sedimentation, fecal flotation or direct examination of the feces for segments (Kiel, 1975). Migrating larvae may cause pathogenicity and must be removed through excision (Kiel, 1975).

For cestode infection, Wallach (1969) observed that di-N-butyl-tin oxide was effective with a dosage level of 35.0mg/kg of body weight. Lehmann (1972a) used Niclosamide (Yomesan) and Piperazine-Niclosamide (Mansonil) to treat cestode infections, and experimental evidence indicated that Niclosamide had a wider therapeutic index. Niclosamide was used with a dosage level of 150mg/kg of body weight, and the treatment should be repeated in 4-6 weeks should a fecal examination indicate the presence of cestodes. Frye (1973) used Scolaban (Bunamidine HCL) for tapeworms with a dosage level of 25-50mg/kg of body weight every 2-3 weeks, but warned that the drug should not be administered to reptiles with a known heart condition. When sparganosis is evident, surgical excision may be warranted (Marcus 1974). As the tapeworm larvae migrate, the position of the lesion may change.

Nematodes.—Nematodes have been encountered in rattlesnakes, specifically *Ophidascaris travassosi* in *Crotalus terrificus* (Vaz, 1938), *O. trichuriformis* in *C. terrificus* (Vaz, 1935), *O. sprenti* from *C. d. terrificus* (Araujo, 1969), *Ascaridia flexuosa* in *Crotalus* sp. from Brazil (Schneider, 1866), *Physaloptera obtussima* from *C. viridis oreganus* (Morgan, 1943), *Physaloptera* larvae from *C. viridis* (Widmer, 1970), *Capillaria crotali* in *C. d. durissus* (Viquez, 1933), *Polydelphis quadricornis* in *Crotalus* sp. (Yamaguti, 1961), *Polydelphis quadrangularis* in *C. d. terrificus* (Araujo, 1971), *Hastospiculum oncocercum majus* in *C. terrificus* (Desportes, 1941), and *Ophidascaris labiatopapillosa* in *C. molossus nigrescens* (Klauber, 1956). *Thubunaea cnemidophorus* has been found in *Crotalus cerastes*, *C. mitchellii* and *C. scutulatus* (Babero and Emmerson, 1974). Various nematodes of the genus *Kalicephalus* have been reported from rattlesnakes (Kreis, 1940; Comroe, 1948; Yamaguti, 1961; Schad, 1962).

Klauber (1956) found nematodes in *Crotalus polystictus*, *C. atrox*, *C. p. pricei* and *C. v. nuntius*, and Mitchell (1903), while checking for baby snakes which he thought crawled into the mouth of the female parent, found "wireworms" in the abdominal cavity near the anus. Telford (1971) noted that members of the large ascarid genus *Ophidascaris* are generally parasites of the stomach and esophagus, and are probably transmitted through amphibian intermediate hosts.

Polydelphis, Ophidascaris and *Kalicephalus* may be diagnosed by fecal flotation (Kiel, 1975). Adult *Physaloptera* are found in the mouth; the eggs can be diagnosed with a fecal sedimentation (Kiel, 1975). Piperazine and thiabendazole may not be effective against *Physaloptera* (Kiel, 1975).

If the parasite load of nematodes is unduly heavy, regurgitation may occur. Telford (1971) observed that the genus *Kalicephalus* may have a direct life cycle and is of low host specificity. Hookworms are found in the intestinal tract and usually do not seriously affect the host. Certain gastric nematodes, namely *Physaloptera*, are found in reptiles that normally prey on ants, but the pathogenicity of these spirurids is minimal (Telford, 1971). Solomon (1974) found two kinds of *Capillaria* eggs in the intestinal contents of two *Crotalus horridus*, and one type of egg was similar to *C. hepatica*. He inferred that snakes, through predation upon infected rodent hosts, are involved in the release and dispersal of nematode eggs. *Capillaria* infections can be pathogenic when the vital organs (i.e. liver) of the host are parasitized (Telford, 1971). The eggs of this nematode genus can be diagnosed by finding the doubly operculated ellipsoidal eggs in fecal flotations (Kiel, 1975).

