ANIMAL DISEASE SURVEY OF NAVASSA ISLAND, WEST INDIES

Richard J. Brown, et al

Naval Aerospace Medical Research Laboratory
Pensacola, Florida

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The wild animals studied on Navassa Island included goats, rats, and several species of birds. Low levels of mercury and DDT were detected in these animals. Radioisotope analysis of animal tissue revealed low levels of plutonium 238 and 239. Light microscopy examination of tissue demonstrated sarcosporidiosis in wild rats, central nervous system degeneration in the goat compatible with a slow virus disease known as scrapie, avian malaria and several pathogenic metazoan parasites in various vital organs.

A contact dermatitis in man caused by the tree, Metopium toxiferum was identified. Sera from goats, rats, birds and bats were negative for rabies and avian influenzia.

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SUMMARY PAGE*

THE PROBLEM

Navassa Island is located 18° 25 minutes north and 75° and zero minutes west and is the closest American possession to the United States Naval Station at Guantanamo Bay, Cuba. The island is uninhabited but has potential use to the United States if any sudden change in the Caribbean political situation should occur. Nearly all overseas American possessions have been surveyed for animal diseases with special cognizance toward zoonotic diseases.

FINDINGS

The wild animals studied on Navassa Island included goats, rats, and several species of birds. Low levels of mercury and DDT were detected in these animals. Radioisotope analysis of animal tissue revealed low levels of plutonium 238 and 239. Light microscopy examination of tissue demonstrated sarcosporidiosis in wild rats, central nervous system degeneration in the goat compatible with a slow virus disease known as scrapie, avian malaria and several pathogenic metazoan parasites in various vital organs.

A contact dermatitis in man caused by the tree, Metopium toxiferum was identified. Sera from goats, rats, birds and bats were negative for rabies and avian influenzia.

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*The animals used in this study were handled in accordance with the "Principles of Laboratory Animal Care" established by the Committee on the Guide for Laboratory Animal Resources, National Academy of Sciences, National Research Council.

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INTRODUCTION

Navassa Island is located at 18° 25 minutes north and 75° and zero minutes west and lies in the windward passage about 32 miles to the west of the western promontory of Haiti. It is the closest American possession to the United States Naval Base at Guantanamo Bay, Cuba.

The United States has had possession of this island since July 1857. It is accessible by water with considerable difficulty because the shoreline is a perimeter of white cliffs up to 75 feet high. The island is deserted and has no human inhabitants. The majority of the creatures living there are goats, cats, rats and birds. Dogs were reported to be on the island running wild but none were observed in our study. Various branches of the United States government have published pilot studies, and in some cases detailed treaties, on animal diseases in American overseas possessions. The main purpose of these surveys is to detect and, if necessary, eliminate diseases of animals transmissible to man and when appropriate reduce and/or eliminate animal diseases of economic importance. As far as the authors were able to determine a study of animal diseases has been accomplished on all American overseas possessions except Navassa Island.

A National Institute of Health National Library of Medicine Medlars review of the literature revealed that there had not been even a pilot survey of animal diseases on Navassa Island.

An American visitor to Navassa in 1969 reported that during his visit foreign nationals slaughtered some of the goats on the island for food. He indicated this was a common occurrence by these foreign nationals. The presence of animal diseases transmissible to man would pose a danger to anyone obtaining food on this island. Absence of residual latent animal diseases transmissible to man on Navassa would absolve the United States of liability should foreign nationals and/or U. S. citizens contract or claim to have contracted such diseases while conducting activities on Navassa.

PROCEDURE

Briefly, the work was accomplished under field conditions and consisted of obtaining both mammalian and avian specimens; physical examination of these animals ; and removal of biological samples from these animals and processing of such samples. This included freezing of sera and fixing of major body organs in fixative for light microscopic examination. The specimens obtained on Navassa were submitted to various laboratories for processing. Tissues for light microscopy were processed in our Pensacola laboratories.

A randomly sampled pilot animal disease study as this requires the capturing, trapping and restraining of animals to obtain medical samples for laboratory analysis. This was accomplished in several ways. Large rats were trapped in live animal traps. These traps were essentially ba ted cages that closed when the animal entered the cage. Ten traps were set in equidistant directions from the lighthouse, which is located at the highest point of the island, approximately two hundred fifty feet above sea level.

Two large wild gray rats were trapped during the five-day stay on Navassa. Both were trapped during the night, reflecting the nocturnal habits of these animals. No one in our group reported seeing rodents during the day.

The standard capture gun was used to obtain larger animal specimens. This device fires darts which injects tranquilizers into the animal. Ketamine was employed as the tranquilizing agent. The single feline specimen was obtained using the tranquilizer gun. One avian specimen was obtained in this manner. The intent with regard to the caprine specimens was to utilize this same tranquilizer dart device. However, the tranquilizer takes up to sixty seconds to render a goat immobile. The Navassa goats, being well-adapted to rapid travel over the rough, jagged, pocked terrain, would quickly disappear in rapid flight into the thick underbrush and would be well out-of-distance when the tranquilizer took effect. Keeping track of these rapidly moving, frightened animals was doubly difficult as it was necessary for us to devote most of our attention to watching our step so as to avoid personal injury. Consequently, the capture gun method was ineffective in obtaining caprine animals. On the third day it was decided to sacrifice ten goats by two teams of two or three men. Each team utilized a .30 caliber M-1 carbine to collect the caprine specimens. The teams prearranged divergent hunting areas to avoid any crossfiring.

A veterinarian or physician was with each team and would perform the necropsy in the field, collecting major body organs and sera which would immediately be relayed back to the lighthouse building for processing. The tissue was fixed in ten per cent neutral buffered formalin and the sera was centrifuged and frozen. Additional samples of tissue were frozen in dry ice for insecticide, pesticide, heavy metal and radioisotope analysis.

Perirenal fat from the mammals and mesenteric fat from the birds was frozen for insecticide and pesticide analysis.

The major avian specimens present on Navassa included the Man-of-War, Fregata magnificens, and Red-Footed Booby, Sula sula. These specimens were obtained by the twelve gauge shotgun method in a large elongated clearing north of the lighthouse. This area appeared to be the beginning of the construction of a short field-landing area.

Two investigators were placed on either side of the clearing with shotguns and a third in the center with 10cc syringes, blood tubes, and slides. The firing of one of the guns would attract the curious Man-of-War birds as they would approach the area, they would be downed while traveling in a direction and velocity such that they would fall in the general area of the investigators. Eight to ten cc of blood would be drawn which was transferred to the blood tubes and allowed to clot. Blood smears were made, placed in a plastic slide box and stored in the refrigerator at base camp. The standard two-slide method of producing blood smears was utilized. The smears were stained with the Giemsa stain upon our return to Florida. Avian blood was centrifuged and frozen in a manner similar to the goat blood. The birds were carried back to the roofless administration building where a pathologist completed the necropsy.

