Nat. Sci.

This thesis was not accepted in fulfilling requirements for the master's degree. Possibly it should not be filed--or at least it might be well to indicate that the degree was not granted.

MGT

AN INTRODUCTION TO SCATOLOGY

by

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I. INTRODUCTION

The purpose of this paper is to present a general introduction to the science of scatology; to describe the morphological and physiological bases of the formation of animal feces; to present the qualitative characteristics of the feces and pellets of some of our common mammals and birds; and to indicate the uses to which this knowledge may be put in the field of wildlife management and forest zoology.

Scatology is the study of animal excrement. Feces and pellets comprise the indigestible matter that is voided in the process of excretion. The study of the composition, form, amount, frequency, color and odor, together with an analysis of the physiological processes involved in the formation of animal excreta constitute the study of scatology. Originally concerned with the analysis of feces for evidences of internal parasites in human and animal pathology, the study of feces has lately been undertaken to ascertain food-habits; to determine animal populations and to aid in the study of the physiological conditions of animals.

The work done for this paper included both laboratory and field studies. Pellets and feces collected in past years and kept at the School of Forestry and Conservation were utilized, as were specimens collected in the field during the school year (1938-1939). Some part of the work on the droppings of the animals not found locally was done from specimens procured from zoological parks. Field work was limited to sections 13, 14, 23 and 24, Pittsfield Township, Washtenaw County, Michigan, and the general vicinity of Ann Arbor.

The writer wishes to take this opportunity to thank Prof. H. M. Wight, Prof. S. A. Graham, and Prof. E. C. O'Roke, all of the faculty of the School of Forestry and Conservation, under whose direction the study was undertaken. Grateful acknowledgment is also made to Willet Wandell, J. R. Smith and Richard Gerstell, graduate students at the School of Forestry and Conservation, for their cooperation in making animals available for study; Dr. S. Shipman, Ann Arbor Meat Inspector, for the digestive tract of the domestic hog; Harry Hershkowitz, graduate student at the University of Michigan, for the invaluable aid in the photography Miss Sylvia May Gittlen, former University student, for her help, suggestions and criticisms of the drawings; the Directors of the National Zoological Park, the Detroit Zoological Park, and the New York Zoological Park for their cooperation in providing fecal samples; and to the entire class in Wildlife Administration and Field Technic for a large part of the field collection of droppings.

II. THE IMPORTANCE OF SCATOLOGY

1. Animal Identification.

Animal signs are most commonly observed in the field by means of tracks, hair, feathers, and feces. Tracks are largely dependable on the time of year and weather conditions while hair and feathers are too rarely encountered to offer a ready means of identification. Feces, on the other hand, are not dependent upon the time of year nor the climate, and can be used, therefore, to a greater degree than can tracks, hair, and feathers in the specific identification of animals. Mammals and birds have been long identified by means of their droppings, but other classes of animals can also be specifically identified in this manner. Moore (1931) and MacDonald (1931) have been able to identify the fecal pellets of mollusks and crustacea withdrawn from marine deposits by the shape and sculpturing of these pellets, and Koch (1928) in his keys for the determination of insects found in spruce and fir trees based on the injury they cause in feeding has employed the character of the excretory discharge in many instances to identify an insect.

Seton (1929) was the first writer to describe some of the pellets of animals. He believed (1925) that although fecus were of little or no value as family or generic characteristics, they were very valuable as a specific feature of identification. Murie (1936) when studying the droppings of foxes in the George Reserve in Michigan reported that the droppings of different animals overlapped broadly, and that he could not distinguish with certainty the droppings of the badger, opossum, coyote, and skunk from that of the fox. He pointed out that in some areas where several species having similar droppings were present in some numbers food habit studies would not be feasible because of the impossibility of definitely identifying the droppings.

It is highly desireable in predator-control studies and food-habits investigations to be able to positively identify the droppings of an animal. Although the pellets of the herbaceous mammals are fairly constant in both shape and size, and may be identified with a high degree of certainity under normal conditions, the feces of carnivorous animals exhibit a wider range of variability and are much more difficult to identify specifically.

2. Food Habits.

The most important use of scatology has been made in the study of food-habits. Previously most work in food investigations have been concerned with stomach contents analysis and feeding observations. Today the trend is toward fecal and pellet examinations in conjunction with the former methods. Cottam (1935) writes that fecal studies have the advantage of sparing the lives of the animals concerned, and of affording and intensive study for a limited area or for a limited number of birds, and further, makes it possible to follow trends in feeding habits through any season of the year.

Although fecal food-habits studies are a comparatively recent development in field technics, its history has not been a short one.

Montgomery (1899) working with short and long-eared owls lists the small mammals; Microtus pennsylvanicus, Microtus pinetorium, Zapus hudsonius, Peromyseus leucopus, Mus musculus, Blarina parva, Blarina brevicauda and Scalops (?) which were found in the pellets of these owls.

Davis (1909) writing of the pellets of the barred owl reported bones of frogs, feathers of a small bird and several water beetles together with grasshoppers.

Townsend (1913) listed the foods found in fox feces taken from sand dunes in Massachusetts.

Bird (1929) in a study of 112 pellets of the adults and nesting great horned owl determined the food habits of that raptor in Manatoba.

Brooks (1929) referring to Bird's study stated that the pellet method was unsatisfactory because only when fur or other absolutely indigestible matter is swallowed is any pellet thrown up, while clean flesh resulted in no pellets. He stated, therefore, that only where bird remains are involved in mammal fur in the captor's stomach is there any evidence of birds being eaten by pelletal examination.

This objection to the pellet method of study is entirely justified and it is primarily for this reason that it is suggested by many writers that pellet and fecal studies be supplemented as far as possible with field observation and stomach analysis.

Errington (1930) makes it clear that raptor pellet analysis is not advocated to the exclusion of other methods. He adds that no single method is absolutely foolproof, that the best way is to employ all possible methods and check the one against the other. The value of the method varies with different animals in different seasons. Winter studies appear to be best because pellets are easier to obtain at that time and, also, do not contain soft juvenile bones.

Errington (1932-3) in his studies of the hawks and owls of southern Wisconsin found that, whereas, owl foods were successfully ascertained, the determination of hawk pellets were more difficult because of the greater activity of the hawk digestive system and the scarcity of sufficient numbers of absolutely identifiable pellets.

Dearborn (1932) made an analytical study of over 3,500 fecal specimens to determine the food habits of fur-bearing predators in Southern Michigan.

Dalke (1935) examined 10,000 pheasant droppings for food determinations and concluded that "fluctuations of various food groups indicated by dropping analyses are in closer harmony with the degree of availability of the foods for any one period than are crop analyses."

Errington (1935) analyzing 1,175 fecal samples obtained from 82 fox dens in Iowa completed a study of the food habits of the mid-west foxes. As previously (1930) he found that these analyses had to be supplemented and correlated with other studies to avoid gross misrepresentation, because of irregular passage of food debris and difficulty of identification of clean meat and remains worn away by digestive action. Here, too, different seasons called for different combinations of methods of analysis.

Ticehurst (1935A & 1936B) examined 165 Barn Owl pellets and 6 pellets of Montagus Harrier and listed the animals contained therein.

Murie (1935) worked out the food habits of western coyotes from 714 feces and 64 stomachs.

Barabash-Nikiforov (1935) examined 500 feces of the sea-otter in a study of food-habits of that animal.

Murie (1936) correlated his fecal analysis with direct field observation trailing foxes on the George Reserve in Southern Michigan and observed that dropping analyses were very useful if used with caution.

Selko (1936) based his study of fall food habits of Iowa skunks on 210 skunk scats found principally near skunk dens and in pathways along fence rows.

Errington and McDonald (1937) in studying the food habits of the barred owl in Iowa were handicapped by the presence of the pellets of the great horned owl, but were able to report on 305 identifiable pellets illustrating the food of the fall, winter and spring seasons.

Hamilton, Hasley and MacGregor (1937) determined the fall food of the red fox in the Harvard Forest as indicated by 36 scats.

White (1937) studied the food habits of the kingfisher from pellets on the Margeree and Apple Rivers in Canada and found that this bird feeds upon those fishes most available within its feeding range. In the estuaries many species were taken, but ascending the rivers the number became less until only salmon and trout or trout alone, constituted the diet.

Wight (1938) summarized the food of the eastern skunk both numerically and volumetrically from feces.

Williams (1939) studied the droppings of sea-otters and found the important foods to be mollusks and sea urchins.

3. <u>Animal Numbers.</u>

Pellets and feces offer ample opportunity for the computation of the relative abundance and absolute numbers of certain mammals in the forest and range. Pellet counts are often employed as an important index to animal numbers.

Both predator and prey populations have been estimated by these methods.

Montgomery (1899) found that pellets gave a good idea of the relative abundance of mice and shrews in the particular hunting area of the long and short-eared owls.

Taylor (1930) in determining rodent populations in range country says that pellets give the basis for definite quantitative determination of relative numbers. He advises the quadrat, transect or spot count methods and adds "that, perhaps, when we know enough about the physiology and ecology of the animals we can derive from the pellets some pretty good reliable information as to absolute numbers."

Trippensee (1934) attempted to work out a pellet spot-count method for determining the rabbit population at Saginaw Forest, near Ann Arbor. Out of a number of 1,603 random samples, only 5 contained rabbit droppings. He concluded that pellet counts in this case were not satisfactory from the standpoint of either accuracy or speed.

Leopold (1936) reports of a method employed by Scotch gamekeepers to obtain an absolute census of grouse nests by counting the groups of "clocker droppings" along the rivulets of the area. Since the "clocker" is deposited at a fixed point, "the number of groups of clockers along a stream therefore constitutes an index to the adjacent population of incubating hens."

Snyder and Hope (1938) in recovering the pellets of the short-eared owl in a 8-9 acre plantation of scattered evergreens prepared a rough estimate of the owl population of that region. Assuming that owls had spent sixty days in this section, and had disgorged one pellet per day, the 1,078 pellets collected gave evidence that eighteen owls had been there.

4. Physiology.

Fecal analysis are also important from the pathological point of view. Examination of the feces of diseased and parasitized animals is important in determining the nature of the disease and the identity of the parasite and in planning a means of control. Too frequent droppings, loose or abnormally hard droppings, offensive droppings, abnormally colored droppings, or any other characteristics present which departs greatly from the normal is a fairly reliable indication of a pathological state. Stoddard (1931), Stafseth (1935), Portal and Collinge (1932), Leslie and Shipley (1912) and other innumerable pathological investigators all collected droppings in their disease investigations to seek evidences of the causal organism involved. Clinical fecal analysis plays an important role in veterinary and human medicine. It is a subject sufficiently comprehensive to be treated as a distinctive field of specialization.

5. Age.

Immature animals have smaller and more fluid feces than do adults. Aside from the smaller body weight of younger which results in a corresponding decrease in the fecal output, the feeding habits of the young determines to a large extent the character of the discharge. Thus, fawn droppings show a characteristic change when the animal foregoes its strictly milk diet for a diet of plant foods. The droppings further increase in size and takes on a different, more regular shape as the animal becomes older and subsists entirely on herboreous and woody plants. Fig. 11 shows the difference between average fawn droppings and those of adults. The length and diameter of the dropping generally increases with increased growth of the animal until maximum size is attained. Wight (1936. Unpublished manuscript) ascertained differences in ages up to a certain limit in Ring-necked Pheasants by averaging the lengths of 25 individual droppings of the bird with the lengths of the same number of droppings in birds of known ages. By applying statistical methods and correlating the results it was possible to get a good approximation of the age of the unknown bird.

III. THE QUALITATIVE CHARACTERISTICS OF FECES

1. Components.

Feces are waste products eliminated from the digestive tract through the anus by the act of defacation. The feces are composed of water, indigestive secretions such as bile acids, bile pigments, mucin, desquamated epithelial cells derived from the digestive tract, numerous dead and live bacteria, and inorganic salts. Strasburger (1902) found that one-third of the dried weight of human feces consisted of bacteria. The proportion of the bacteria present increases with each addition to the diet and the average weight of dried bacteria in the feces is 8 grams. Voit (1932) concluded in experiments on dogs and man that the amount and composition of fasting feces are fairly constant if compared with the body surface, but varies directly with the quantity of the food as soon as food is taken.