A large number of anthelmintic drugs have been reported as being successfully employed in the treatment of nematodiasis in reptiles, as follows: Santonin or levant wormseed (Noël-Hume and Noël-Hume, 1954), Nematolyt (papain) (Backhaus, 1963), Piperazine (Dobbs, 1973; Hunsaker, 1966), Atgard V (Vandeford, 1968), Thiabendazole (Frye, 1973; Backhaus, 1963), and Vermiplex (Glenn, *et al.*, 1973). Disophenol is not recommended (Kiel, 1975).

Santonin (Noël-Hume and Noël-Hume, 1954) was used as an anthelmintic for tortoises, but other products have a higher margin of safety. Rather than directly killing the helminths, santonin appears to irritate them into moving into the intestine where they are expelled.

To control helminth infections in snakes, Backhaus (1963) found that Nematolyt, used with antibiotic therapy (Terramycin) to lessen intestinal inflammation, was an effective anthelmintic. The recommended dosage was 0.5g/meter of snake and surrounding air temperature was increased.

Piperazine (Dobbs, 1973; Hunsaker, 1966,) has been proposed as a successful anthelmintic, since it is readily soluble in water and easily absorbed from the gastrointestinal tract. Hunsaker (1966) suggested that Piperazine (diethylenediamine) be administered in two separate doses one week apart with a dosage level of 50mg/lb of body weight orally. Dobbs (1973) recommended a dosage rate of 25mg/lb of body weight orally.

Atgard V (2.2 dichlorvinyl dimethyl phosphate) has been recommended as a successful anthelmintic in reptiles (Dobbs, 1973; Vandeford, 1968; Wallach, 1969). The dosage is 12.5mg/kg of body weight daily for two days and, the drug can be administered either through the food or in pellet form. In order to reduce the drug's potency to reptiles in poor condition, the pellets should be "seasoned" by allowing them to remain uncovered for three days (Wallach, 1969).

Thiabendazole (2-(4-thiazolyl)-benzimidazole), like Atgard V, has been used to control *Strongyloides* in reptiles. Thiabendazole, according to Frye (1973), is hydroscopic and should be mixed with water in order to eliminate fluid shifts or gastrointestinal impaction. The dosage is 100mg/kg of body weight administered at bi-weekly intervals. If the snake is feeding, the drug can be placed in the prey item.

Glenn, *et al.* (1973a) reported Vermiplex (Di-Phenethane-7 Methylbenzene) as an anthelmintic which appeared to be useful for the control of parasites in *Crotalus*. The effective dosage was 0.25ml/lb of body weight, but difficulty was encountered in administration due to the lodging of the capsule in the esophagus. Flushing with water (30-50ml) or placing the drug in a food animal appeared to be more effective.

Zwart and Jansen (1969) treated the colubrid snakes *Natrix natrix* and *N. tessellata* for lung worm infection when a necropsy indicated that *Rhabdias* nematodes had caused extensive verminous pneumonia and fecal samples indicated the presence of larvae. The larvae may be found in the feces by using a direct smear or the Baermann technique (Kiel, 1975). The snakes were treated with intraperitoneal injections of Ripercol (tetramisole) with a dosage of 10mg/kg and antibiotic therapy (oxytetracycline) once daily for 14 days orally. Should a positive parasite load register after seven days, the treatment may be repeated. Oral anthelmintics may be given via a stomach tube, but care must be taken to prevent regurgitation by expressing the drug distally in the snake (Soifer, 1974). The drug may be placed in suspension or solution.