The bird remains were disposed of by dropping them down a 30 x 30 x 275 ~~427~~ foot deep shaft near the lighthouse. While dropping these avian remains in this shaft at dusk, several bats were observed leaving the shaft. Apparently they resided there during the daylight hours immediately under the building constructed over the shaft. This provided us with the manner of collecting bats for rabies studies. Several mist nets were spanned across the shaft opening the next day. These nets are large 2.4 by 12 meter nets with a mesh of 36 millimeters, giving them the appearance of a very large woman's hair net. The mesh is so fine that birds and bats are not able to determine its presence; they fly into and become entangled in these nets.

Rain fell the first night the nets covered the shaft and no bats were caught. The next night three bats became entangled in the nets and they were captured and frozen for submission to the Rabies Laboratory.

Aquatic animal specimens were difficult to obtain by the usual methods. One cravelle jack was obtained with a spear gun.

RESULTS AND DISCUSSION

The results will be presented by generally considering findings of each class of animals surveyed. Within each animal grouping will be sub-headings as appropriate. Discussion of pertinent points will be included with the associated results to provide a more meaningful correlation of pathologic entities and their significance, such as life cycles, etc. Chemical, radiological and serological tabulations will be considered separately.

Twelve random samples of liver, kidney and mesenteric fat from bird, goats, and fish were analyzed for mercury. All contained less than one microgram of mercury per gram of tissue. Radioisotope analysis of harvested tissue from the animals is listed in Table I. Results of insecticide and pesticide analysis of mesenteric fat samples from goats and birds are listed in Table II.

Background Radiation Measurements

Background levels of beta and gamma radiation in combination and gamma radiation alone were measured at selected locations on Navassa Island using a portable battery-operated AN/PDR-27CY Radiac Set. This instrument, serial number 3910, had been calibrated by the Naval Electronic Systems Command, Southeast Division, Radiac Repair Facility on November 16, 1970 and certified to be ± 20 percent or better of its design specifications.

Immediately before the field trip, battery condition was checked and reference sensitivity readings established for the 0.5 and 5.0 milliroentgens per hour scales using a MX-1083 13/PDR-27 radioactive test sample as input. Upon setup of the instrument at the Navassa Island field site adjacent to the lighthouse, the same procedure was repeated to verify proper operating status for the instrument.

With the instrument set to the 0.5 millitoentgen per hour range (maximum sensitivity), and using the built-in meter as visual reference in conjunction with simultaneous head set monitoring, sample background radiation data were collected in a variety of locations immediately surrounding the lighthouse. In all cases, the background radiation, beta plus gamma as well as gamma alone, remained at a normal low-level of approximately 0.02 milliroentgens per hour.

Though the rock formation in the vicinity of the lighthouse was representative of that found elsewhere, the above data were derived solely from surface measurements. For this reason, further measurements were made along the railroad bed cut into the rocks below the lighthouse which was directed toward Lulu Bay. Sample data were collected along the subsurface walls of this cut, as well as from various large piles of rocks that had been excavated from the area. Again the radiac set indicated the previously mentioned low-level background throughout these areas.

A last subsurface test was performed in the large pit found adjacent to the lighthouse. Using a stop watch calibrated in seconds to time the free-fall of a rock dropped into the pit, it was estimated that its bottom was approximately 275 to 300 feet below surface level. To collect background data along one vertical wall of this pit, a 200 foot coaxial cable was tied to the radiac set and used to lower the instrument to the full length of the cable. This coaxial cable also served to electrically extend the instrument headset circuitry so that audible monitoring of background level could be maintained during the descent. The instrument was lowered two times, once with the probe in the radiac set well with its shield in place and once with the probe placed outside the well and taped to the side of the instrument with shield removed. This represented the gamma and beta plus gamma, respectively, measurement capability of the instrument. Again the headset count stayed at a frequency comparable to that obtained for the previously described background. The only disturbance (nonradiation related) encountered was the hurried departure of several bats as the instrument was first lowered into the pit through the central hole of the measurement station.

Avian Diseases

Blood Parasites

A gamma stained smear from one Man-of-War (Fregata magnificens) bird demonstrated an intraerythrocytic protozoan parasite (5). Blood smears from several other birds were within normal limits. Figure 1 illustrates a microgametocyte in the cytoplasm of an erythrocyte.

Microscopic examination of the tissues from this case revealed hepatic malarial pigment. There was also a mild focal chronic myocarditis.

Plasmodium is one genus of the several intraerythrocytic protozoan parasites found in birds. Haemoproteus, a close relative, does not undergo asexual reproduction in circulating erythrocytes as does plasmodium. Consequently plasmodium can regularly be transmitted from an infected animal to a susceptible host by injection of infected blood

or by a bloodsucking insect vector. Kikuth reported the German thrush to be the host for Plasmodium circumflexium, while Levine and Hanson reported it in a Canadian goose (12, 13).

The life cycle of Plasmodium circumflexium reportedly involves all stages occurring in the circulating blood and the various stages tend not to displace the nucleus of the host's erythrocytes (4).

The life cycle of plasmodium in the Man-of-War bird is uncertain. Vectors of avian malaria are generally conceded to involve the Culex and Aedes mosquitoes. It is unnecessary to dwell here on the general life cycle of avian malaria as such information is available in nearly any text of protozoology.

Because of time limitations, the survey of Navassa was restricted to vertebrates. No attempt was made to identify the mosquito population. Mosquitoes were noted to be present near the potable water cistern in the old lighthouse administration building atop the island. Hopefully the Navassa mosquitoes can be identified on the next visit to the island.

A proventricular parasite, identified as belonging to the genus Tetrameres, was found in the Reddish Egret, Dichromanassa rufesceus (Figure 2). Both the female and male forms were seen in microscopic sections. Several cross sections of the gravid female demonstrated many embryonated ova. The males were in the lumen of the proventriculus while the female is buried in the glandular wall. Little inflammatory response is elicited by the female.

The life cycle of this parasite requires grasshoppers, locust, crickets, cockroaches or water fleas as intermediate hosts. After the bird ingests an intermediate host containing an embryonated larvae, the larvae migrate to the proventriculus and develop into adults. This parasite is most likely Tetrameres fissispina which is reported to occur in wild aquatic birds (21).

Trematodes or flukes of the kidney were found in two Man-of-War birds (Fregata magnificens). The flukes were distending the collecting tubules with a subacute inflammatory response surrounding the dilated tubules. The flukes were identified by their single dorsal sucker (Figure 3).

The intermediate hosts of avian kidney flukes are land snails, most commonly Subulina octona (4). No land snails were identified by members of the group. Birds become infected upon ingestion of infected snails containing encysted metacercariae. Avian nephritis caused by trematodes has been reported in Puerto Rico and South America previously (4). These parasites are placed in the Genus Tamerlania.