The percentage of water in the feces of animals varies from 65 - 85% normally according to the species and the kinds of food. An average figure for man is 75%, horse 75%, cow 83% and sheep 68%. An increased vegetable diet increases this percentage not only because of the larger water intake, but also because this diet permits a larger amount of water to escape absorbtion.

2. <u>Amount.</u>

The amount of the daily fecal deposits depends upon the species, the quantity and quality of the food eaten and the condition of the animal.

The following table gives observed daily amounts of dried feces of various species of animals together with the proportion of this weight to the body weight:

TABLE I

Table of Observed Air-Dried Daily Amount of Feces in Some Animals

Species	No. of daily pellets or defacations	Total Wt. (grams)	Body Wt. (grams)	Total Wt. / Body Wt.
E. White-footed mouse *Peromyscus maculatus*	132	1.06	11	9.6%
Cottontail Rabbit *Sylvilogus americanus*	169	28.0	1,490	1.9%
Ring-necked Pheasant *Phasianus colchicus torquatus*	18	6.3	1,041	.6%
Domestic cat *Felis domestica*	1	10.5	2,067	.5%

Within an individual animal there may be a wide variation in the amount of the daily output. This variation is more apparent in the carnivarous mammals which depend upon the capture of prey, than in the herbivores. The importance of cellulose in the animal diet greatly affects the amount of the feces. Cellulose is unaffected by digestive enzymes and interferes with the absorbtion of other foods, so that an increased cellulose diet tends to increase the total undigested residue.

Feeding experiments on a caged house cat were undertaken by the writer to determine the average daily amount of feces. The results demonstrated that the products of a single evacuation ranged in air-dried weight from 5.2 - 30.0 grams. An average weight of 13.3 grams for a single evacuation was obtained and the animal was found to defacate once every 28.5 - 38 hours. That these results represent the minimum output is very evident, since the lack of normal exercise altered the natural conditions. Data for this work follows:

TABLE 2

TABLE OF FEEDING AND FECES DATA FOR THE HOUSE CAT, FELIS DOMESTICA

Date	No. of Feedings until defacation	Total Wt. of Food	Type of Food	Air-dried Wt. of Feces	No. of separate Pellets in each defacation	Color	Max. Size	Min. Size	Time
	No.	Grams		Grams	No.		Cms.		Hours
2/10/39	4	156.6	Salmon	5.2	5	med. brown	L.2.7 D.1.3	L.1.5 D.1.0	21 - 29
2/12/39	3	256.5	Prepared cat food	30.0	6	dark brown	L.6.5 D.1.5	L.2.2 D.1.1	23 - 34
2/14/39	6	300.0	Beef Heart	10.3	8	dark brown	L.3.0 D.1.7	L.1.3 D.1.2	49 - 51
2/16/39	4	127.5	11 Peromyscus mice	8.4	9	clayey brown	L.4.0 D.1.5	L.1.2 D.1.2	27 - 43
2/18/39	3	29.8	3 Peromyscus mice	10.0	8	dark clayey brown	L.4.4 D.1.7	L.1.9 D.1.7	24 - 36
2/19/39	1	75.0	Raw Beef; 1 Mus; 1 Peromyscus mouse	12.6	5	dark brown	L.7.2 D.1.9	L.2.2 D.1.4	18 - 23
2/20/39	4	774.0	Salmon and raw meat	12.2	3	dark glossy brown	L.5.5 D.1.5	L.37 D.1.5	42 - 60
2/23/39	1	125.7	Prepared cat Food	17.8	5	black	L.4.1 D.1.3	L.3.5 D.1.6	24 - 27
TOTALS	26	1845.0		106.5	49				228-303
AVERAGE	3.25	230.0		13.3	6.1				28.5-38.0

Figure 1

Feces collected from the House Cat; - Felis domestica as indicated in Table 2. The first six evacuations indicated in the table are here shown (1 - upper-left; 2 - middle-left; 3 - lower-left; 4 - upper-right; 5 - middle-right; 6 - lower-right.)

3. Frequency of Discharge.

The frequency of the intestinal discharge depends upon the quality and quantity of the food, the rapidity of the digestive processes and the morphological characters of the intestinal tract. In general herbivorous animals which have a large proportion of indigestible matter in the food have a high frequency. Carnivorous animals have a lower frequency of discharge. Birds, because of their high metabolic rate, spend most of their waking hours finding food. The quantity of the food ingested by birds makes it necessary for them to have a high frequency of defacation.

Rabbits defacate from 150-350 times daily, mice 100-150 times, cats and dogs .5-2, foxes 1-2, cattle 5-10 and pheasants 15-20.

4. Feces Disposal and Sanitation.

The location of feces is an important factor in the specific identification of the dropping. Thus, fox droppings are commonly found in open situations on roads and paths, in front of the den, and watering places, while the feces of the coyote is more likely to be found concentrated near a defacating post in heavier cover. Seton (1925) discusses the habits of different animals in the disposal of the feces by burying, water dilution, and open-air disposal, and writes that "no animal can have a home unless it has developed with it the rudiments of sanitation which carries with it a limitation of the number of daily evacuations." He cites the deer as an example of a nomadic existence due to the large number of evacuations. It is noted that this does not hold for the rabbits and the various rodents, all of which have a high frequency of disposal and yet have a permanent home by the simple expedient of dropping their feces far away from the home to prevent any contamination. Birds may have special adaptations for the disposal of feces, expecially in the case of nestling birds.

Thompson (1934) observed that among the Passeriformes the adult bird removes the fecal mass as it leaves the cloaca of the nestling immediately after feeding. The mass is partially enclosed in a gelatinous matrix which makes possible easy transportation in the bill of the adult birds. This mass may be sometimes carried more than 50 feet away from the nest before it is discarded, or it may be dropped just outside of the nest. A lepidopterous larva, *Neossiosynoeca scatopha*, was found to be present in the bottom of the nest of the Golden-shouldered Parrot, *Psephotus chrysopterygius*. The larva devoured the feces of the young parrots and lived in a definite commensal association with with them. Other birds get on just as well without any definite mechanism for expulsion. Sunlight and air-drying in these cases act as antiseptic agents in protecting the birds.

5. Duration of Passage.

The duration of the passage of food is dependent upon the quality, quantity and water content of the food, the physiological processes of digestion, and the morphology of the intestine.

Duration of passage is important in connection with the quantitative and qualitative determination of the fecal residue. In food-habits studies it is of the greatest importance to know the time of ingestion of certain substances that appear in the feces. Thus, hair and feathers may be found present in the feces in considerable quantities long after the original prey had been ingested. The interpretation of such data is extremely difficult unless the time for the complete evacuation of all the remains of a single meal is known.

Habeck (1903) found that chickens fed fuchsin with their feed showed the bluish-red stain in their feces from $2\frac{1}{2}$ - $3\frac{1}{2}$ hours after feeding. Soft foods passed through more rapidly than did dry foods, and animals given larger guantities of water passed their food more rapidly than did the animals given a limited amount of water.

Stevenson (1933) fed finely cracked corn, stained with neutral red, gentian violet, or janus green to song birds to determine the rate of food passage. The average time required for the first stained food to pass through the digestive tract in previously starved birds (Fringillidae) was 1 hour and 32 minutes. Where birds were not starved previously there was a delay of approximately an hour in the appearance of the first colored excrement.

In mammals markers such as colored beads, rubber discs and other inert materials have been used.

Moore and Winter (1934) in studying food passage in the bovines observed that iron oxide appeared 10 - 13 hours after ingestion, and rubber rings 11 - 19 hours. The high point of these two substances was not reached until 33 and 23 - 60 hours, respectively. The lag in the case of iron oxide was 115 - 156 hours and with the rubber rings 142 - 215 hours.

Other experiments (Elliott and Barclay-Smith, 1904) showed that rabbits excreted on the average 20% of the beads fed them in 24 hours. Sudan III appeared in man feces in 15 - 25 hours, cow 16 - 17 hours, goat 14 - 17 hours.

More important than determining the normal duration of passage of food materials, is the problem of the retention in the stomach for long periods of time of hard, indigestible parts of animals as claws, teeth and horny materials. Errington (1935) noted that such parts were very likely to be represented in the feces for several days and if not critically analyzed would lead to erroneous conclusions concerning the food-habits of the animal under consideration Investigation along these lines will undoubtedly prove of inestimable value.

6. Color.

The brownish coloration of most feces is due to the bile pigments (hydrobilirubin) which are excreted with the food residues. Other colors may be due to the nature of the food eaten, such as fur and hair, pulpy fruits and vegetative matter.

Animals which feed largely on woody material during certain times of the year, as beaver and rabbits, have light-brown feces. In the winter, when the food becomes more concentrated and less fibrous, the pellets are a darker brown. Squirrels, mice and chipmunks have brown to black pellets and they vary but little among these species in color. Deer, elk and antelope show fairly constant coloring in their droppings.

Carnivores, on the other hand, exhibit wide variations in color. Foxes on a high meat diet have dark fecal residues. Feeding on a mixed vegetable and meat diet will change the output to a light-brown or greenish-brown color, while if fed very largely on bones the feces will exhibit a distinct yellowish tinge. Dog feces may range from grayish-brown to black depending upon the food taken. Distinctive colorings in house cat droppings were observed in the feeding experiments as shown in Table 2, The feces collected after tha animal was given 11 Peromyscus mice over a period of two days showed the unmistakeable coloration due to the ingestion of mice skin and hair.

The color of the feces of game birds ranged from yellow-green to brown. Pheasants, quail, partridge and ruffed grouse fed on the same diet of cracked grain in captivity showed similar light-brown coloration in their droppings.

Diseased birds are often distinguished from healthy birds by the abnormal color of their droppings. Thus, unusually greenish or yellowish chicken droppings in connection with certain other symtoms are signs of tuberculosis. Again, white watery chicken droppings can be caused by Pullorum Disease, Coccidiosis or Aspergillosis.

Color may be used to a limited degree in determining the identity of animal feces, but owing to its transitory character and its subjectivity to change by weathering, it is not very reliable. However, the red-black haematin character of some mink feces, the black sheen of the insect parts of the skunk feces, and the ashy-gray color of weathered Canidae feces are often very useful indications in the field.

7. Odor.

The odor of feces depends upon the nature of the food, the time of retention, and the decomposition changes undergone during the digestive stages. Skatole and indole are the chief putrefactive products of digestion and to these is attributed the odor of feces. Sulphuretted hydrogen methove, phosphin, phenol, and paracresol are also eliminated to a considerable degree in the feces.

(Dukes, 1935)

The bile plays an important part in digestion and indirectly affects the odor. Schmidt (1927) explains that when the bile does not enter the intestine fat absorption is greatly diminished and fat coats the other food constituents. Therefore, digestion is hindered and the putrefaction of the proteins develops an offensive odor in the feces. In this way pathological conditions may cause an unusually fowl odor of the feces.

The feces of some animals have a characteristic odor which can often be used as sole means of identification. The familiar barnyard poultryhouse odor will be sufficient to distinguish chicken droppings from those of the pheasant and the domestic pigeon. Feces of the cat is singularly offensive even days after it has been kept exposed to the air. Long association with any common animal leads to an ability to identify the feces of that animal by sense of smell.

In general, the carnivores exhibit stronger disagreeable odors in their feces than do the herbivores, since the amount of the protein foods and the products thereof account for the odors of feces.

8. Consistency.

The consistency of the feces is determined in health by the quantity of water, and the quality and quantity of the food eaten. Animals on a mixed diet have fairly firm feces. A herbaceous diet tends toward softer feces, and a strictly carnivorous diet to very firm feces.