Linguatulida.—The family Linguatulidae, a group of degenerate arthropods known as tongueworms or lungworms, have been reported as occurring in rattlesnakes. Hill (1935) found *Kiricephalus coarctatus* in *Crotalus adamanteus*, Penn (1942) listed *C. d. terrificus*, *C. d. durissus*, *C. atrox*, *C. h. horridus*, and *C. adamanteus* as hosts for the linguatulid *Porocephalus crotali*. *P. crotali* was found also in *C. viridis*, *C. b. basiliscus* and *C. tortugensis* (Klauber, 1956). *Raillietiella furcocerca* has been reported in *C. tortugensis* (Klauber, 1956). Self and McMurry (1948) located the linguatulid *Porocephalus crotali* commonly in *C. atrox* where the parasite was transmitted through a rodent intermediate host. *P. crotali* has been reported in *C. adamanteus* in South Carolina (Forrester, *et al.*, 1970) and in *C. atrox* from Isla Santa Cruz (Soulé and Sloan, 1966).

Page (1966) reported that linguatulids of the genus *Armillifer* infected rattlesnakes, causing lung destruction and lessening the ability of the lung to function properly. The nymphs reside in mammals and birds whereas the adults are found in the lungs of snakes. The presence of cysts may be determined by investigating lung tissue and sputum. Linguatulids can be transferred via a water dish.

Some snake dens were negative for a parasite load while others registered high counts, and in some cases, rising counts which suggested that there was evidence of reinfection (Self and McMurry, 1948).

Additional information on liguatulid parasites can be obtained from Diesing (1851), Hett (1924), Hill (1948), Humboldt (1811), Leidy (1884), Penn (1942), Sambon (1922), Self (1969) and Telford (1971).

Until recently, there were no known successful cures reported for linguatulid parasites, but Kauffeld (1969) found the product Caricide (diethylcarbamazine) effective against linguatulosis. Manual removal with a pair of tweezers is also effective.

Mites, Chiggers and Ticks.—One of the most persistent scourges of any captive reptile collection is an infestation of the snake mite *Ophionyssus natricis*. It is generally felt that this parasite might be confined mostly to captive ophidians, but Yunker (1956) found *O. natricis* attacking wild populations of *Coluber florulentus, Psammophis sibilans, Psammophis schokari, Spalerosophis cliffordi, Naja haje,* and *Telescopus dhara obtusus* in Egypt. The level of infestation in nature was lower, due possibly to lower surface humidity, a small number of eggs deposited by the female mite, and elimination of mites through ecdysis.

The life history of *Ophionyssus natricis* has been treated by Camin (1953) and Schroeder (1934), and sex determination of this mite can be accomplished by using Oliver, *et al.* (1963).

Camin (1953) and Camin, *et al.* (1964) characterized the life history of *O. natricis* as follows: the mite feeds on an ophidian host during the protonymph and adult stages, and these stages can exist from one to five weeks. The protonymphs are unable to molt into nonfeeding deutonymphs, and the adult female mites cannot produce eggs unless they have fed on reptilian blood. Camin (1953) and Oliver, *et al.* (1963) noticed that male eggs (haploid) are produced parthenogenetically by unmated females and male (haploid) and female (diploid) eggs are produced by mated females. Schroeder (1934) found that the female mite lays approximately thirty eggs and they hatch within seventy-two hours. The mites tend to like dark, somewhat moist, areas and they have an apparent affinity for soil.

Ophionyssus natricis has been implicated as a carrier of *Aeromonas hydrophila* (Camin, 1948; Heywood, 1968; Marcus, 1971) and, through ingestion of blood, has transmitted a microfilariae load of *Macdonaldius seetae* in *Elaphe* and *Pituophis* (Hull and Camin, 1959). Filarial parasites may be killed by maintaining the snake at

35°C for 24 hours in a low humidity environment (Wallach, 1971a). In addition, the snake mite serves as a vector of a hemogregarine disease (Hull and Camin, 1960). *Aeromonas* infection in snakes is a septicemic disease in the acute form which is evident upon necropsy (Heywood, 1968). The acute form is manifested by weakness and convulsions, and marked sluggishness. A pneumonic form, characterized by a disinclination toward feeding or regurgitation, nasal discharge, inflamed oral mucosa and ulcerative stomatitis, has less severe reactions, but death occurs within five days.