Nematodes, or round worms, recovered at autopsy from the Fregata magnificens on Navassa included the genus, Contracaecum, probably species granulosm (order Ascaroidea). The life cycle of Contracaecum is not well known. Larval forms occur in water crustacea (21). Contracaecum are found in other water fowl such as duck, geese, etc. This parasite elicited a mild hemorrhagic enteritis in this Man-of-War bird.

A 2 cm bladder worm was found at necropsy of a Fregata magnificens between the right and left lobes of the liver (Figure 4). Since the diet of these birds is tropical salt water fish, it is probably an intermediate stage of a tetraphyllidean or pseudophyldidean, fish tape worm. The life cycle of these cestode species has not been worked out, but is believed to also include a copepod.

A cestode of the genus Hymenolepis, probably Hymenolepis compressa, was recovered from the duodenum of another Fregata magnificens. The developmental cycle of this genus is unknown but heavy infections can lead to a general debility.

A Reddish egret demonstrated an early mild case of simple or colloidal goiter. Several acini are moderately distended and filled with colloid and the acinal epithelium is thinned. No interacinal connective tissue increase was noted. Goiter is generally associated with a deficiency in iodine although other factors such as calcium and sodium chloride imbalance, amino acid and co-enzyme deficiencies, impaired iodine uptake and utilization are also believed to cause goiter (10). Generally sea water is believed to contain adequate amounts of iodine and since the Navassa avian biota consume almost entirely fish, an iodine deficiency in the animals would be surprising. However, Baker and Lindesy reported goiter in animals due to excess dietary iodide (3). As is mentioned elsewhere in this report, a wild feline captured on Navassa also had a simple or colloidal goiter.

The Navassa ground dove, Columbigallina passerina, contained numerous amorphous birefringent crystals in the liver sinusoids. They were identified as calcium carbonate crystals but their source and significance has not been determined.

One Fregata magnificens had a fibrous thickening of the valves of the heart, known as endocardiosis. The cusps were shortened and thickened and the surfaces of the valves were smooth and glistening. Microscopically, there was no evidence of an inflammatory basis for this condition. Lesions such as this are probably due to excessive cardiac work load. This bird also had a diffuse, mild, suppurative hepatitis. Special stains revealed no specific etiology.

A contact dermatitis was developed by seven of the eleven members of the team during the week long stay on Navassa. The inciting agent was the milky, acrid, resinous sap from the Florida Poison tree, Metopium toxiferum (Figures 5 and 6). This tree had a smooth dull gray bark with spherical smooth green poisonous fruits about one-half inch in diameter. Team members came in contact with this tree sap while enlarging the landing area for the helicopter. Twenty-four hours after exposure the contacted area of the skin developed erythematous confluent vesicles approximately 2-3 mm in diameter. Several had broken down with release of clear serous fluid. These lesions were primarily on the flexor aspect of forearm and the wrist (Figure 7). They were markedly pruritic and moderately painful. There was no regional lymphadenopathy or systemic symptoms. Smoke from burning Metopium toxiferum is also reported as irritating to the skin, eyes, and lungs (2). In an excellent Botanical summary of Navassa in 1959, Procter mentioned Metopium toxiferum as one of the trees he identified (17). One

Navassa lighthouse keeper was incapacitated by a tree contact dermatitis in 1928 and had to be relieved from duty. Presumably, the above mentioned species was responsible (8).

The existence of bats on Navassa Island was first reported in 1928 (8). These mammals reportedly inhabitaied several small caves near the center of the island. The bats were identified as Artibeus jamaicensis,a fruit eating species of the West Indies (Figure 8). Sera from these bats were negative for rabies and type A influenza.

The goats examined utilizing light microscopy on Navassa are interesting from a standpoint of what was found as well as what was not found. These animals were absolutely free of the ubiquitous pulmonary anthrocosilicosis seen universily in man and animals in areas of even sparse population. This is an inhaled pigment, undoubtedly from combustion products of automobiles, factories, etc. The absence of this pigment is indicative of the lack of air pollution in this area of the world (19).

The livers of all of the goats examined contained small foci of extramedullary hematopoiesis. In the adult animal, this usually represents impaired ability of the bone marrow to produce blood or the presence of a condition causing excessive destruction or loss of blood cells. Exposure to ionizing radiation and some diets will cause this condition. The most likely cause of this condition in wild goats would be chronic anemia due to intestinal parasitism. However, the fecal egg count from these animals was low. Tissues from these animals revealed no evidence of infectious hemolytic diseases. Plants causing hemolytic anemia and thus extramedullary hematopoiesis include onions, Heliotropium, Senecio and subterraneum clover but none of these plants were identified on Navassa. Perhaps one of the usual Navassa dietary plants of these animals causes a bone marrow depression.

The dermal toxicity of the abundant Metopium toxiferum is discussed elsewhere in this report. When fruits are consumed from trees that cause contact dermatitis, they frequently will cause ulceration of the intestinal tract (15). Leaves from this tree were found in the stomach of the Navassa goats and it can be presumed that the fruits are also occasionally consumed. Therefore, it is possible that the extramedullary hepatic hematopoiesis in the Navassa goats is due to chronic blood loss resulting from intestinal ulceration due to ingestion of foliage and fruits of the Metopium toxiferum.

Caprine central nervous system changes included focal thickening of the meningies by cap cells. These cells are normal inhabitants of the meningies and occasionally undergo hyperplasia, causing meningeal thickening (Figure 9). In man this is considered a normal aging change (9). This condition has been reported only once previously in animals (6).

Other changes in the caprine central nervous system are spongiosis of gray matter vacuolization of neurons and loss of Purkinje cells in the cerebellum (Figures 10, 11, and 12). These changes are reminiscent of a slow virus disease of goats and sheep known as scrapie. Similar neuropathologic changes are seen in man in New Guinea in a disease called Kuru.

Scrapie is a non-febrile chronic disease of sheep and goats characterized clinically by pruritis and abnormalities of gait (16). It has a very long incubation period and is caused by a virus-like agent capable of withstanding the usual virucidal procedures. The incubation period may be as long as three years while the average period is 18 to 20 months. The clinical signs are an intense pruritis, muscle tremors and marked abnormalities of walking as well as severe emaciation. Persistent rubbing causes loss of hair and wool over the areas along the back, hence the name scrapie. The animal may shake its ears severely causing a hematoma. Great interest has been shown in the disease scrapie in the past few years because the histopathological lesions of scrapie are identical with the presumed temperate virus infection called Kuru in man in the New Guinea highlands. This disease is fatal in man. In scrapie as in Kuru it is suspected to be a viral meningocephalitis. However, very little in the laboratory findings or its epidemiology has been discovered to support a suspicion that it is an encephalitis. In both diseases there is nothing in the neuropathology picture to suggest an acute infection. In Kuru, the epidemiological pattern suggests some genetic expression of the disease. In scrapie in animals, however, the population restriction and geographical isolation of the animals involved usually is not available. In the case of Navassa Island, however, this would not be true.