The water content of the feces of domestic animals is approximately 80% by volume, and results in a mediumly firm discharge. Unusual quantities of water, excessive grass-feeding or bacterial infection may cause extreme watery feces. Young immature animals also tend to discharge soft feces. In song birds the fecal discharge is in the form of a whitish liquid, while in gallinaceous birds the feces is mostly solid in character. The feces of the gallinaceous birds are of two types-- the intestinal droppings and the cecal droppings. The latter have a larger volume, a pastier consistency, and a darker color than the regular intestinal discharges. They are less frequent and in captive birds appear to be largely deposited in the very late night or early morning.

9. Form and Shape.

Feces are cylindrical, spherical, ovoid, fusiform, spiral, or massive depending upon the sizes of the aggregate food masses that are formed during peristalsis, and the nature of the morphological structure of the large intestine and the anus. Form together with a consideration of size, weight, and composition offers good diagnostic features for specific identification.

The feces are soft and formless when in the small intestine, but upon arrival in the large intestine with the subsequent absorption of water, the feces become harder and take on their characteristic shapes. The examination of the large intestine of most mice, squirrels and rabbits will show these formed pellets as semi-solidified masses separated by unfilled areas in the intestine. In the fox squirrel, the first formed pellet was observed at the 30th cm. of the 44.41 cm. long large intestine, or 4 cms. beyond the beginning of the rectum. Howell (1926) in the wood rat noticed that it was not until 15 cms. beyond the colic loops of a 82 cm. rectum were there formed pellets.

The rodent pellet with its tapering cylindrical shape is characteristic of the mice and rats. Squirrels have thicker pellets which are fusiform in character. The shape of the pellets of the cottontail and snowshoe rabbits are identical and can hardly be confused with any other pellet outside of the order Lagomorpha.

The pellets of the elk with its thick, short, cylindrical form; the domestic sheep with its acuminate or multi-faceted appearance; and the antelope with its irregularly fusiform pellets offer good characters which when used in conjunction with other information may be utilized for purposes of identification.

With carnivores, however, the situation is somewhat altered. Shape is too variable and too dependent upon the kind of food to offer a readily discernable diagnostic character. Almost the entire list of fur-bearing predators have an irregularly cylindrical form, with the ends tapering gradually to abruptly.

Despite this similarity, there are some carnivorous feces which may usually be distinguished by form. The weasel and mink feces when they contain hair in sufficient quantities are spirally twisted in a characteristic manner. The size of the diameter of the racoon feces and its similarity to the form of the human feces is sometimes very evident.

A change in the food intake may change the form of the feces. Thus, animals kept in zoological parks and fed artificial foods do not show any definite form. Instead the feces are generally deposited in an amorphous mass.

The size of the animal, age, and condition of health may also influence the usual form of the feces

10. Size and Weight of Feces.

The diameter of the feces is chiefly determined by the size and tone of the anal opening. The length of the dropping is determined by the specific motions of the intestine during digestion. Food masses are acted upon by the involuntary muscles of the digestive tract so that they become separated into individual aggregations which pass through the anus.

The diameters are more consistent than the lengths and may range in different animals from less than 1 mm. in some mice to over 6 cms. in the bears. The lengths vary greatly, especially in the carnivores studied, and are, therefore, less dependable for identification studies.

The weight of the pellet or individual component of the feces in the following table is computed on an air-dried basis. The table gives the ranges in size and weight of sample feces procured through collection in the field and from zoological parks. The numbers of droppings of each animal measured to secure the data were varied, and are approximately indicated in the parentheses after each species.

TABLE 3

Table of Ranges in Size and Weight of Some Common Animal Feces

Species	Diameter Centimeters	Length Centimeters	Weight Grams
House Mouse (500) (Mus musculus)	.23-.29	.48-.61	.008-.012
Field Mouse (500) (Microtus pennsylvanicus)	.17-.21	.51-.61	.003-.006
E. White-footed Mouse(500) (Peromyscus maculatus)	.12-.18	.40-.54	.005-.009
House Rat (40) (Rattus norwegicus)	.32-.60	1.27-1.94	.11-.25
Cotton Rat (15) (Sigmodon hispidus)	.21-.39	.48-.61	.005-.010
E. Red Squirrel (35) (Sciurus hudsonicus)	.36-.52	.70-.93	.02-.08
N. Fox Squirrel (10) (Sciurus Niger)	.30-.42	.46-.87	.02-.06
E. Gray Squirrel (25) (Sciurus carolinensis)	.24-.47	.63-.95	.04-.07
E. Flying Squirrel (50) (Glaucomys volans)	.30-.39	.56-.89	.005-.02
Prairie Dog (250) (Cynomys ludovicianus)	.32-.88	80-2.10	.02-.20
Eastern Chipmunk (20) (Tamias striatus)	.46-.53	.62-1.26	.02-.05
Canada Porcupine (30) (Erethizon dorsatum)	.80-1.01	90-1.79	.04-1.00
Eastern Woodchuck (50) (Marmota monax)	.59-1.00	1.00-2.12	.08-3.42
Cottontail Rabbit (250) (Sylvilagus floridanus)	.60-1.40	.60-.95 (thickness)	.06-.32

TABLE 3 (Continued)

Species	Diameter Centimeters	Length Centimeters	Weight Grams
Common Brown Rat (20) (*Eptesicus fuscus*)	.24-.36	.58-.79	.005-.015
Canadian Beaver (15) (*Castor canadensis*	1.92-2.54	2.39-4.58	1.00-4.42
Virginia Deer (250) (*Odoicoileus virginiana*)	.52-1.58	.66-1.92	.05-.38
Domestic Sheep (100) (*Ovis domestica*)	.50-1.84	.98-1.54	.12-.87
American Elk (100) (*Cervus canadensis*)	1.36-1.65	1.60-2.16	.76-.89
Pronghorn Antelope (300) (*Antilocapra americana*)	.78-1.10	1.28-1.69	.15-.55
Common Mink (15) (*Mustela vison*)	.30-1.00	2.0-6.9	.30-1.70
New York Weasel (15) (*Mustela noveboracensis*)	.40-.89	1.84-5.71	.2-1.0
Black Bear (5) (*Euaractos americanus*)	3.21-6.10	3.20-6.17	10.00-30.25
Coyote (10) (*Canis latrans*)	1.35-2.69	3.87-6.30	5.15-10.83
Virginia Opposum (35) (*Didelphis virginiana*)	.80-1.85	1.04-4.37	.87-1.89
Red Fox (20) (*Vulpes fulva*)	.80-1.92	2.56-8.17	3.04-5.50
E. Raccoon (55) (*Procyon lotor*)	1.05-3.22	2.66-5.26	3.03-10.00
E. Skunk (25) (*Mephitis nigra*)	1.17-1.82	3.10-5.74	1.62-7.31
Bobcat (2) (*Lynx rufus*)	1.41-2.06	3.97-6.43	4.00-5.01

TABLE 3 (Continued)

Species	Diameter Centimeters	Length Centimeters	Weight Grams
Muskrat (30) (Ondatra zibethica)	.29-.48	.47-2.50	.05-.20
House Cat (50) (Felis domestica)	1.13-1.70	1.35-7.28	2.1-7.3
Badger (2) (Taxidea taxus)	1.80-2.24	4.52-6.78	9.12-15.40
Ring-Necked Pheasant (200) (Phasianus colchicus torquatus)	.70-.92	1.39-2.39	.12-.61
Ruffed Grouse (200) (Bonasa umbellus)	.60-.88	1.41-3.02	.07-.42
Bob-White Quail (200) (Colinus virginianus)	.52-.78	.78-1.00	.03-.08
Hungarian Partridge (200) (Perdix perdix)	.49-.69	.92-1.40	.03-.09
Domestic Pigeon (25) (Columba livia)	.70-1.05	1.05-1.83	.12-.21

The above table in most instances was compiled from measurements taken of the feces of more than one individual of the species. To determine the variations in the measurements within a single individual of a species, the droppings of a single animal were collected and measured. The standard deviations and the time averages (standard errors of the arithmetic averages) were computed. The following table shows the variations in droppings of a single individual of a species.

TABLE 4

TABLE SHOWING VARIATIONS IN DROPPINGS WITHIN AN INDIVIDUAL OF A SPECIES

Species	No. of Total Droppings Computed	Standard Deviation of Length	True Average of Length	Standard Deviation of Width	Time Average of Width
House Mouse (Mus musculus)	10	± .06	.56 ± .02	± .05	.28 ± .02
Field Mouse (Microtus pennsylvanicus)	10	± .04	.56 ± .01	± .01	.20 ± .003
E.White-footed Mouse Peromyscus maculatus	10	± .06	.48 ± .02	± .02	.15 ± .006
E. Red Squirrel (Sciurus hudsonicus)	10	± .10	.81 ± .03	± .05	.46 ± .02
Canadian Porcupine (Erethizon dorsatum)	10	± .24	1.76 ± .08	± .08	.91 ± .02
Virginia Deer (Odoicoileus virginianus)	10	± .11	1.42 ± .04	± .04	.75 ± .01
American Elk (Cervus canadensis)	10	± .18	1.92 ± .06	± .08	1.49 ± .03
Pronghorn Antelope (Antilocapra Americana)	10	± .10	1.39 ± .03	± .09	1.0 ± .03
House Cat (Felis domestica)	14	± 1.91	3.62 ± .51	± .21	1.48 ± .05
E. Racoon (Procyon lotor)	18	± .88	3.87 ± .21	± .17	1.23 ± .04
E. Skunk (Mephitis lotor)	12	± .90	4.22 ± .26	± .20	1.33 ± .06
Virginia Opposum Didelphis virginiana	25	± 1.03	3.89 ± .21	± .24	1.10 ± .01
Red Fox Vulpes fulva	10	± .78	3.73 ± .25	± .22	1.24 ± .07

From this table it is obvious that the diameters of the droppings are more consistent than are the lengths. It is also shown that the standard deviations of the widths of the carnivorous droppings differed but little from the standard deviations of the lengths were considerably greater for the carnivores than they were for the hervivores.

11. Composition.

The composition of the feces is dependent upon the nature of the food intake. The latter according to Leopold (1933) depends upon the presence, availability and palatibility of the food plus the physiological need and habits of the animal. There is extensive data available on the composition of animal feces and some of these works have been mentioned and summarized (pp. 4-7).

The main methods of carrying out these studies as described by Wight (1938) have been by volumetric, gravimetric and numerical measurements. The gravimetric method may be wet or dry; the volumetric method by means of white squares or cubic centimeters; and the numerical counts by frequency of occurrence over a period of time, and by direct count of each item.

On a local basis, composition may be used as a good indication of the specific identification of the dropping. Seton (1925) writes that "the output of the fox and wolf may be of precisely the same form but the great difference of size and the fact that the fox will contain more or less mouse traces, and the wolf the remains of deer and cattle to the exclusion of mice will usually settle the problem." However the fact that the foods of an animal vary with the seasons, and the availability of certain prey types usually makes this sort of comparison too uncertain. The matter is further complicated by the question of average composition. Most of the food-habits compilations are based on year-round or seasonal averages. A single dropping, however, may be quite at variance with the results obtained from these results. It can be seen that the comparison of the composition of similar feces may be inadequate, in itself, to definitely solve the problem of identification.

Hairs of the animal evacuating the feces may offer reliable clues, since some animals have the habit of swallowing hairs from some part of their bodies. Mathiak (1938) points out that "skunk feces may include a few skunk hairs most often from the legs."

The safest and most reliable method of identification appears to be a consideration of each of the qualitative factors already discussed. By combining all the known facts of composition, size and weight, form, odor, color, and location, it may be possible to arrive at a specific conclusion regarding the identity of the animal which deposited the feces.

IV. THE MORPHOLOGY OF THE DIGESTIVE TRACT

1. General Description of the Mammalian Digestive Tract.

The form, size, weight, and the daily number of evacuations of the feces of animals depends to a large extent upon the morphological structure of their digestive tracts. These features are generally ordinal characters and show definite taxonomic relationships.

The mammalian digestive tract consists of the buccal cavity, pharynx, esophagus, stomach, small intestine and large intestine. The small intestine is composed of the duodenum, ileum and jejunum, and extends to the caecum. The large intestine or hind-gut extends from the caecum to the anus, and consists of caecum, colon, rectum and anus.