Various recommendations have been proposed for the eradication of *Ophionyssus natricis:* Neguvon (Backhaus, 1963; Ashley and Burchfield, 1966), aqueous solution of rotenone (Schroeder, 1934), 4% malathion powder for 4 hours (Page, 1966), American Cyanamid 18706, Ortho Dibrom 8E and Diazinon 25E (Camin, *et al.*, 1964), vaseline, liquid paraffin or olive oil (Graham-Jones, 1961), naphthalene or nicotine sulfate (Conant and Perkins, 1931), Sorptive dust SG 67 (Tarshis, 1960, 1961a, 1961b), and Vapona No-Pest Strips (Lentz and Hoessle, 1971). Experience in the reptile collection at Dallas Zoo indicates that Vapona No-Pest Strips seemed to be easiest to administer and the most effective means of controlling *O. natricis.*

Ophidian lung mites of the family Entonyssidae have been found in *Crotalus* (Turk, 1947). Ewing (1924) found the ophidian dermanysoid lung mite *Entonyssus rileyi* in a Texas rattlesnake (species undetermined), and Hubbard (1939) described *Entonyssus ewingi* from *Crotalus atrox.* Turk (1947) felt that the mere presence of acari in the lung tissue of the host was not necessarily a precipitating factor for pulmonary disease. Entonyssid mites can be diagnosed by use of a tracheal swab in anesthetized snakes or a fecal flotation, but no effective treatment is known (Kiel, 1975).

Wolfenbarger (1952) found two larval chiggers, *Trombicula (Entrombicula) alfreddugesi* on *Crotalus horridus* in Kansas. Loomis (1951) felt that *Trombicula* damaged the facial pit of *Crotalus* and increased ecdysis.

The tick *Amblyomma dissimile* has been found on *Crotalus durissus* (Klauber, 1956), *Sistrurus miliarius* and *C. adamanteus* (Bishopp and Trembley, 1945). *Dermacentor* has been found on *C. durissus* (Klauber, 1956). Ticks can be killed with a drop of alcohol and then carefully removed with tweezers. Wallach (1969) noted that the wounds should be treated with organic iodine, methylene blue in 10% isopropyl alcohol or thimerosal.

Lacerations, Lesions and Abscesses.—Unless lacerations involving rattlesnakes are treated quickly and successfully, potential shock and infection may result. Occasionally, internal organs may be involved (Marcus, 1971). Excessive dampness, contact with droppings and malnutrition may be predisposing factors (Marcus, 1971). It is necessary, in the case of hemorrhaging, to halt the blood flow with a stiptic (Negastat) or hemostatic powder. Dobbs (1973) recommended the use of two antimicrobial drugs with cortisones to lessen shock. These are Flucort (Flumethasone)-1.25mg/lb of body weight IM or Meticorten (Prednisone)-1.0mg/lb of body weight. Marcus (1971) suggested undiluted benzalkonium chloride as an irrigant.

A proteolytic enzyme ointment (Kymar) is recommended in those instances where necrotic wounds are present. For superficial lacerations, topical ointments such as Panolog (nystatin, neomycin sulfate), Forte-Topical (procaine penicillin, neomycin, polymyxin oil suspension), Furacin (nitrofurazone) and Topazone aerosal powder (furazolidone) are effective.

In those cases where caseated, pustulated or granular dermal lesions and epidermal cysts are present, the area should be incised, drained and treated with an antibiotic ointment. Bacteriologic culture and sensitivity tests should be performed on the exudate (Marcus, 1971).

For the treatment of a prolapsed cloaca, the technique recommended by O'Connor (1966-1967) was used successfully with a *Crotalus d. terrificus*. The area was cleaned with physiological saline, treated with a decongestant and the organs manually replaced in the following manner: the anal opening was extended, the organs coated with a antibiotic ointment and replaced, and the area covered by a compress. Other suggestions include a sugar compress and the use of ice water.