Generally neither disease shows a febrile response. There is insufficient perivascular cuffing of the spaces of Virchow-Robin or other neuropathologic reactions to suggest an acute infectious etiology. Kuru has been associated with extensive cannibalism but this has been dismissed as unlikely (11). Cannibalism among goats or sheep also is essentially unheard of. While the exact etiology of Kuru still is in dispute, Hadlow in 1959 pointed out that in animals the susceptibility to the scrapie virus is generally accepted as being genetically determined. Inbreeding of animals on a restricted island could well accentuate the genetic susceptibility to scrapie. Scrapie in sheep and goats is probably best considered a chronic degenerative disease of the central nervous system and caused by viral agents with prolonged incubation periods.

Figure 13 demonstrates a caprine neuron containing a rectangular, deeply basophilic, cytoplasmic structure. The nucleus of this neuron is not visible and neuronal nuclei in this or any other caprine from Navassa does not resemble this structure. Autopsies of ten Navassa goats revealed considerable amounts of ingested periwinkles, Catharanthus roseus. This plant, harvested from Madagascar, is the source of the chemotherapeutic agent Vincristine used as an antileukemic drug. Schochet reported similar structures in neurons of rabbits administered intrathecal Vincristine (18). The possibility that ingested periwinkles can produce changes similar to Vincristine is an interesting one and needs further study.

Several goat lungs revealed small inflammatory cell nodules comprised of lymphocytes, plasma cells and eosinophiles (Figure 14). Special stains for bacteria and fungi were negative. This subacute granuloma is probably due to the lung parasites, Dictyocaulus filaria. This parasite occurs in the bronchi of sheep, goats and other wild ruminants. Dictyocaulus filaria has a world-wide distribution and in large numbers causes serious losses. The eggs may hatch in the lungs but are usually coughed up and swallowed and hatched while they pass through the alimentary tract of the host. The

first stage larvae are passed in feces. The three stages do not feed but exist on food granules in the intestinal mucosa. The larvae require moisture for their development and become infective in six to seven days. They can withstand moderately dry conditions for a few days. The animals are re-infected orally. The larvae penetrate into the intestinal wall within three days and pass via the lymph vessels to the mesenteric lymph gland where they develop and perform their third ecdysis about four days after infection. In the fourth stage larvae the males and females can be distinguished. The worms now pass via the lymph and blood vessels to the lung where they are arrested in the capillaries and break through into the air passages. Development to maturity in the host lungs takes about six weeks. The worms live in the small respiratory passages where they suck blood and irritate the mucosa. This produces a catarrhal bronchitis. The inflammatory process spreads to the surrounding peribronchiolar tissues and the exudate frequently passes back into the bronchioles and alveoli causing atelectasis. Pneumonia can be set up if bacteria are present in large numbers. The most effective prophylaxis against this condition is keeping the animals off infected grounds.

Two large aggressive rats, Rattus sp. were obtained on Navassa Island. Cysts of the parasite Sarcosporidia were found in the masseter muscle of one of them. Sarcosporidiosis is familiar to veterinary pathologists as an infection of striated muscle by the organism of the genus Sarcocystis. It is much less familiar to the human pathologists as there have been only 13 well documented reports of this condition in man where it is usually an incidental finding at autopsy (7). These organisms in man are known as Sarcocystis lindemanni.

The sarcosporidia life cycle is not completely known. It is commonly found at post mortem inspection of animals slaughtered for food, mostly cattle and sheep. Since it is not known whether or not its life cycle involves man, all infected meat animals are condemned for human consumption. This represents a loss of several million dollars annually. What is known about the life cycle was first demonstrated by Theobold Smith in 1901 using the mouse. Smith demonstrated that mice could be infected with Sarcocystis muris by feeding the feces of other mice infected with S. muris (7). The exact methods of transmission to man remains obscure but based on the original work by Smith, it is probably that man is infected by oral ingestion with fecal material containing Sarcosporidia muscle cysts. Complete passage of the parasite through the intestine may be a necessary part of the developmental cycle (21). There appears to be no intermediate host or insect vector. The infective stage or trophozoite probably passes through the intestinal wall, into the blood stream and lodges in various striated muscles.

The skeletal muscle of the head of one of the rats contained numerous Sarcosporidial cysts (Figures 15, 16, and 17). The sarcolemma of the infected muscle is displaced and, as in trichinosis, there is no inflammatory response.

A close relationship between Sarcocystis and Toxoplasma has been demonstrated in that both react with cytoplasm modifying antibody in the Sabin-Feldman dye test. Cross reactions between the two organisms are common. This serologic relationship of Sarcosporidia to Toxoplasma and the current publicity regarding fetal toxoplasmosis in

man is also worth consideration (14). The coccidia of the cat has been recently shown to be toxoplasma. Future studies may also show that sarcosporidiosis is still another variant of Toxoplasma gondi.

The importance of this zoonotic organism on Navassa is the possibility of infection of any food producing animals that might be raised or are already present on Navassa. The lighthouse keepers in years past frequently consumed goat meat for its protein content. While no sarcosporidial cysts were identified in our caprine tissue, Navassa goat consumption should be discouraged in the future.

The occurrence of a disease, whose life cycle is not completely clear, on a small island provides an excellent opportunity for someone to do further work on the life cycle. Extensive microscopic examination of the muscles of additional goats and birds should also be carried out.

A nematode of the genus Gongylonema was found in one rat from Navassa. Nematodes of this genus have been reported in many animals including nonhuman primates (1) and man (20). This is another one of the parasites that is associated with malignant tumors in rats. The adult worms live in the epithelium or submucosa of the esophagus. Within the epithelium they are found lying in a zigzag fashion (Figure 18). Their life cycle is indirect, the intermediate host being dung beetles and cockroaches which ingest eggs from the feces of the definitive hosts.

Additional sections of the terminal esophagus and upper stomach of one rat revealed eggs with scolices typical of tapeworm eggs. The tapeworm, Tenia teniaeformis, (Batsch, 1786) which as an adult tapeworm occurs in the small intestine in the cat and other related carnivores has been identified from Navassa animals. The bladder worm is known as Cysticercus fasciolaris, also known as Strobilocerus fasciolaris (Figure 19). The stage that occurs in the liver is the strobilocercus. The cysticercus is fairly common among rodents, especially rats and mice and in the liver is found as a large ivory white cyst. The larvae are peculiar as they are comprised of an extruded scolex followed by a strobila which is already segmented and terminates in a relatively small bladder so that the whole larva looks like a small adult tapeworm. When the eggs are shed in segments in the cat's feces, they are ingested by the rat. In the rat's stomach the oncospheres are released from the eggs and reach the liver of the rodent as an intermediate host and grows rapidly to become the cysticerci and they are infective 30 days later. Initially these larvae appear to be relatively harmless to the rat, even when they occur in large numbers, but they induce a malignant sarcoma in the liver some two to fifteen months after infection. This parasite has been widely studied because of its ability to produce fatal cancer. It appears that certain strains of rats are much more susceptible to the development of these tumors than are others. Furthermore, immunity in rats against this parasite may be induced by more than one method such as injections of extracts of either the larva or the adult worm. Immunity developed in this way persists for considerable periods of time and may be passively transferred. Where cats and rats live together this disease usually is seen. Descendants of cats left by the lighthouse

keeper on Navassa Island in 1929 still live in the wild and presumably are the primary host for this tapeworm while the rats are the intermediate host containing the strobilocercus.