Under the influence of the character of the food, the stomach in mammals undergoes more numerous modifications than are present in any other vertebrate class. Ordinarily transverse with a soc-like form consisting of a cordiac and pyloric region, it becomes larger and more complicated in some of the herbivorous mammals. In ruminants, there are four chambers which are called respectively: rumen, reticulum, psalterium and abomasum. Two are storage cavities, the food returning from them into the mouth for repeated mastication. It then passes into the psalterium and finally into the abomasum, which serves as the true digestive stomach.

The small intestine is usually long, coiled and has a small diameter. It is closely associated with blood vessels for the absorption of food materials.

The large intestine is separated from the small intestine by a definite constriction and is distinguished from it by a greater width. In carnivores, the large intestine is relatively short and simple. In herbivores with simple stomachs it is more complex and voluminous, while in the cud-chewing mammals it is long and narrow.

2. The Digestive Tract of Carnivores.

Studies on the digestive tracts of a raccoon and cat demonstrated that 15-17% of the total length of the intestines was in large intestine . The large intestine was small and obviously secondary. In the raccoon the stomach was small. A thin-walled pouch which extended from the concave side of the stomach provided additional capacity. No caecum was present, while the large intestine remained undifferentiated. In the cat, the duodenum may be separated from the ileum, no caecum can be seen, and the large intestine is short with no external differentiation. In dogs, there is a spirally-twisted caecum present.

The diameter of the large intestine of the cat when full of fecal residue was found to be 2.27 cms. in diameter. The diameters of the air-dried feces of this animal ranged from 1.12-1.90 cms. From this it would appear very likely that in the case of this animal 2.27 cms. would be the maximum diameter of the feces possible. The average air-dried diameter would be considerably lower than this due to loss of H_2O and subsequent shrinkage.

The diameter of the large intestine of the raccoon in the collapsed state was found to be 1.7 cms. No feces of this animal could be obtained for comparison with the diameter of the intestine. The range of diameters of air-dried raccoon droppings as indicated in Table 3, is 1.05-3.22 cms.

The measurements of the digestive tracts were as follows:

TABLE 5

Table of Measurements of the Digestive Tracts of the House Cat and Raccoon

Part of Tract	House Cat *Felis domestica*		Raccoon *Procyon lotor*	
	Length in cms.	Width in cms.	Length in cms.	Width in cms.
Stomach	6.59	3.01	6.92	4.81
Small Intestine	107.45	.86	124.79	1.45
Large Intestine	21.47	2.27	22.44	1.7
Total Length (cms.)	135.51		154.15	
Body Length (cms.)	39.45		48.82	
Proportion of tract to body length	3:1		3:1	

Figures 2 and 3 show the digestive tracts of the house cat and raccoon.

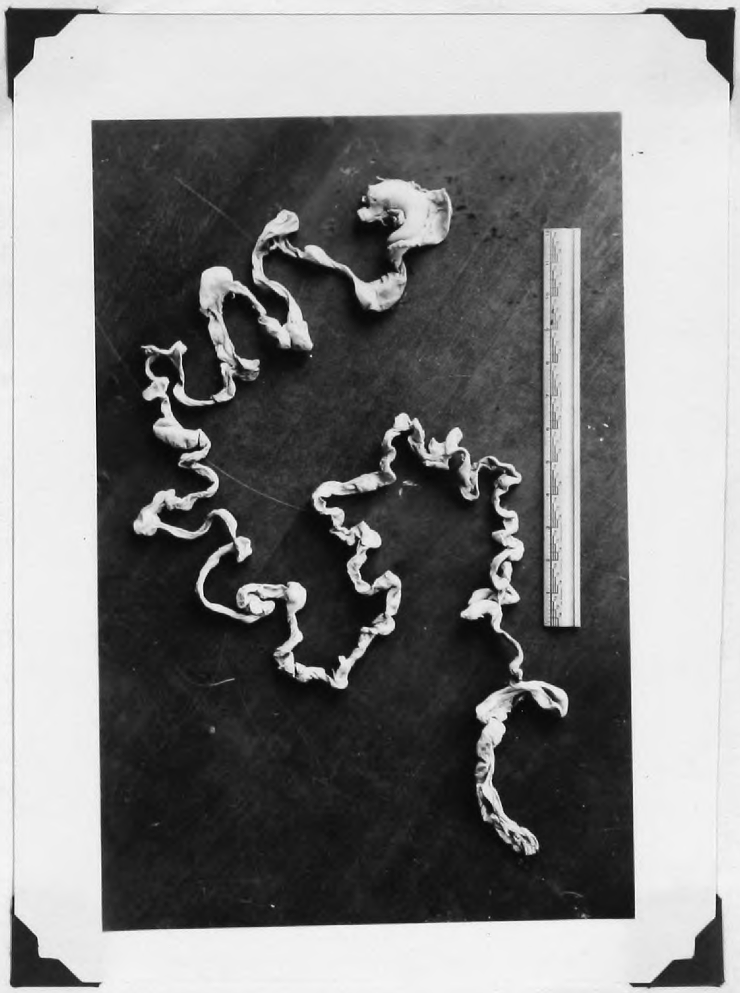


Figure 2

The digestive tract of the Eastern Raccoon.

<u>Procyon lotor</u>

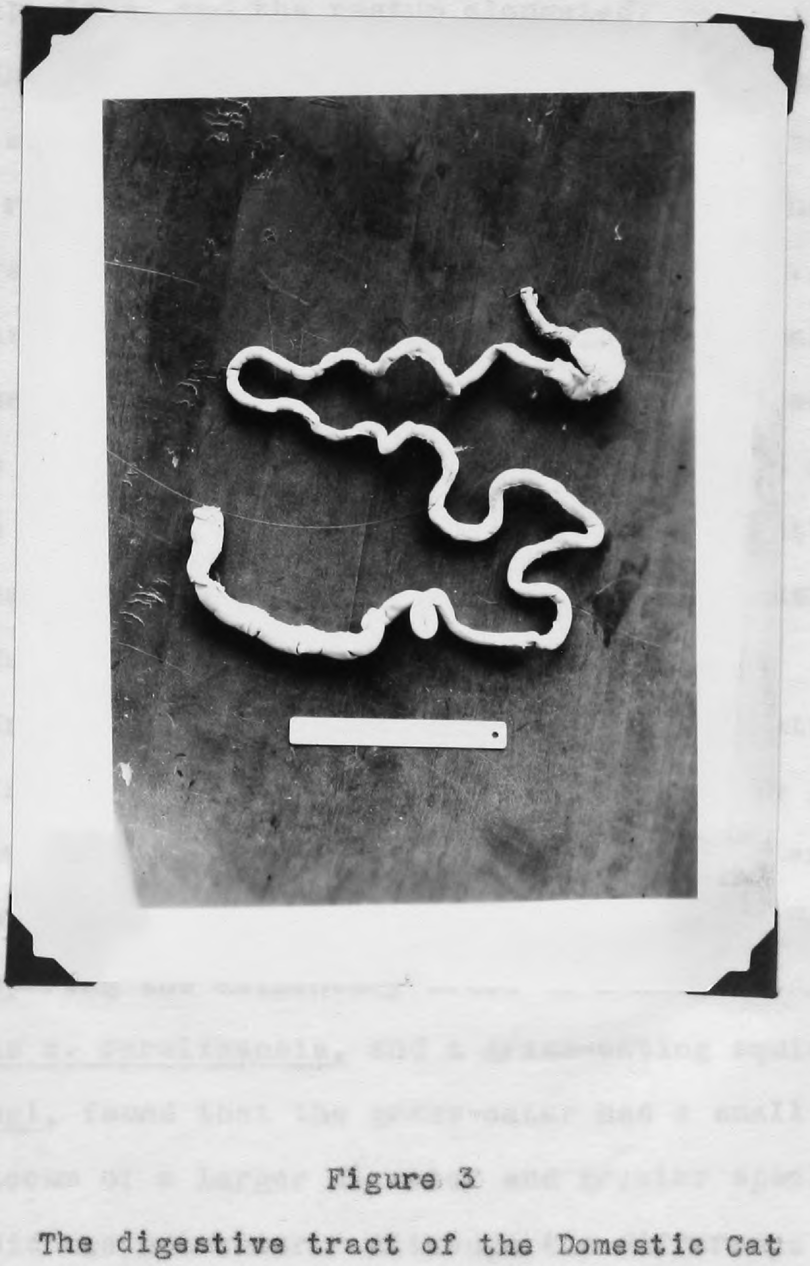


Figure 3

The digestive tract of the Domestic Cat

Felis domestica

3. <u>The Digestive Tract of Rodents.</u>

Examinations of the common house rat, house mouse, and fox squirrel digestive tracts showed that 20-32% of the total length of the intestine was in large intestine. In these, the duodenum could be distinguished, the caecum was large and capacious, and the rectum elongated.

In the house rat the diameter of the distal end of the colon was found to be .35 cms. Table 3 gives the range of house rat feces collected as .32-.54 cms. In the fox squirrel the diameter of the rectum was .60 cms., while 3 pellets taken from the large intestine of the animal averaged .31 cms. in diameter. In the house mouse the rectum where it was distended by formed pellets measured .36 cms. In the spaces between adjacent pellets the large intestine measured .21 cms. in diameter, showing an average distension of .15 cms. due to the passage of the dropping.

In the rodents the digestive tract is relatively longer than in the carnivores. This elongation of the gut may be interpreted as an adaptation to the omniverous and gramnivorous habits of the animals of this order. Howell (1925) in comparing the alimentary tract of a nut-eating squirrel, <u>Sciurus c. carolinensis</u>, and a grass-eating squirrel, <u>Citellus beldingi</u>, found that the grass-eater had a small intestine and caecum of a larger diameter and greater specialization than did the nut-eater. Although the difference in the sizes of the stomachs of the two were not of very great importance, this was compensated for by the greater muscularity of the stomach of the grass-eating squirrel.

Kestner (1929) proved the important role of the influence of food on the development of the digestive tracts of rats. He found that rats fed a vegetable diet during their growth period had a larger intestine, and a larger and longer caecum than did rats fed meat.

The following table gives the measurements of the digestive tracts of the house rat, house mouse and fox squirrel:

TABLE 6

Table of Measurements of the Digestive Tract of the House Rat, House Mouse, and N. Fox Squirrel

Part of Tract	House Rat		House Mouse		N. Fox Squirrel	
	Rattus norwegicus		Mus musculus		Sciurus niger	
	Length in cms.	Width in cms.	Length in cms.	Width in cms.	Length in cms.	Width in cms.
Stomach	2.23	1.51	1.65	.90	4.71	1.90
Small Intestine	74.93	.56	46.83	.24	112.21	.83
Caecum	4.14	2.05	2.51	.55	8.65	1.37
Colon	8.87	.62	6.28	.21	26.02	.68
Rectum	5.16	.35	4.83	.21	18.41	.64
Total Length	75.33		62.10		170.00	
Body Length	11.03		5.34		20.95	
Proportion of Total Length to Body Length	7:1		12:1		8:1	