Anesthesia.—A number of suitable anesthetic agents have been available recently for the safe and rapid immobilization of snakes, including venomous species. Somewhat extreme measures have been proposed for the initial restraint of venomous forms, including pinning, snake tongs and loop poles (Kaplan, 1969). Over 100 species of venomous snakes, including 40 species and subspecies of rattlesnakes, have been immobilized at the Dallas Zoo in the acrylic plastic immobilization tubes described by Murphy (1971) for sex probing (Schaefer, 1934), shedding assistance, injections and other procedures without a single mishap to either snake or attendant.

King (1971) cautioned that fluctuations in temperatures yielded inconsistent results when anesthetics were utilized, and Kaplan (1969) warned that an altered relative humidity could be dangerous. The temperature and humidity during recovery should be within the normal range for the species (Calderwood, 1971).

Some of the anesthetics which have been reported for use with snakes include the following: Betz (1962)—Nembutal (Na-pentobarbital) and Surital (Na-thiamylbarbiturate); Karlstrom and Cook (1955)—Pentothal Sodium (thiopental sodium) and M.S. 222 (tricaine methanesulfonate); Livezey (1957)—Procaine (procaine hydrochloride); Brazenor and Kaye (1953)—ether and chloroform; Hackenbrock and Finster (1963), and Jackson (1970)—Fluothane (halothane); Frye (1973), and Glenn, *et al.* (1972)—Ketalar (ketamine hydrochloride); Wallach and Hoessle (1970), and Hinsch and Gandal (1969)—M-99 (etorphine).

The injection of intraperitoneal anesthetics should be accomplished in the midsection of the pleuroperitoneal cavity on the ventral surface away from the pericardial cavity, and the injection should be administered slowly (Kaplan, 1969; Calderwood, 1971). The use of a 2% solution of Xylocaine (xylocaine hydrochloride) through local infiltration may be warranted when minor surgery is required (Wallach, 1974).

Karlstrom and Cook (1955) tested three anesthetics, Pentothal Sodium (thiopental sodium), Nembutal (pentobarbital sodium), and M.S. 222 (tricaine methanesulfonate), and found that all three were effective for immobilizing snakes. Thiopental was dissolved in Ringer's solution and injected IP with a dosage level of 15-30mg/kg. The induction time was 25-45 minutes, but recovery time could be altered drastically if the normal temperature (20°-22°C) was increased upwards to 38°C. Pentobarbital was also administered to snakes (Betz, 1962; Karlstrom and Cook, 1955) and was found to be a satisfactory anesthesia in doses of 15-30mg/kg. Deep anesthesia was maintained for 15 hours and the recovery period ranged from 18-36 hours. A suitable concentration of anesthesia resulted in the loss of the tail-withdrawal reflex. Laughlin and Wilks (1962) found that *Crotalus atrox* responded to intraperitoneal injections of sodium pentobarbital. The optimum dosage was 0.35-0.45gr/kg. The average time for anesthesia was 31.4 minutes and the average recovery time was 7.8 hours. The criterion for total anesthesia was loss of large-muscle reflexes.

Karlstrom and Cook (1955) tested M.S. 222 and determined that the dosage level of 15-30mg/kg caused suitable anesthesia when injected IP. The induction time was 12-40 minutes, deep anesthesia was maintained up to 60 minutes, and recovery was apparent after 90 minutes. Betz (1962) recorded deep anesthesia in the watersnake, *Natrix rhombifera,* in 40-60 minutes with a Surital (Nathiamylbarbiturate) dosage of 30mg/kg. The loss of the tail-withdrawal reflex was the best indication of surgical anesthesia, but the tongue-withdrawal reflex was not a suitable parameter.

Livezey (1957) found that sublethal doses of procaine (procaine hydrochloride) could be used successfully as an anesthetic, but injections of 0.47mg/kg in the pleuroperitoneal cavity caused death.