Multiple granulomas were found in the mesenteric and internal iliac lymph nodes, spleen, liver, urinary bladder wall, maxilla, mandible and in multiple skin foci of a rat. The center of these granulomata contain large pools of polymorphonuclear leukocytes harboring numerous sulphur granules (Figures 20 and 21). Special stain for tuberculosis and mycotic organisms were unrewarding. However gram stains revealed gram positive cocci within these sulphur granules typical of staphlococcus. This condition represents a delicate balance between the staphlococcus and its host, where neither can overcome the other. It is known as botryomycosis. By careful dissection and meticulous gross examination a nematode parasite was found in association with one of these botryomycotic lesions. This parasite was identified by a parasitologist as a member of the order Spirurida, family Thelaziidae and either the genus Rictularia or Pterygiodermatides. It is probable that the extra-enteric somatic migration of this nematode was the cause of these granulomatous murine lesions. Species of the genus Rictularia that have been reported to infest rats include cristata, magna, oligopectinea, and whartoni.

The nematode, Mastophorus muris, was recovered from the intestinal tract of one of the Navassa rats. The rat and the cat are the definitive host for this parasite with the flea as the intermediate host.

Only one Felis domesticus was identified and examined on Navassa Island. Simple or colloidal goiter was diagnosed in this animal. The thyroid acini were markedly enlarged, distended and filled with colloid (Figure 22). The usual cause of this condition is iodine deficiency; the aspects of this condition on an island are considered earlier and the same comments are applicable here.

Feline multiple granulomatous nephritis is probably due to extra enteric parasitic migration (Figure 23). Special stains on these lesions for bacteria, mycotic organisms and tuberculosis were unrewarding. A mild granulomatous glossities in the feline was considered as caused by foreign body penetration (Figure 24). Special stains on this organ were also unrewarding.

DISCUSSION

Discussion of the pertinent points of each disease entity was included under results to achieve a meaningful correlation of pathologic entities and their significance. Only additional general comments will be made here.

The isolation of the island from the outside world suggests that the conditions reported have been here for many years. The authorized visitors number only a dozen or so a year and these are usually active duty military and/or scientific groups, probably with above average health status.

Most of the Navassa birds are classed as non-migratory although avian travel throughout the Caribbean is probably common. It is not impossible that a passing hurricane could deposit small rodents and micro-organisms here.

The rain nights precluded bats from leaving their daytime roosting places and this diminished the total number of harvested bats. The negative report of bat rabies should not be taken to mean that the disease does not exist on this island in the bat population.

Metazoan parasites comprised several of the disease conditions, a common finding in tropical areas.

The DDT content of the animal tissue was higher than would be expected. The Coast Guard has maintained jurisdiction over Navassa since 1916 and so far as can be determined, the island has never been sprayed with this insecticide.

RECOMMENDATIONS

The purpose of a pilot study such as this is to uncover further areas of study. Sarcosporidiosis was not seen in the caprine population, however this zoonotic parasite occurs most often in the masseter, diaphram and intercostal muscles. Subsequent visits to the island should concentrate on this entity.

Feeding of harvested Navassa Sarcosporidia to experimental animals, thus repeating some of the research performed before could determine if these protozoan are of a different virulence than usually expected. Plasmodium circumflexum is commonly found in more northerly latitudes. Since it is not known what genus of mosquito is involved in the life cycle of this malarial disease in the tropics, collection and identification of mosquitos would be worthwhile during the next visit.

The possibility that periwinkle ingestion in goats may cause central nervous system changes should be explored further. The neuronal changes described in this paper are reported in the ganglia of other experimental animals and future caprine autopsies on Navassa should include ganglia examination.

Another possibility involves replanting of the Navassa periwinkles at some study area in the southern United States and feeding these to various animals in search of the vincristine changes reported (18).

Finally any return to Navassa should collect as many large rodents and bats as possible. Bats are excellent sentinals for rabies and the Navassa rats are apparently afflicted with an unusually large number of pathologic entities.

The ruggedness of the terrain and the year-round heat make collection of samples and specimens from the animals a difficult and time-consuming task. These field environmental factors greatly extend the time required to perform laboratory procedures on Navassa. Further disease surveys on Navassa should be extended to approximately ten days.

Table I

Disintegrations per minute per sample of Plutonium 238 and 239 from animal tissues from Navassa Island

ANIMAL	TISSUE	WEIGHT	Disintegrations per minute per sample	
			Plutonium 238 (d/w sample)	Plutonium 239
Jack Fish	Liver	29	0.012	0.008
Goat No. 6	Liver	30	0.036	0.060
Goat No. 101	Kidney	20	0.000	0.159
Goat 10-NBI	Kidney	18	0.018	0.072
Goat No. 1	Kidney	29	0.004	0.000
Avian (Frigate) 14	Kidney	24	0.012	0.000
Goat No. 5	Lung	26	0.000	0.013
Avian (Frigate) 13	Liver	83	0.009	0.017
Cat 11	Liver	9	0.000	0.000
Cat	Kidney	33	0.000	0.000
Cat	Lung	5	0.181	0.084
Avian (Ganet) 12	Liver	4	0.000	0.066
Avian (Ganet) 12	Unknown	18	0.000	0.013
MOF 14	Kidney	2	0.002	0.002
Goat HB-8	Liver	68	0.008	0.004
Avian (Frigate)	Liver	21	0.017	0.011
Avian (Frigate)	Liver	20	0.035	0.048
Avian (Frigate)	Liver	121	0.049	0.691
Goat	Liver	70	0.011	0.044
Goat	Kidney	212	0.024	0.018
Goat	Liver	439	0.107	0.018
Goat	Lung	170	0.062	0.031

Based on the background variation within the method and the recovery, the above values are less than 0.08 disintegrations/minute/sample at the 95% confidence level.