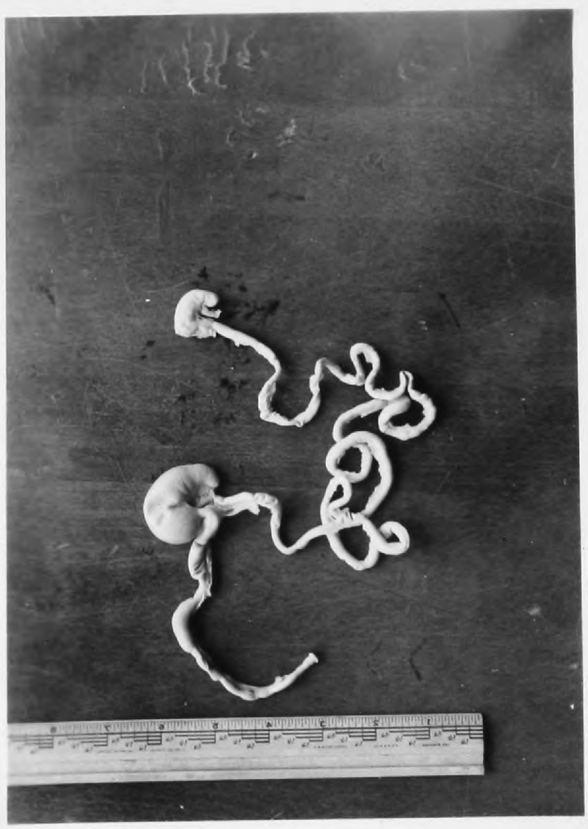


FIGURE 4

The Digestive Tract of the House Rat

Rattus norwegicus

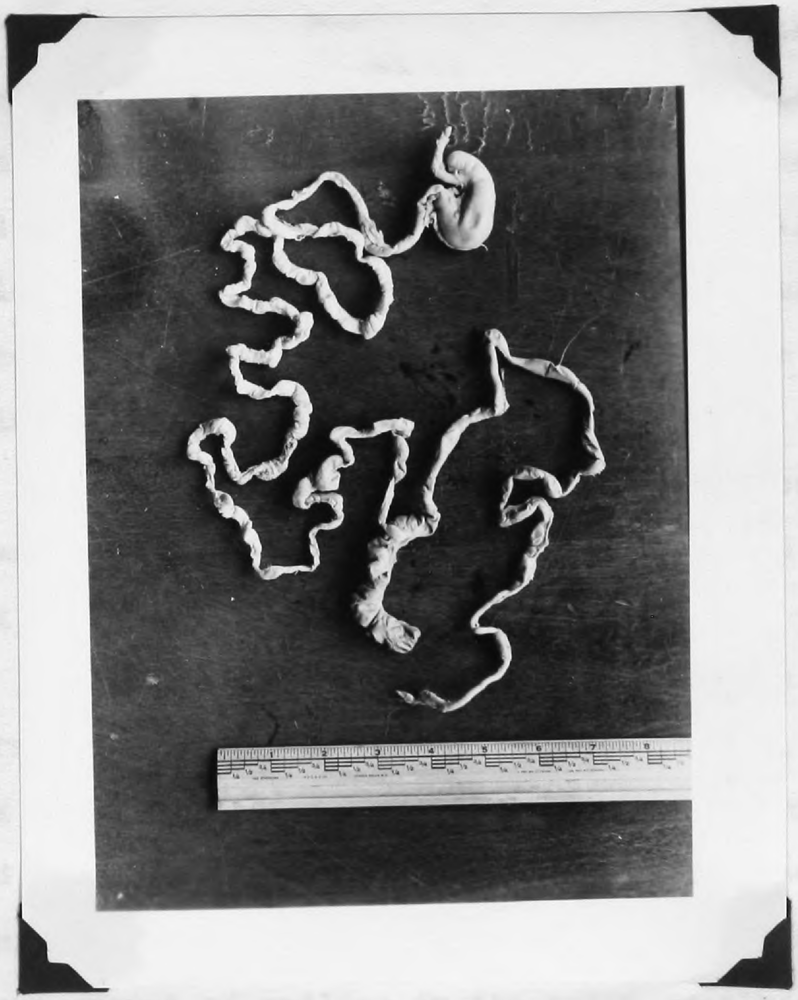


Figure 5

The Digestive Tract of the N. Fox Squirrel

<u>Sciurus niger</u>

Figures 4 and 5 show the digestive tracts of the house rat and fox squirrel.

4. <u>The Digestive Tract of Artiodoctyls.</u>

The digestive tract of the even-toed hoofed ungulates are characterized by their enormous length and modifications for herbivorous and omniverous habits. In the domestic hog the duodenum is distinct, the remainder of the intestine is long, closely coiled and sacculated. The caecum is long and wide and marks the beginning of the small-diametered colon. The animals in this order may possess ruminant or non-ruminant stomachs, the differences which have been pointed out before.

The digestive tract of the sheep was found to be 25 times the body length, the goat 27 times and the domestic hog 16 times.

The small-sized singly disposed pellets of such comparatively large animals as the sheep, deer, antelope and elk are explained on the basis of the characteristic size and convolutions of the large intestine. The small diameter coupled with the frequency of constriction induced by the large amount of coiling in the colon precludes the formation of larger food masses such as is found in animals which possess less specialized large intestines.

The following table gives the measurements of the parts of the digestive tract of the domestic hog:

TABLE 7

Table of Measurements of the Digestive Tract of the Domestic Hog

Part of Tract	Length Centimeters	Width Centimeters
Stomach	29.1	14.0
Small Intestine	2132.6	2.5
Caecum	24.0	9.5
Large Intestine	391.3	4.4
Total Length	2577.0	
Total Body Length	173.8	
Proportion of Total Length to Body Length	16:1	

Figure 6 shows the digestive tract of the domestic hog.

Figure 6

The Digestive Tract of the Domestic Hog

Suis scrofula

5. The Digestive Tract of Birds.

The digestive tract of birds consists of the buccal cavity, crop, proventriculus, gizzard, small and large intestine, cloaca and anus. The small intestine is divided into the duodenum and the ileum and becomes the large intestine at the point of the location of the caecum. The large intestine differs little in diameter from the small intestine and opens to the cloca and thence to the outside by the anus.

The caeca may be paired, single or even entirely absent. In the ring-necked pheasant the caeca are long and paired and show a difference in length of 5.75 cms. In the English sparrow and Golden-eye the caeca are paired but relatively short. While in the screech owl, the caecum was found to be single and approximately equal in length to the small and large intestines. In some of the rapacious and song birds the caeca are degenerate and functionless, while they may be entirely absent in the kingfishers, humming birds and parrots.

The presence of the long caecum in the screech owl seems to contradict the assumption that this is an anatomical modification for herbivorous birds. Newton (1893-1896) explains this anomaly by pointing out that a change in diet may occur in a shorter time than it takes to modify the digestive organs.

The relative lengths of the digestive tract is very constant in the birds and, like in the mammals, may be interpreted as anatomical specialization for the adaptations of specific foods. Thus, it is expected that birds feeding on animal matter would have a shorter relative length of intestine than those birds feeding on grains and grasses. This increased length, however, may in some cases be offset by differences in width and in muscularity as indicated in mammals by Howell (1925).

The proportion of the length of the entire digestive tract to the body length (measured from the root of the neck to the anus) in all of the four birds as shown in Table 8 ranged from 5-6:1 and may be termed "short-gutted." Of these the Golden-eye and Screech Owl are predominantly animal feeders; the English Sparrow is omniverous and the Ring-necked Pheasant gramnivorous. Stevenson (1933) in a table of the relation between the type of food consumed and the length of the intestine in the cooper's hawk, broad-winged hawk, English sparrow, and black-capped chickadee found that the average length of the small intestine divided by the total length of the body was 4.1, 6.0, 4.0, and 3.6 respectively. It was also shown that female passerine species possess relatively larger small intestimes than do males, and immature birds of the same species possess relatively longer intestines than do adults.

These facts tend to show that other factors than food-habits play an important part in determining the relative length of the digestive tracts of birds.

Table 8 gives the measurements of the entire digestive tracts of the 4 birds described:

TABLE 8

TABLE OF MEASUREMENTS OF THE DIGESTIVE TRACTS OF SOME BIRDS

Part of Tract	Ring-necked Pheasant		Screech Owl		English Sparrow		Golden-eye	
	Length cms	Width cms	Length cms	Width cms	Length cms	Width cms	Length cms	Width cms
Esophagus	8.28	.56	5.60	.70	3.85	.37	16.40	.72
Crop	2.61	? 1.87	? 2.53	? 1.32	1.98	.70	0.0	0.0
Proventriculus	4.20	1.26	1.59	1.16	.89	.58	4.04	1.72
Gizzard	4.19	3.92	2.14	2.60	1.50	1.22	5.09	4.72
Small Intestine	70.52	.60	14.03	.47	12.23	.50	132.85	.90
Caecum	16.25 22.00	.72	22.78	.51	4.70 6.74	.40	4.32 4.61	.5
Large Intestine	8.36	.76	8.05	.49	3.68	.32	7.70	.68
Total Length of Tract	136.41		56.72		35.57		175.01	
Body Length (root of neck to anus)	21.84		11.12		6.46		29.42	
Proportion of Length of Tract to Body Length	6:1		5:1		5.5:1		6:1	

Fig. 7 shows the digestive tract of the Golden-eye duck:

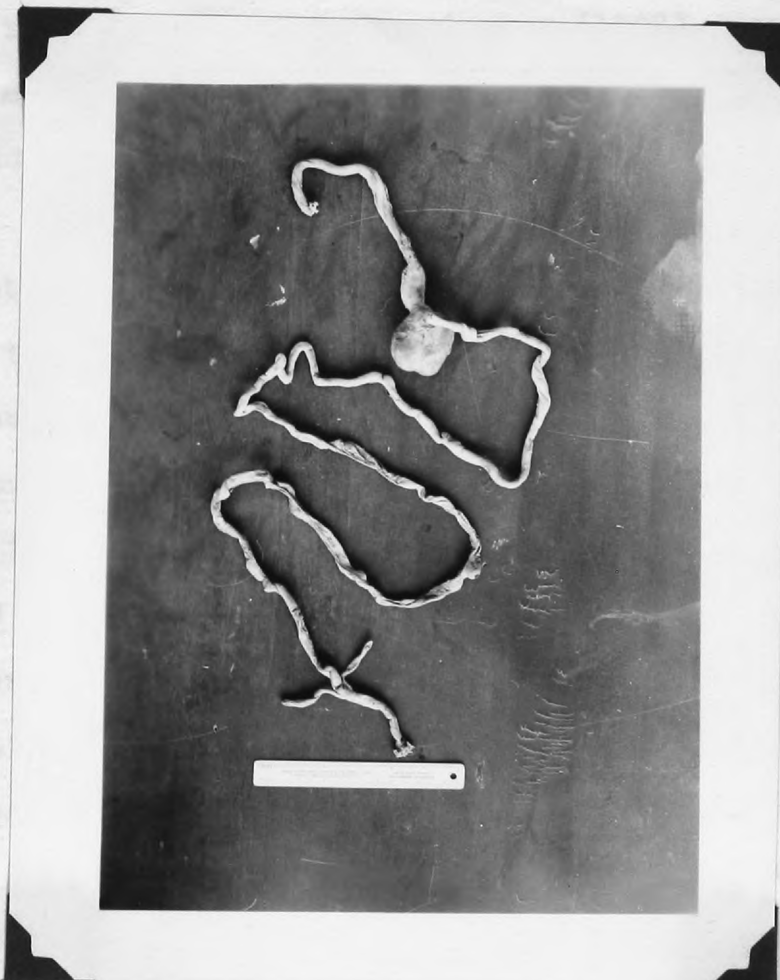


Figure 7

The Digestive Tract of the Golden-eye Duck

Glaucionetta clangula americana

V. THE PHYSIOLOGY OF THE DIGESTIVE TRACT

1. Digestion and Defacation in Mammals.

In the small intestine movements take place which act to thoroughly mix the digestive contents and the intestinal juices and tend to propel the entire mass forward to the large intestine. Alvarez (1928) describes four kinds of movements of the human intestine: rythmic segmentation, pendulum movements, peristaltic rush and reverse peristalsis.

Peristalsis is chiefly concerned with the mass movement of the material forward, while rhythmic segmentation is the mechanism by which the food particles are intimately brought into contact with the walls of the intestine and subsequently absorbed. By this process, food is broken up into small masses. These are then further subdivided, and the ends of the adjacent masses coalesced, so that this kneading effect, continually effective throughout the entire time of passage thoroughly mixes the food material present.

The movements of the large intestine according to Elliott and Barclay-Smith (1904) consists of:

A. Backward running waves of constriction which repels food that has entered from the ileum and temporarily prevents its forward movement.