M-99 (etorphine) has been recommended as an anesthetic for immobilizing snakes (Wallach and Hoessle, 1970), but IM injections of the colubrid snake genera *Drymarchon* and *Pituophis* produced no significant effects after three hours (Hinsch and Gandal, 1969). Wallach and Hoessle (1970) found that IP injections ranging from 2-15 mg/kg caused a loss of the righting reflex, altered forward locomotion and induced surgical anesthesia.

A number of *Crotalus* species were anesthetized with Ketalar (ketamine hydrochloride) and the LD_{50} was determined to be 70mg/lb with *C. atrox* (Glenn, *et al.*, 1972). For snakes weighing 2 pounds or less, a dosage level of 10-30mg/lb IM is necessary, whereas a dosage level of 40-50mg/lb IM, administered in several locations, is suitable for larger snakes. With a dosage level of 50-mg/lb or less, recovery time ranged from 2-4 days. For dosages above 50mg/lb, it may be necessary to utilize endo-tracheal tubes and oxygen.

Inhalant anesthetics have been mentioned as effective for the successful immobilization of snakes, but since intercostal muscles are used for pulmonary ventilation (Kaplan, 1969; Brazenor and Kaye, 1953), use of ether and chloroform may require artificial respiration. Ether can cause surgical anesthesia, a condition determined by loss of all spinal reflexes in 20-60 minutes with the variation in time due to the ambient temperature.

Chloroform has been used as an anesthetic for snakes, including *Crotalus* (Kaplan, 1969). The drug was administered to snakes in a small wooden box. The induction time varied from 20-45 minutes and surgical anesthesia was determined by the lack of reflex coiling in the tail, the loss of the tongue-withdrawal reflex and the elimination of gross movements. Artificial respiration may be required.

A number of *Crotalus h. horridus* and *C. h. atricaudatus* were anesthetized with Fluothane (halothane) in a wooden box with a lucite top (Hackenbrock and Finster, 1963). The snakes were placed in the box with a piece of gauze saturated with Fluothane, and the dosage level varied with the size of the snake and the container. Induction time usually lasted 5 minutes and surgical anesthesia between 5-20 minutes. The recovery time was rapid, usually within 10 minutes. When an overdose has been administered, recovery can be initiated by tracheal intubation followed by artificial respiration. Venomous snakes seem to require more agent than non-venomous species (Calderwood, 1971).

Generally, the use of one of the injectable anesthetics seems advisable, since the ease of administration with the use of the immobilization tube (Murphy, 1971), and the accuracy in determining a suitable dosage level, are definite advantages.

For further information on the pharmaco-dynamics of various anesthetics, consult Soma (1971).

Nutritional deficiencies.—Generally, if premium mice and other high quality items are used as food, serious nutritional deficiencies should not occur (Wallach, 1969, 1971a, 1971b). Severe avitaminosis and mineral deficiencies can occur when reptiles are improperly fed (Wallach, 1971b). Avitaminosis A has been reported in reptiles and can be counteracted with a few drops of cod liver oil (Wallach, 1969). Rickets can be caused by avitaminosis D and the clinical signs include enlarged articulations, ataxia, anorexia and various skeletal deformities (Wallach, 1971b). Overuse of vitamin D can result in medial calcification of elastic blood vessels (Wallach, 1971b). Avitaminosis E can cause steatitis, and skeletal muscle atrophy and anorexia may be the only clinical sign (Wallach and Hoessle, 1968). Low levels of vitamin C may be the predisposing factor for ulcerative stomatitis (Wallach, 1971a). Dietary supplementation should be initiated for severe avitaminosis (Wallach, 1971b). All endothermic food items used at the Dallas Zoo are carefully inspected and issued certificates of health by a licensed veterinarian.

In cases of anorexia, Bernstein (1972) suggested hypodermoclysis with an amino acid, dextrose, electrolyte solution (Ambex). The subcutaneous site of injection should be the middle one-third of the body along the dorsolateral line. Weekly injections of 2ml/lb are satisfactory and smaller snakes should receive slightly more. Gentle massaging will counteract the effects of local infiltration.