Table II

Insecticide and Pesticide Analysis of Mesentary Fat Samples From Goats and Birds From Navassa Island

SAMPLE IDENTIFICATION		TISSUE OR FLUID	AMOUNT TAKEN FOR ANALYSIS	RESULTS OF GAS-LIQUID CHROMATOGRAPHY						
TYPE OF ANIMAL	NO.		(MG)	o,p'-DDE (PPM)	p,p'-DDE (PPM)	o,p'-DDD (PPM)	o,p'-DDT (PPM)	p,p'-DDT (PPM)	Dilan (PPM)	Other (PPM)
Goat	1	Fat	216.5			0.122	0.88		0.27	
Ganet	2	Fat	238.8		4.85		7.61	0.77		Lindane 0.023
Frigate Bird	3	Fat	221.0		8.9		3.23	2.56		
Goat	4	Fat	227.3				1.90			
Goat	5	Fat	208.5				0.377			
Goat	6	Fat	253.2		0.044		3.0	0.058		
Goat	7	Fat	244.5			0.522	1.86			
Goat	8	Fat	213.0	0.103			0.92			
Goat	9	Fat	226.0			0.156	0.71		2.45	
Goat	10	Fat	255.0		0.067		1.17		Dieldrin 0.297	Hep.Epox. 0.117
Goat	11	Fat	277.0	0.28			0.58	0.52	3.5	Dieldrin 0.067
Fish	12	Fat	210.7				0.34			
Goat	13	Fat	229.5			0.72	3.27			

Figure 1

Microgametocyte of the species Plasmodium (arrow) in the blood smear from a Navassa Island Fregata magnificens rothschildi (Geimsa X 1000).

Figure 2

Proventricular parasite, Tetrameres from the Egret, Navassa Island, West Indies, H & E X 100.

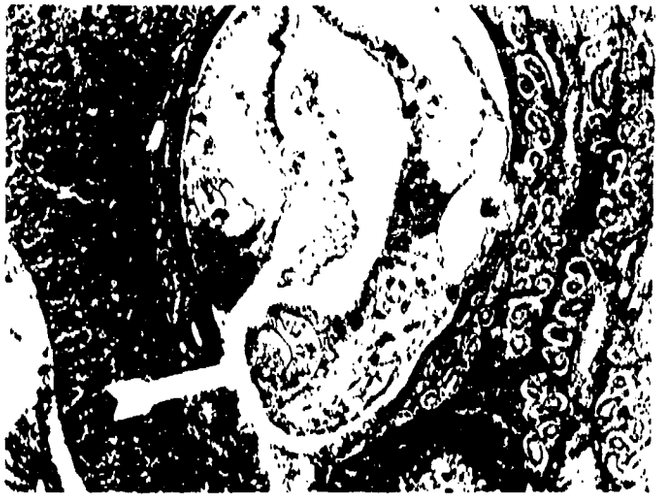

Figure 3

Renal trematodiasis, Fregata magnificens rothschildi from Navassa Island, West Indies. A sucker (arrow) is clearly identified. H & E X 100.

Figure 4

Cestode bladder worm found between the right and left lobes of the liver, Fregata magnificens rothschildi. H & E X 40.

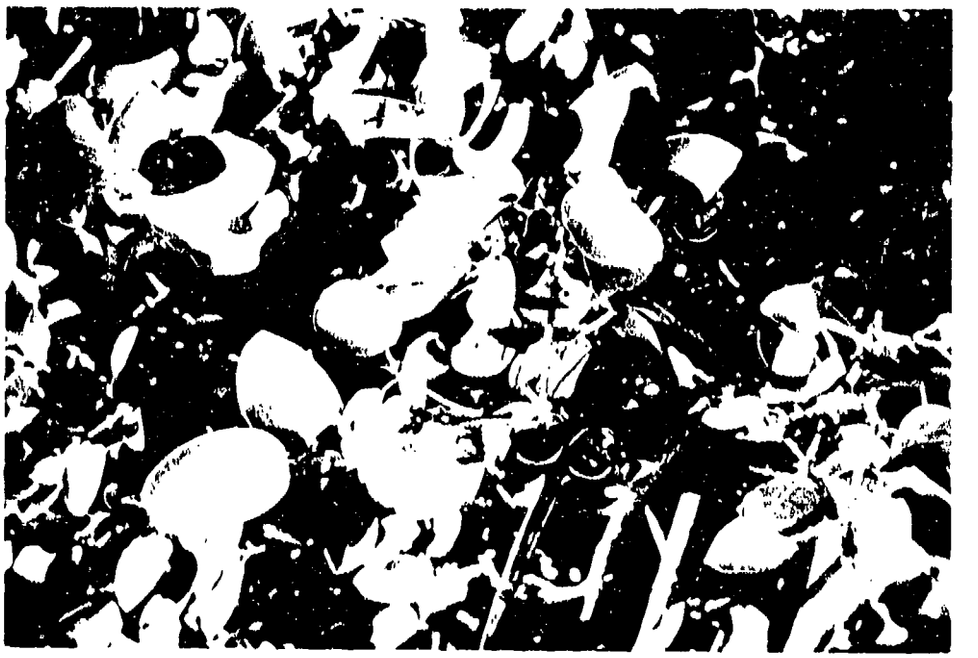

Figure 5

Foliage from Metopium toxiferum on Navassa Island, West Indies

Figure 6

Close-up view of the foliage of Metopium toxiferum.

Figure 7
Contact dermatitis caused by the sap of Metopium toxiferum, Navassa Island

Figure 8
Artibeus jamaicensis, a fruit eating bat of Navassa Island, West Indies.

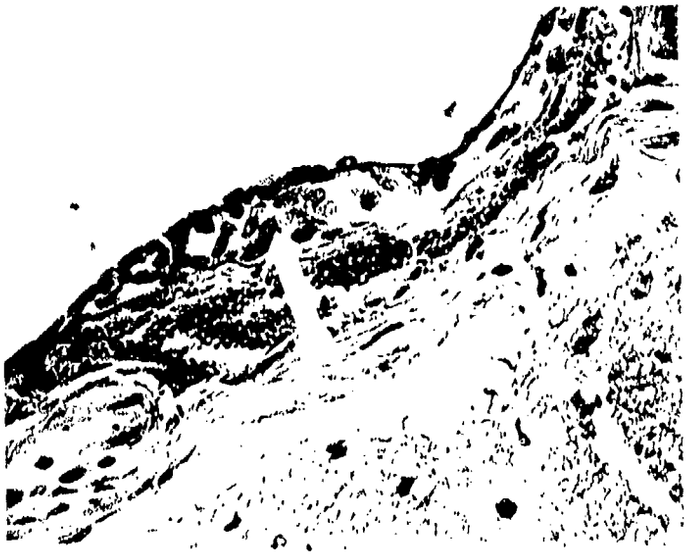

Figure 9

Cap cell hyperplasia (arrow), thickening, meningies, goat.
H & E X 450.