B. Coordinated peristalsis which drives the food in one direction only, that is from the stomach to the anus.

C. The strong contraction for the purpose of evacuating the final reservoir.

The exact nature of the final evacuation process or defacation has been worked out by Hurst (1909) and Cannon (1919) by means of roentgen-ray studies on humans and cats fed barium compounds with their food. The following accounts are taken from them.

"In man, the whole of the large intestine below the splenic flexure is emptied in defacation. The sensation of fullness in the rectum which leads to the desire to defacate is brought about by the entry into the rectum of some of the feces which have accumulated in the pelvic colon during the previous 24 hours.

Increased intra-abdominal pressure causes more feces to enter the rectum, which becomes more distended. This gives rise to afferent nervous impulses, which pass to a center in the lumbar spinal cord. There they set into action the efferent impulses, upon which depends the reflex act required to complete the process of defacation. This consists in strong peristaltic contractions of the colon, contraction of the voluntary muscles enclosing the abdominal cavity and relaxation of both anal sphincters. The fecal mass is forced through the relaxed anal canal by the wave of contraction passing down the pelvic colon and rectum and by the raised intra-abdominal pressure."

"In the cat, the material throughout the colon was brought into position for expulsion in the rectum by the extensive sweeping movement of the gut coupled with broad contraction of the circular muscles. The region of the strongest contraction was apparently drawn downward with the rest of the gut by a shortening of the descending colon. As the intestine swung around, more material was forced into the rectum; and when the swinging of the intestine stopped, the constriction which divided the lumen passed slowly downward and with the aid of the muscles surrounding the abdominal cavity pushed the separated mass out of the canal.

Further performance of the act is accomplished primarily by increased intra-abdominal pressure--a result of voluntary contraction of the abdominal muscles and the diaphragm. As the diaphragm contracts the entire transverse colon is pushed downward, and the ascending colon and caecum are forced into an almost globular form. The intra-abdominal pressure (4-8x normal) causes more feces to enter and distend the rectum and anal canal. The distension of these parts now arouses reflexes which start strong penstaltic contractions of the colon, continues the tendency to strain with the voluntary muscles and produces relaxation of both anal sphincters."

In herbivorous animals, especially those with small droppings and greater frequency of expulsion as with the rabbit, rodents and sheep, the defacating mechanism is probably more simplified and localized. Dukes (1934) states that in herbivores the emptying of the rectum through the relaxed anal sphincter is accomplished by the combined contraction of its own wall and of the voluntary muscles of the abdomen. It is logical in view of the greater frequency of defacation that herbivorous animals would develop a more automatic mechanism than the method prevalent in carnivores.

2. Digestion and Defacation in Birds.

The digestion of food in birds, with certain exceptions, closely parallels that of mammals. The absense of teeth are compensated for by the muscular gizzard and its contained grit; the crop acts as a preliminary digestive organ and storage place, while the caeca extracts all the soluable food materials.

Digestion in birds is more rapid and complete than in any other class of mammals. Defacation in birds has not been worked out with any degree of thoroughness that has been done with mammals. It seems highly probable that the process is much less complex in the birds. The lack of differentiation in the large and small intestine, the fluidity of the undigested mass and the frequency of discharge, coupled with the rapidity of the excretory act suggests a simple contraction of the large intestine brought about by nervous stimulation of that part of the tract.

3. Pellets and Pelletal Formation.

Pellets are the indigestible remains of the food of birds which are extruded by the way of the mouth. They occur in hawks, owls, crows, kingfishers and gulls. However, those of the owls and the hawks are the most frequently observed.

Pellets are only formed in birds when there is present in the digestive tract indigestible matter such as bones, fur, feathers or skin.

Guerin (1928) observed that the formation of pellets was not due to any specialized structural modifications. The raptors and gulls with thin-walled stomachs had identical pellets as did the crows with a short, thick-muscled stomach, while the gallinaceous birds did not form pellets although they had identical stomachs as did crows.

The mechanism of pellet formation in the great horned owl has been investigated by Reed and Reed (1928) by fluoroscopic examination after barium paste was given with the food. The observations indicated that three general factors were involved:

"1. The mechanical factor of high placement and the small size of the pyloric opening.

2. Feeble gastric motility which would preclude stirring up or freeing of hair and feathers enmeshed in the whole mass.

3. Potent peptic activity which would readily digest all other material free from hair, feathers and bones, and liquify it so that the pyloric passage would be facilitated."

The mechanical process of the pellet expellation has not yet been definitely ascertained. While Reed and Reed (1928) observed nausea in the bird occassionally after the discharge of the pellet, Sumner (1934) observed no effort or after-effects in the discharge of the pellet of the same species. Guerin (1928) did not observe nausea in the case of the gulls, but did see it in some of the diurnal raptors. The writer has observed the act once in the red-shouldered hawk and once in the Screech Owl. Both acts were characterized by a slight shaking to and fro of the head and a slight up-raising of the neck which lasted approximately 5 seconds. No after-effects were observed.

In view of the fact that the pellet discharge appears to be a conscious act and can be hastened or retarded at will (Guerin, 1932) it appears highly improbable that is is closely associated with vomiting. Chitty (1938) on experiments with the Short-eared Owl concluded that "the length of time a pellet is retained increases logarithmically with the weight of the meal, but that several factors may influence this relationship." Thus, night pellets were retained longer than day pellets; hunger may increase the interval, and excess food shorten it.

The normal time involved in the entire process from the time the food is ingested to the time the mass of bones, feathers and fur are discharged differs among the birds studied. In the screech owl, the average time observed by the writer was 17-20 hours. The shortest time recorded was 9 hours and the longest time 28 hours. In the great horned owl (Reed and Reed, 1928) 12-40 hours was considered normal. In the short-eared owl (Chitty, 1938) 2-13 hour intervals were noticed.

The bones contained in most owl pellets show little signs of digestive action or corrosive deterioration. This presupposes the absence of free acid in the stomach of the owls. Reed and Reed (1928) found that the total acidity of the pellet and the stomach never exceeded 0.43%. On the other hand, the pellets of the hawks differed from those of the owls. In the pellets of the red-shouldered and sparrow hawks there were frequently no traces of bones at all; or when present they were badly shattered, fragmentary and difficult to identify. The fact that hawks, as a whole, tend to break the bones of their prey while feeding coupled with their high digestive activity would account for this. Errington (1932-1933) as mentioned previously found that while food-habits analysis of owls were satisfactory from pellet studies, hawk pellets proved less fruitful in the results obtained.

Although most pellets consist entirely of indigestible masses freed from other materials, it sometimes occurs that prematurely dropped pellets may contain bits of undigested meat. It was found in Screech Owls that when food was given earlier than was customary, the pellets were not as thoroughly freed from digestible materials as when long intervals between feedings were observed.

VI. FECES AND PELLETS AS SPECIFIC FEATURES OF ANIMAL IDENTIFICATION

1. General Considerations of the Key.

From the preceding discussion it is evident that there exists qualitative differences in the excretory remains of mammals and birds that may be subject to specific identification. It was also made clear that these characteristics are by no means constant, but may vary among individuals. Although it is felt that field experience plus an intimacy with wild animals is the most effective way of being able to identify the feces and pellets encountered in the field, it is thought that there may be a shorter and as effective a method for specific determination. To this end a key for the identification of some of the most common feces and pellets has been prepared.

The difficulties encountered in the preparation of such a key might well be mentioned in order to facilitate its use. The short time available has made necessary the procuring of some of the specimens from zoological gardens and laboratories. They were used with utmost caution because they do not always represent the conditions found in the wild. Average weights, sizes and forms were determined by selecting only those fecal specimens which appeared to be generally similar. From the number of such typical specimens ten were selected at random and measurements were taken. Sufficient samples of ten typical samples were thus measured until it was evident that the best averages were obtained. In some of the cases 2-3 such groups were sufficient and in others it was necessary to test 20-30 groups before a wide enough range could be established. The question of sufficient sampling still remains as one of the most pressing problems to be solved in all quantitative work, and the writer must still rely upon his own judgment for any question of the sufficiency of his sample percentage. Size and the age of the animal were found to affect greatly the characteristic measurements. Location had to be considered as locality influences food selection which in turn influences the nature of the feces. Excess moisture, extreme dissication, activities in walking and sitting, and disease, all tend to be important factors in producing atypical droppings. It is not intended that all the varieties of such distorted droppings can be identified here, as this work has been confined to typical, average pellets of normal animals found in a relatively fresh state.

A dichotomous plan has been followed. Alternate choices dealing with the same feature employed for separation have been given equal rank in the numbering. No identations have been used because it is felt that the simplicity of the key is best preserved without its use.

All final identifications made should be carefully checked with the photographs and drawings at the end of the key.

Phylogenetric relationships have not been followed in preparing the key, although they may appear to be distinctly present in many cases. This is due to the morphological affinities of the digestive tract. The characters used in separation are the same characters that have been described of feces previously. The rodents, artiodactyls, lagomorphs and chiroptera are keyed out largely on the basis of form, weight and size plus additional factors as location and relative abundance. Form, weight and size appear to be sufficiently constant to afford diagnostic characters. Carnivores on the other hand, cannot be so definitely separated. Although identification through food residues, hairs, form, color and size may sometimes be feasible, it is often impossible to distinguish the feces with any degree of certainty on this basis. Here the location of the dropping together with a knowledge of the distribution of the animals in the general region will prove of great value.

Only those specimens which could be procured and studied by the writer are included in the key. The carnivores included here are all indigenous to the state of Michigan, but some rodents and artiodactyls not locally found have been included because of their general interest. Domestic animals were excluded except in the case of the sheep, dog, cat, and pigeon which were included because of their similarity to wild species.

2. Procedure.

To successfully use the key little equipment is needed. A pair of dividers and a centimeter rule or a vernier caliper with a centimeter scale are used to measure the lengths and the widths of the droppings. An analytical balance for weighing the smaller specimens and a gram-weight scale for the larger specimens completes the equipment necessary.

All the measurements are based on the averages for ten representative samples. In applying the key it is necessary to use the aggregates instead of the individual droppings to determine the characters employed. This is especially important for all the droppings weighing less than .1 gram. It is necessary in many cases to study more than one of such representative groups of ten.

3. The Feces Key.

1. Wt. less than .1 gms.................................. 2

1. Wt. more than .1 gms..................................12

2. Greenish-yellow to brown; presence of whitish deposit of urates on many of the droppings indicating bird feces; commonly found in good cover in agricultural and forested lands.................................. 3

2. Not possessing a whitish deposit of urates.......... 4

3. Mostly irregular; twisted and lumpy appearance; av.

dia. .66 cms. (.52-.78); length .98 cms. (.81-1.00) cms.; wt. .04 gms. (.02-.08) gms.; commonly found in small clearings in brushy types, along fence-rows, near good food-types in agricultural areas............

Bob-white Quail - Colinus virginianus virginianus, Fig. 12 and 19.

3. Not as irregular as above; mostly ovoid or fusiform with smoother surface than above; found in intensively cultivated agricultural areas........................

Hungarian Partridge - Perdix perdix perdix, Fig. 12 and 19.

4. Flattened sphere to spherical; av. dia. .72 cms. (.60-.80); av. wt. .06 gms. (.04-1.3); brown to dark brown with lighter "pepper and salt" markings..........

Cottontail Rabbit - Sylvilagus floridanus, Fig. 17.

Snowshoe Rabbit - Lepus americanus.

4. Not a flattened sphere nor spherical................... 5

5. Globular to ovoid; one end (occasionally both ends) abruptly narrowing; av. dia. .59 cms. (.52-.68); length .83 cms. (.66-1.01); av. wt. .08 gms. (.05-.10); dark brown to black; found in runways in forested areas.......................................

Virginia Deer (fawn) - Odocoileus virginianus, Fig. 11.