Wallach and Hoessle (1967) discovered visceral gout in *Crotalus lepidus klauberi*, which was recognizable due to gross deposits of uric acid crystals within the tubules of the kidneys, the epicardial surface, liver and perietal peritoneum. Dehydration and a protein diet probably contributed to the condition. Soerensen, *et al.* (1962), Belluomini (1965), Belluomini and Hoge (1962), and Furlanetto, *et al.* (1964) discovered outbreaks of uric visceral gout which were responsible for a number of rattlesnake deaths. Machado (1969) studied the incidence and localization of cardiac involvement by uric gout in *Crotalus durissus terrificus*. This affliction was encountered in 53.3% of the cases. Lesions of the endocardium were especially significant. The conclusion was drawn that cardiac lesions, in conjunction with the fact that the sympathetic cardiac ganglia are not protected by a true capsule, developed by the compressive depositing of urates around the ganglia.

Miscellaneous difficulties.—Frye (1973) suggested an oral administration of D.S.S. Capsules (dioctyl sodium sulfosuccinate) in the case of constipation. Palpation and the use of long forceps is advised in difficult cases.

Murphy, *et al.* (1975) reported colonic torsion in *C. atrox*.

Langlada (1973) has observed agenesis of the pupil, large intestine, cloaca and genital organs in newborn *C. d. terrificus*. Congenital anomalies included the fangs, esophagus, stomach, small intestine, liver, kidneys, ureters and cloaca.

Neoplasms.—Relatively few malignant neoplasms have been recorded from rattlesnakes. Wadsworth (1956) diagnosed cystic hemangioma from the cloaca of *Crotalus viridis helleri*, and a growth attached to the intestine of *C. horridus atricaudatus* proved to be an adenocarcinoma. Wadsworth (1954) found a fibrosarcoma in the neck of *C. atrox*, and Klauber (1956) mentioned a fibrosarcoma in *C. v. viridis* and *C. atrox*. Wadsworth (1956) reported a fibrosarcoma from the retropharyngeal area in *C. v. viridis.* An adenoma was collected from the intestine of *C. h. horridus* (Wadsworth, 1956). Other references to tumors are Glidden (1936) and Dewhurst (1951).

Surgical techniques.—Surgical techniques for extirpation of the venom gland (Tait, 1938; Burke, 1971; Langlada and Belluomini, 1972a), occlusion of venom glands (Glenn, *et al.*, 1973b), occlusion of venom duct by electrocoagulation (Jaros, 1940), removal of the maxillary bone (Murphy and Joy, 1973), bilateral hemipenicectomy (Langlada and Belluomini, 1972b), intestinal derivation, colostomy and cloacorraphy (Langlada and Shinoiya, 1972), and caesarean procedures (Clark, 1937; O'Connor, 1966-1967) have been reported. The justification for the routine practice of surgical removal of various elements of the poison apparatus is highly questionable, unless a definite clinical problem is apparent.

Panophthalmitis with orbital abscessation was encountered in a subadult *Crotalus willardi silus.* An incision was performed beneath the corneal shield and the inspissated pus was removed. An ophthalmic ointment containing chloramphenicol was applied and the condition cleared temporarily. After the condition recurred, cultures were taken from the fluid beneath the brille and *Penicillium* was recovered.

Preoperative and postoperative procedures have been described elsewhere (Frye, 1973, 1974; Wallach, 1969).

Resumen

Desde noviembre de 1966, un número de observaciones se han hecho concernientes al mantenimiento en captividad y enfermedades, infecciones y tratamientos de cascabeles, genera *Crotalus* y *Sistrurus.*

Un análisis de los distintos componentes del ambiente, en conjunción con observaciones dispersas en el campo y el laboratorio, deben asistir a desarrollar un conocimiento de los patrones de comportamiento y mantenimiento en captividad de estas especies.

Recomendaciones preliminares para el mantenimiento en captividad son ofrecidas a travez de una evaluación de evidencia termoregulatoria, relaciones acuáticas y varias técnicas de alimentación en combinación con requisitos de seguridad.