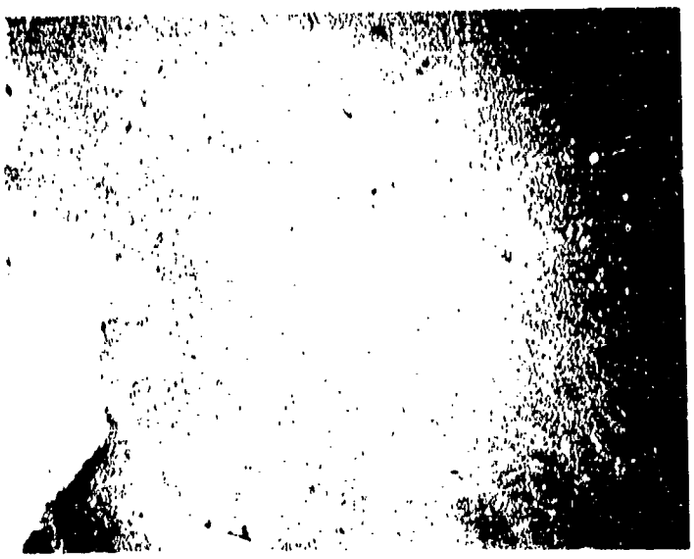

Figure 10

Spongiosis of gray matter, brain, goat.
H & E X 40

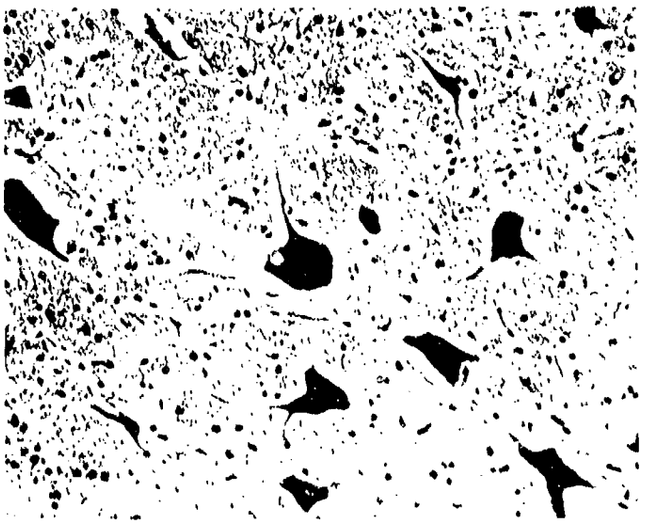

Figure 11

Vacuolated neuron (arrow), brain, goat.
H & E X 200.

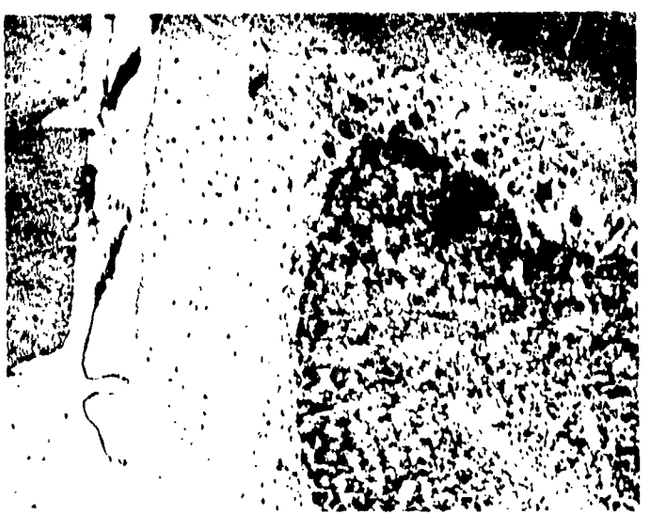

Figure 12

A marked loss of Purkinge cells in the cerebellum, goat.
H & E X 200.

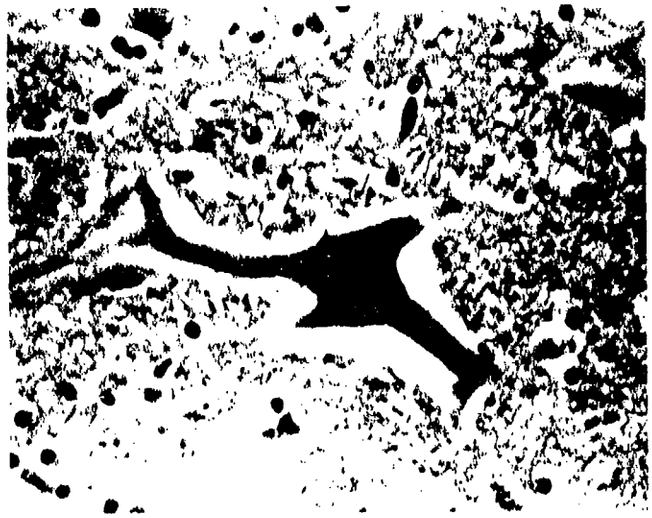

Figure 13

Rectangular neuronal cytoplasmic inclusion, goat.
H & E X 325.

Figure 14

Pulmonary granuloma, lung, goat.
H & E X 200.

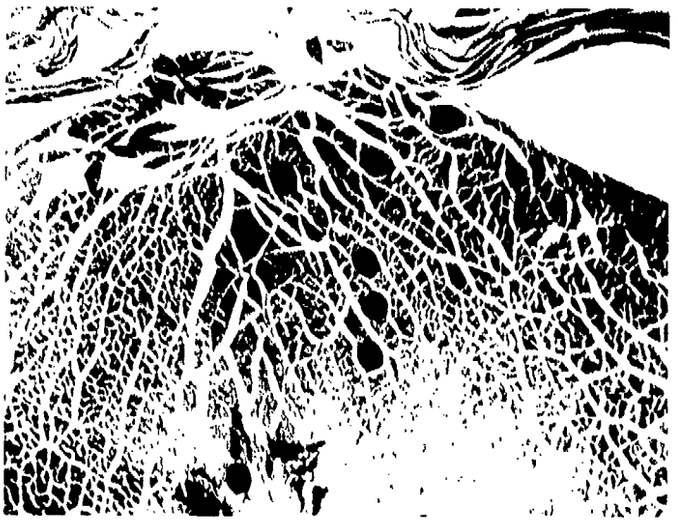

Figure 15

Several sarcosporidial cysts, masseter muscle, rat.
H & E X 100.

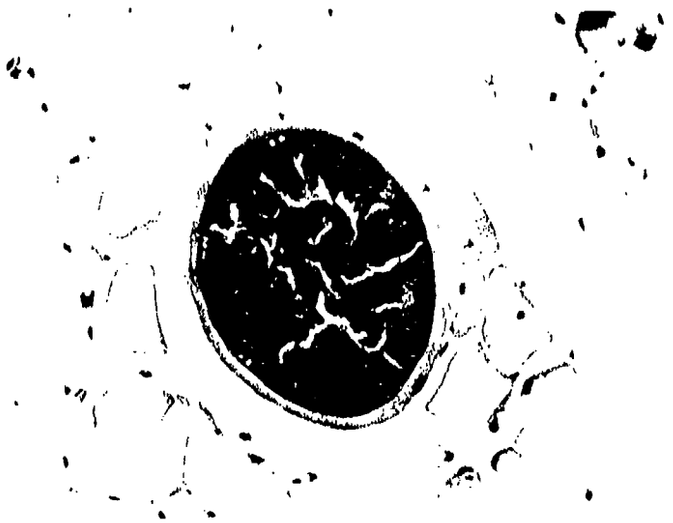

Figure 16

High magnification, sarsocporidial cyst, masseter muscle, rat. Note the absence of inflammatory response and the numerous banana shaped organisms (Rainey's corpuscles) packed within the hyaline wall.
H & E X 450.