5. Not globular nor ovoid with abruptly narrowing end (or ends).. 6

6. Irregularly to regularly cylindrical; av. dia. not exceeding .35 cms.; av. wt. not exceeding .02 gms... 7

6. Fusiform, acuminate or irregularly cylindrical; av. dia. exceeding .35 cms.; av. wt. exceeding .02 gms... 9

7. Very brittle and composed of indigestible remains of flying insects; av. wt. .01 gms. (.005-.015); av. length .66 cms. (.58-.79); av. dia. .34 cms. (.24-.36); commonly found in dilapidated barns, dwellings or caves.................................

Common Brown Rat - Eptesicus fuscus, Fig. 10.

7. Not brittle nor composed of indigestible remains of flying insects.................................... 8

8. Av. dia. exceeding .30 cms........................

E. Flying Squirrel - Glaucomys volans, Fig. 9.

Only found in forested regions; not common; dia. (.30-.39) cms.; length (.56-.89) cms.; wt. (005-02) gms. ....

Cotton Rat - Sigmodon hispidus, Fig. 9.............

Common in grasslands and open places in Southern U. S.; dia. (.21-.39) cms.; length (.48-.61) cms.; wt. (.005-.010) gms.

8. Av. dia. ranging from .10-.30 cms.; av. length (.40-.60) cms.; av. wt. (.003-.015) gms.; typical mice pellets..

Field Mouse - Microtus pennsylvanicus, Fig. 8......

Never found in barns or dwellings but commonly in all situations in agricultural and wooded areas..

E. White-footed Mouse - Peromyscus maculatus, Fig. 8 and 17; may be found in barns and out-buildings, but more commonly in hedgerows, roadside grasslands and wooded areas; generally smaller than above..

House Mouse - Mus musculus, Fig. 8 and 17...........

Most commonly found in and near barns and out-buildings, occasionally in fields, meadows and weed patches; largest of the three most common mice pellets..

Cotton Rat - Sigmodon hispidus, Fig. 9.

Common in grasslands and open places in Southern U. S.; dia. (.21-.39) cms; length (.48-.61) cms.; wt. (.005-.010) gms.

9. Av. dia. exceeding .50 cms.; Av. length exceeding .90 cms.; common in burrows, dens and runways in agricultural areas..................................

Eastern Woodchuck - Marmota monax, Fig. 9.

9. Av. dia. not exceeding .50 cms. nor av. length exceeding .90 cms.. 10

10. Mostly acuminate; diameter (.32-.88) cms; length (.80-2.10) cms.; wt. (.02-.10) gms.; commonly found in the open fields of the great plains region........

Prairie Dog - Cynomys ludovicianus, Fig. 8.

10. Mostly fusiform.................................... 11

11. Gray-brown to brown; dia. .50 cms. (.46-.53); length .83 cms. (.62-1.26); wt. .025 gms. (.020-.047); commonly found near fence-corners, decayed trunks and rocky shelters in forests...............

Easter Chipmunk - Tamias striatus, Fig. 9.

11. Darker, usually brown to black; dia. (.24-.50) cms.; length (.45-.95) cms.; wt. (.02-.08) gms.; commonly found in stumps, hollow trees and nests in forested areas.................................

Eastern Red Squirrel - Sciurus hudsonicus, Fig. 8.

Eastern Gray Squirrel - Sciurus carolinensis, Fig 8.

Northern Fox Squirrel - Sciurus niger. Fig. 9.

12. Greenish-yellow to brown; presence of whitish deposit of urates on many of the droppings indicating bird feces; commonly found in good cover in agricultural and forested lands in small clearings. 13

12. Not possessing a whitish deposit of urates......... 14

13. Irregularly circular, cylindrical or acuminate; lumpy and twisted appearance usually...............

Ringed-nedked Pheasant - Phasianus colchicus torquatus, Fig. 12, 15, and 19. Av. Dia. 84 cms. (.70-.91); av. length 1.76 cms. (1.39-2.02); av. wt. .22 gms. (.15-.61) commonly found in clearings in

overgrown brushy types in agricultural areas.
Domestic chicken - Gallus domesticus, Fig. 12 and 18. Measurements similar to pheasant but more variable generally; may be either irregular or regularly cylindrical; can be definitely associated with chicken-house odor.
Domestic Pigeon - Columba livia, Fig. 18; usually compressed laterally; av. dia. .89 cms. (.70-1.05); av. length 1.27 cms. (1.05-1.83); av. wt. .15 gms. (.12-.21); found in cities on building ledges and rooftops.

13. Mostly regularly cylindrical; smoother than above.
Ruffed Grouse - Bonasa umbellus umbellus, Fig. 12 and 19. Av. Dia. .77 cms. (.50-.88); av. length 1.75 cms. (1.41-3.02); av. wt. 1.25 gms. (.07-.42); commonly found in thickly- wooded regions near water margins or base of tree.

14. Composed of a matted mass of fur, hair or feathers together with bones; almost always containing no other indigested food material; distinguished from some similar carnivorous feces by a lesser degree of compactness, lack of furrowed appearance, and ease of separation into the component parts......... 25

14. Not usually composed of a matted mass of fur, hair or feathers together with bones; but if so, containing other undigested food material, more compact and

harder to separate into the component parts than above.. 15

15. Light-brown ovoid; composed of easily discernible gross vegetative fibers; av. dia. 2.35 cms. (1.92-3.07); av. length 3.13 cms. (2.39-4.58); av. wt. 1.23 gms. (.96-4.42); only occasionally encountered; along streams and shallow ponds and in the water in forested areas..................
Canadian Beaver - Castor canadensis.

15. Not an ovoid mass composed of grass vegetative fibers.
.... 16

16. Regularly flattened sphere; av. dia. 1.30 cms. (.80-1.40); av. thickness .87 cms. (.60-.95); av. wt. .18 gms. (.13-.32); summer pellets; brown to light-brown with "pepper and salt" markings.......
Cottontail Rabbit - Sylvilagus floridanus, Fig. 10.
Snowshoe Rabbit - Lepus americanus.

16. Not a regularly flattened sphere.................. 17

17. Composition more or less consisting of a homogeneous herbaceous character; no skin, hair or bones present in the feces........................ 18

17. Composition heterogeneous; skin, hair, bones, insect parts, seeds, and other materials may be present.. 23

18. Longitudinal axis well defined and exceeding 1.5x the horizontal axis............................ 19

Longitudinal axis not as well defined and not exceeding 1.5x the horizontal axis.............. 21

19. Decidedly fusiform or spindle-shaped; thicker at the center and tapering towards the ends.....

Prairie Dog - Cynomys ludovicianus, Fig. 8, dia. (.32-.88) cms., length (80-2.10) cms.; wt. (.1-.2) gms.; commonly found in the open fields of the great plains region.

Eastern Woodchuck - Marmota monax, Fig. 9, dia. (.59-.1.00) cms.; length (1.00-2.12) cms; wt. (.10-.34) cms.; common in burrows, dens and runways in agricultural areas.

Hoary Marmot - Marmota caligata, Fig. 9, av. dia. .85 cms. (.70-1.00); av. length 1.48 cms. (1.20-2.12); wt. .22 gms. (.13-.34); found in burrows and dens in mts. of Western U.S.

19. Not definitely fusiform or spindle-shaped; mostly regularly to irregularly cylindrical............. 20

20. Av. Diameter usually not exceeding .60 cms., av. wt. not exceeding .25 gms.; typical rat-like pellets..

House Rat - Rattus norvegicus, Fig. 8, dia. (.32-.60); length (1.27-1.94) cms.; wt. (.11-25) gms.; common everywhere near dwellings, barns, wharves, storehouses, cellars, grain houses, etc.

Muskrat - Ondatra zibetheca, dia. (.29-.48) cms.; length (.47-2.50) cms.; wt. .05-.20 gms.; common on small piles of mud and vegetative islands in marshy ponds and sluggish streams.

20. Av. diameter usually exceeding .60 cms. and wt. usually exceeding .25 gms........................

Virginia Deer - Odoicoileus virginianus, Fig. 11, 16, and 20. Av. dia. .75 cms. (.50-1.58); av. length 1.42 cms. (.66-1.92); av. wt. .56 gms. (.17-.98 gms.); common in forest runways.

Canada Porcupine - Erethizon dorsatum, Fig 9, dia. (.80-1.01) cms; length (.90-1.79) cms; wt. (.04-.92) gms.; less common than above; near dens and food trails in forested areas.

21. Regular short cylinder, ends rounded fairly abruptly, av. dia. 1.49 cms. (1.36-1.65); av. length 1.92 cms. (1.60-2.16); av. wt. .78 gms. (.50-1.02); may be found in mountains, forests or plains, very rarely..

American Elk - Cervus canadensis, Fig. 11, 16.

21. Not a regular short cylinder........................ 23

22. Usually irregularly fusiform to acuminate; av. dia. 1.0 cms. (.78-1.10) av. length 1.34 cms. (1.28-1.69); av. wt. 23 gms. (15-55); found in the western region of the U.S. on barren rolling plains (not in forests or high mountains)..................

Pronghorn Antelope - Antilocapra americana, Fig. 11 and 16.

22. Very variable in shape, irregularly faceted, acuminate oblongate or circular; av. dia. 1.05 cms. (.50-1.47); av. length 1.29 cms. (.98-1.84); av. wt. .26 gms. (.12-.87); domestic; commonly found in pastures in cultivated fields...........

Domestic Sheep - Avis aries, Fig. 11, 15 and 18.

23. Narrowly cylindrical with a spirally twisted appearance......................................

Common Mink - Mustela vison, Fig 14, dia. (.3-.10) cms.; length (2.0-6.9) cms.; wt. (.31-1.70) gms.; composed of small mammalian remains, crawfish, fish and birds; found near banks or streams or lakes; hard to distinguish from weasel feces but may be larger, may contain crawfish and fish, and is generally found near water margins.

Bonaparte Weasel - Mustela cicognani, Fig. 14, and 15, dia. (.40-.89) cms., length (1.84-5.71) cms.; wt. (.2-1.0) gms.; composed of mice, shrew and rabbit remains, occasionally birds and reptiles; found in dense thickets, under logs and hollow stumps, and along fences; may be distinguished from mink feces by the smaller size, absence of crawfish and fish, and location.

23. Not narrowly cylindrical with a spirally twisted appearance.. 24

24. Irregularly massive; wt. 10 grams or over; dia. (3.21-6.10) cms; composed of mice, small mammals, frogs, fish, insects, fruits and berries; found in wooded areas near dens, fallen trees and rocky shelter; in spring and summer the prominent fruit pits wherever they are available serve as a means of ready identification..........................
American Black Bear - Euroctos americanus.

24. More or less cylindrical; wt. usually less than 10 grams...
Eastern Skunk - Mephitis nigra, Fig. 13 and 17.
Dia. (1.17-1.82) cms.; length (3.10-5.74) cms.; wt. (1.62-7.31) gms.; composed of insects, small mammals, grains and fruits; found in fence-rows, hollow trees, deserted woodchick burrows, and fruit patches; ordinarily distinguished from other feces by the predominance of indigestible insect parts, dark-brown to black color, commonness of occurence in agricultural areas, and by the occasional presence of skunk hairs.
Eastern Raccoon - Procyon lotor, Fig. 14 and 16.
Dia. (1.05-3.22) cms.; length (2.66-5.26) cms., wt. (3.03-10.00) gms.; composed of mice, fish, mollusks, fish, nuts, fruit and herbaceous plants;

found under trees, banks of streams and lakes, and exposed on the forest floor; usually larger than skunk droppings, often deep-red to brown color.

Virginia Oppossum - Didelphis virginiana, Fig. 14 and 15. Dia. (.80-1.85) cms.; length (1.04-4.37) cms.; wt. (.87-.1.89) gms.; composed of mice, birds, fruits and berries, and insects; found commonly along fence-rows in agricultural fields, and in open positions in woodlots.

Red Fox - Vulpes fulva, Fig. 14 and 17. Dia. (.80-.1.92) cms.; length (2.56-8.17) cms.; wt. (1.04-5.50) gms.; composed of mice, rats, rabbits, shrews and other small mammals, fruits, insects and birds; found along definite feeding paths, truck trails, clearings, and near dens; turns ashy-gray after exposure as do the feces of the other members of the Canidae; usually more compact and cylindrical than oppossum or skunk feces.