Debido al "Sindrome de Mal Adaptación" los crótalidos se ajustan pobremente a la captividad y están sujetas a numerosas enfermedades. Una reseña de los varios organismos de bacteria, protozoarios, y helmintos que se saben infestan a las cascabeles debe hacerse.

Sugerencias para el tratamiento de lesiones físicas y el uso de anestésicos son ofrecidas, así como también una lista de procedi-

mientos quirurgicos. Recomendaciones para tratamientos de lo arriba mencionado también son proporcionadas.

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Appendix A—Products Mentioned in Text

Aerosporin (Burroughs Wellcome) Polymyxin.

Ambex (Elanco) Amino acid, dextrose, electrolyte solution.

Amphyl (National Laboratories, Lehn & Fink Industrial Products, Div. of Sterling Drug, Inc., Toledo, O.) o-Phenylphenol.

Atgard V (Shell Chemical Co., St. Louis, Mo.) 2.2 dichlorvinyl dimethyl phosphate.

Aureomycin (Lederle) Chlortetracycline hydrochloride.

Bayrena. Sulfamethoxydiazine.

Biosol (Upjohn) Neomycin sulfate.

Caricide (Am. Cyanamid) Diethylcarbamazine.

Chloromycetin (Parke-Davis) Choramphenicol.

Combiotic (Pfizer) Penicillin and dihydrostreptomycin.

D.S.S. Capsules (Hall Drug Co.) Dioctyl sodium sulfosuccinate.

Diazinon 25E (Geigy) 25% Emulsifiable Conc.

Diodoquin (Searle) Diiodohydroxyquin.

Emetine hydrochloride (Lilly).

Entamide (Boots Pure Drug, Ltd., England) Diloxanide.

Entero-Vioform (Ciba) Iodochlorhydroxyquin.

Flagyl (Searle) Metronidazole.

Flucort (Syntex, Palo Alto, Calif.) Flumethasone.

Fluothane (Ayerest Laboratories, Inc., N.Y.) Halothane.

Forte-Topical (Upjohn) Procaine penicillin, neomycin, polymyxin oil suspension.

Fugillin (Abbott Laboratories Ltd., England) Fumagillin.

Furacin (Eaton) Nitrofurazone.

Fungizone for infusion (Squibb) Amphotericin B.

Gentocin (Schering) Gentamycin sulfate.

Hemostatic Powder (Haver-Lockhart) Iron subsulfate, iron sulfate, alum, tannic acid.

Ketalar (Parke-Davis) Ketamine hydrochloride.

Kymar (Armour-Baldwin) Neomycin sulfate, proleolytic enzyme.

Lomotil (Searle) Diphenoxylate hydrochloride.

M-99 (Am. Cyanamid) Etorphine.

M.S.-222 (Finquel, Ayerest Lab.) Tricaine methanesulfonate.

Meticorten (Schering) Prednisone.

Mycostatin (Squibb) Nystatin.

Nembutal (Abbott) Na-pentobarbital.

Panolog (Squibb) Nystatin, neomycin sulfate.

Pentothal (Abbott) Thiopental sodium.

Piperazine citrate (various mfr.) Diethylenediamine.

Resortren Comp. (Farbenfabriken Bayer A G) Chloquinate.

Scoloban (Wm. Cooper and Nephews) Bunamidine HCL.

Sulmet (Am. Cyanamid) Sodium sulfamethazine.

Surital (Parke-Davis) Thiamylal sodium.

Thiabendazole (Thibenzole, Equizole, Merck) 2-(4-thiazolyl)-benzimidazole.

Topazone (Eaton) Furazolidone.

Tylan, Tylocine (Corvel) Tylosin.

Shell No-Pest Strip (Vapona) (Shell Chemical Co., 50 W. 50th St., N.Y.).

Vermiplex (Pitman-Moore, Inc.) Di-phenethane-7 methylbenzene.

Xylocaine (Astra) Lidocaine.

Yomesan (Chemagro Corp.) Niclosamide.

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