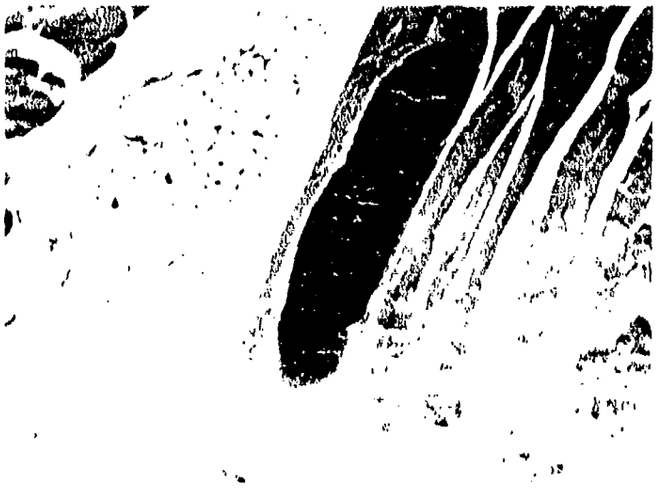

Figure 17

Sarcosporidial cyst in longitudinal section, masseter muscle, rat.
H & E X 450.

Figure 18

Adult Gongylonema (arrow), epithelium, rat.
H & E X 450.

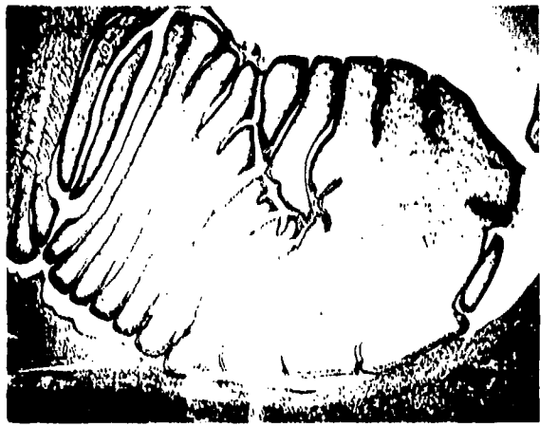

Figure 19

Cysticercus fasciolaris, liver, rat.
H & E X 40.

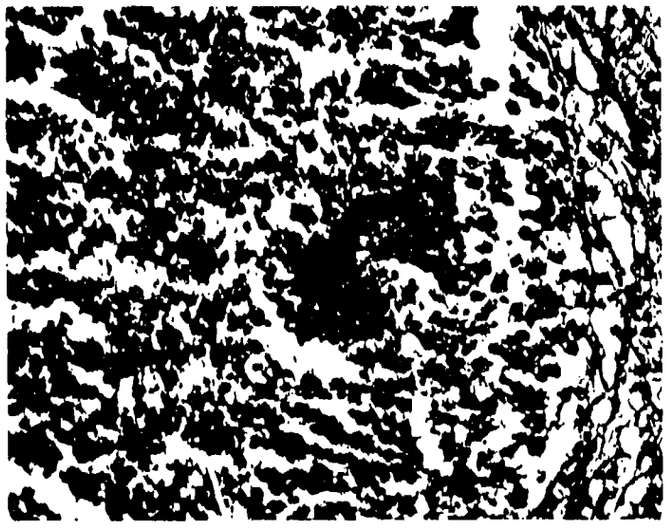

Figure 20

Sulphur granule, in a pool of polymorphonuclear leukocytes,
botryomycosis, rat.
H & E X 1000.

Figure 21

Sulphur granule (arrow) comprised of gram positive bacteria, purulent exudate, mandible, rat.
H & E X 450.

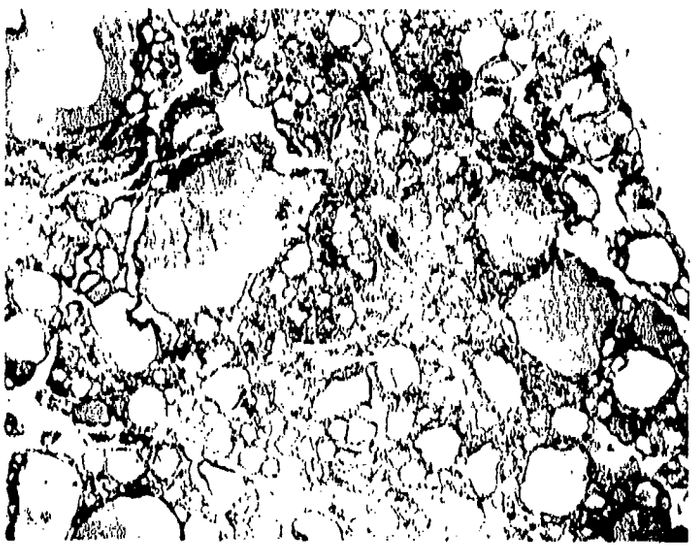

Figure 22

Simple or colloidal goiter, feline. Note the large dilated follicles.
H & E X 40.

Figure 23

Granulomatous nephritis, kidney, feline.
H & E X 100.

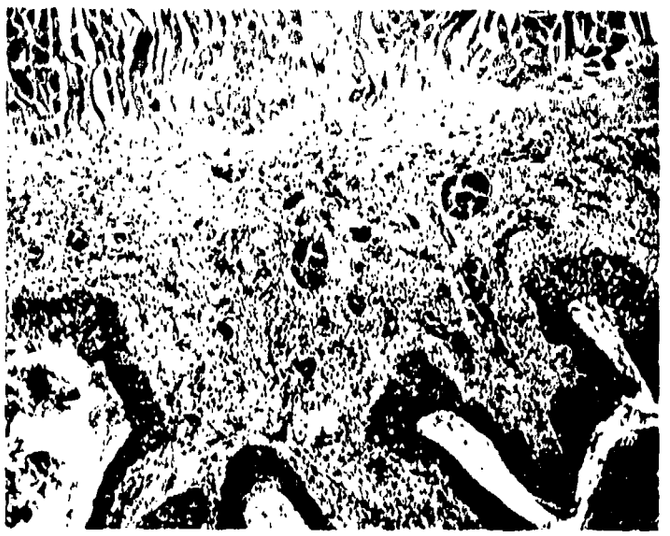

Figure 24

Granulomatous glossitis, tongue, feline.
H & E X 100.

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