Coyote - Canis latrans, Fig. 16, dia. (1.35-2.69) cms.; length (3.87-6.30) cms.; wt. (5.15-10.83) gms.; composed of rodents, rabbits, deer, domestic stock, carrion, lizards, snakes, insects, birds, and fruits; may be distinguished from fox feces by its larger diameter and its more concealed location near trees or logs on the edges of timbered areas.

Dog - Canis familiaris, dia. (.90-3.42) cms.; length (1.67-6.87); wt. (3.0-11.2) gms.; heterogeneous composition; common everywhere frequented by man; often mistaken for raccoon, fox, coyote and other carnivorous droppings; so variable in size and composition according to the breed of the dog that little qualitative characters can be given.

Common Badger - Taxidea taxus. Dia. (1.9-2.1) cms.; length (4.5-6.5) cms.; wt. (.91-10.2) gms.; composed of mice, ground squirrels, rabbits, red squirrels, insects, birds and eggs, and insects, found near burrows in open forested areas; not as common as fox or coyote droppings, but very similar in appearance.

Bobcat - Lynx rufus, dia. (1.41-2.06) cms.; length (3.97-6.43) cms.; wt. (4.00-8.50) gms.; composed of rodents, rabbits, birds, stock and occasionally snakes and frogs found in deep, damp sheltered woods; not common.

Domestic Cat - Felis domestica, Fig. 1. dia. (1.13-1.70) cms.; length (1.35-7.28) cms., wt. (2.1-7.3) gms.; composed of rodents and birds in the wild state; not commonly found as feces are generally buried; very strong disagreeable odor when fresh and often persisting for weeks.

25. Bones which may be present usually broken into very small fragments and demonstrating a high degree of digestive action plus a tendency to tear and crush the prey captured for food........ Hawk Pellets. (Red - shouldered Hawk - Buteo lineatus lineatus, Fig. 22.

25. Bones which may be present not usually shattered into small fragments and demonstrating a good degree of preservation.......................... Owl Pellets. (Wilson (1938) in his owl studies at Ann Arbor, Michigan found that he could identify typical pelletal shapes of the different species of owls. From a brief consideration of sizes, weights and form of owl pellets collected from wild and captive birds by the writer, it was evident that the shapes are so varied and the sizes so overlapping in the case of most of the common species that the direct observation of the nesting birds is the only method of certain identification. The following measurements show the maximum and minimum sizes observed in some of the common species of owls: (No. in parenthesis indicates no. of pellets measures).

Barn Owl - Tyto alba pratincola (52), Fig. 21, and 23. Dia. (1.8-2.7) cms.; length (2.9-9.3) cms.; wt. (1.5-9.3) gms.

Great Horned Owl - _Bubo virginianus virginianus_, (14) Fig. 22. Dia. (2.7-4.6) cms.; length (5.4-9.7) cms.; wt. (10.8-19.8) gms.

Short-eared Owl - _Asio flammeus flammeus_, Fig. 24. Dia. (1.7-3.1) cms.; length (1.0-6.9) cms.; wt. (4.1-10.9) gms.

Long - eared Owl - _Asio wilsonianus_, (.7), dia. (1.55-3.52) cms.; length (2.65-6.27) cms.; wt. (1.20-8.87) gms.

Eastern Screech Owl - _Otus asio naevius_, (45) dia. (.96-1.71) cms.; length (1.29-3.40) cms.; wt. (.78-3.96) gms.

Northern Barred Owl - _Strix varia varia._ (11) dia. (2.4-2.8) cms.; length (4.4-5.9)cms. wt. (4.2-7.8) gms.

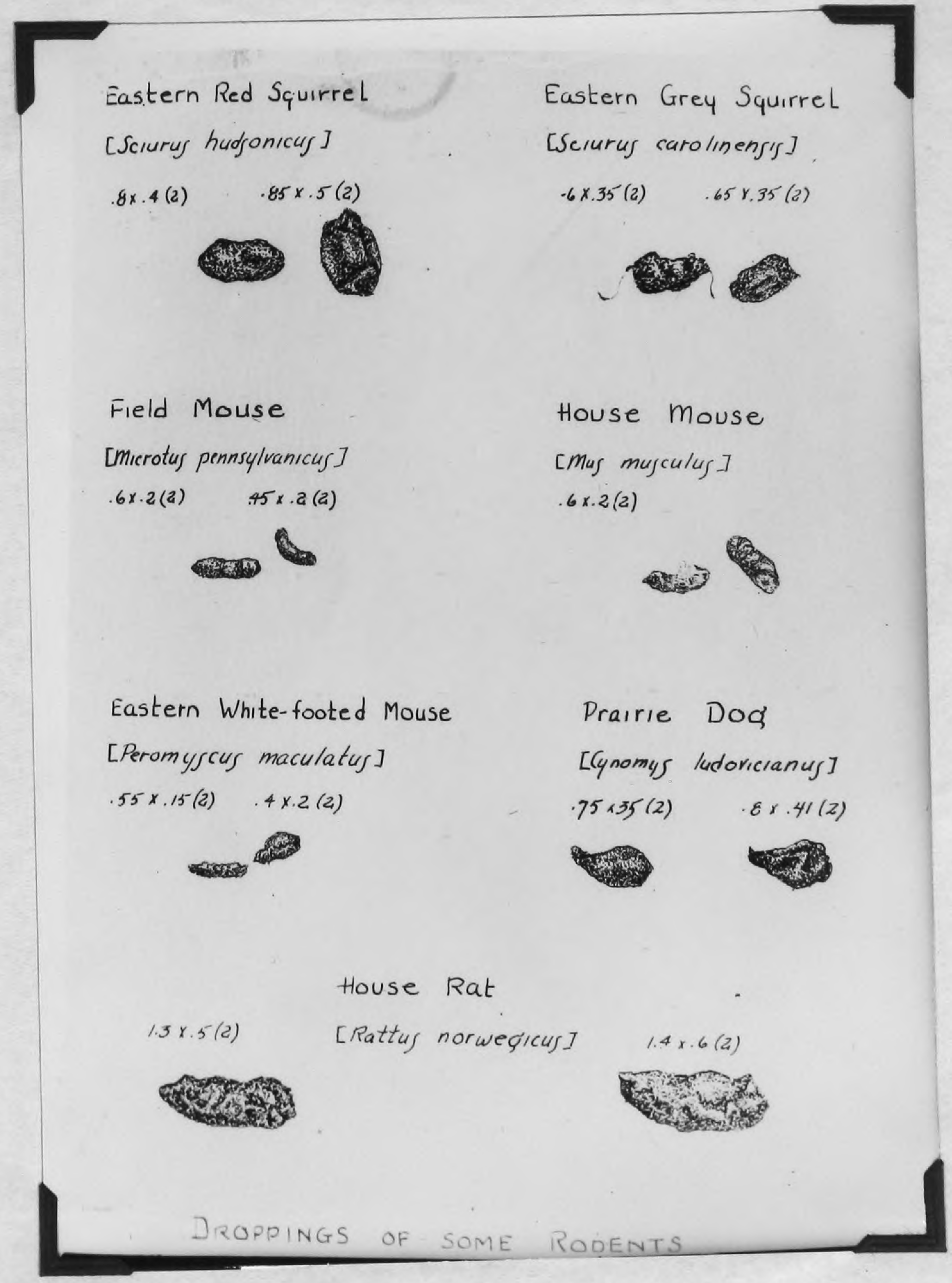

Eastern Red Squirrel
[Sciurus hudsonicus]
.8x.4(2) .85x.5(2)
Eastern Grey Squirrel
[Sciurus carolinensis]
.6x.35(2) .65x.35(2)
Field Mouse
[Microtus pennsylvanicus]
.6x.2(2) .45x.2(2)
House Mouse
[Mus musculus]
.6x.2(2)
Eastern White-footed Mouse
[Peromyscus maculatus]
.55x.15(2) .4x.2(2)
Prairie Dog
[Cynomys ludovicianus]
.75x.35(2) .8x.41(2)
House Rat
[Rattus norwegicus]
1.3x.5(2) 1.4x.6(2)
DROPPINGS OF SOME RODENTS

Figure 8

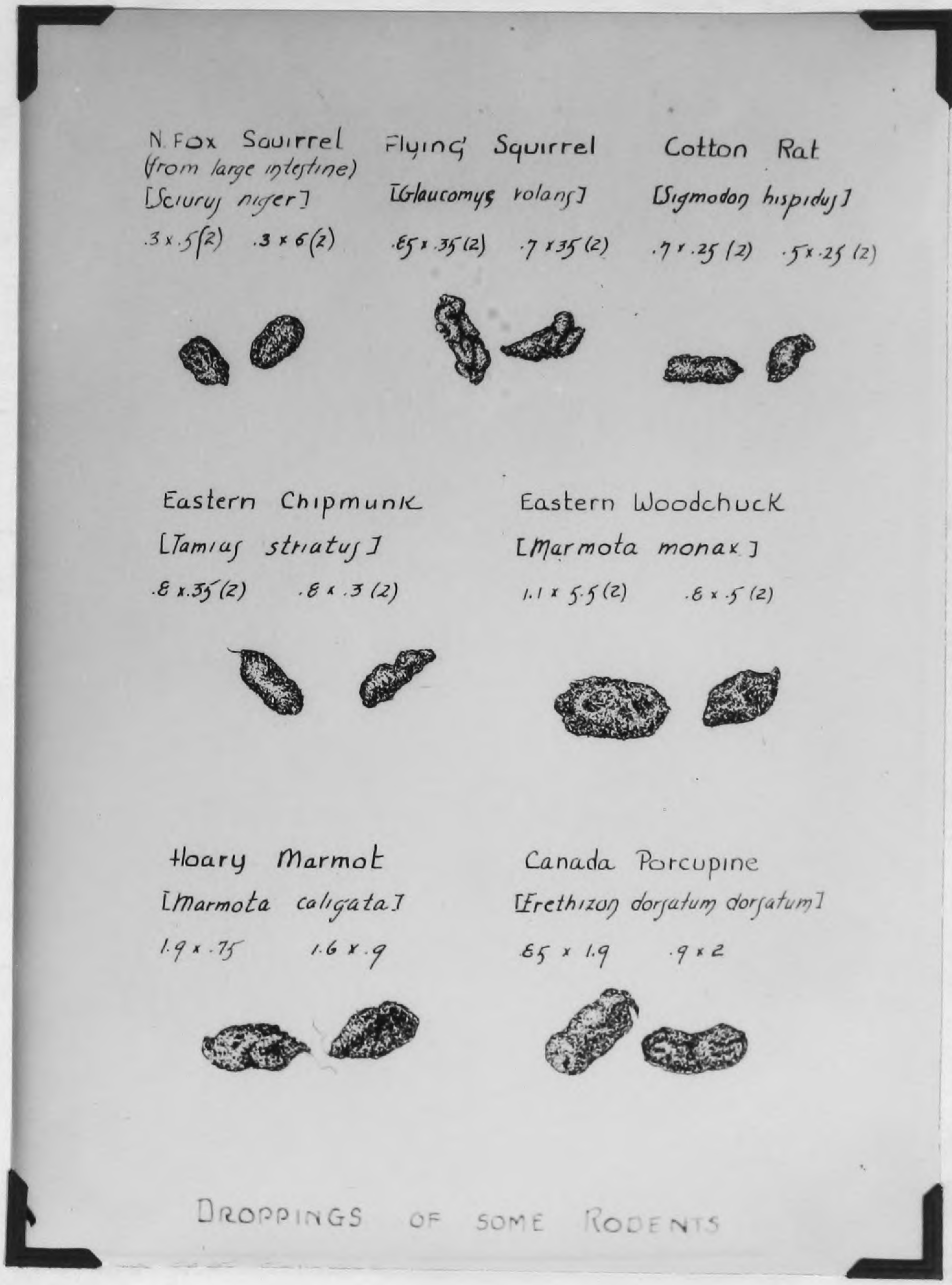
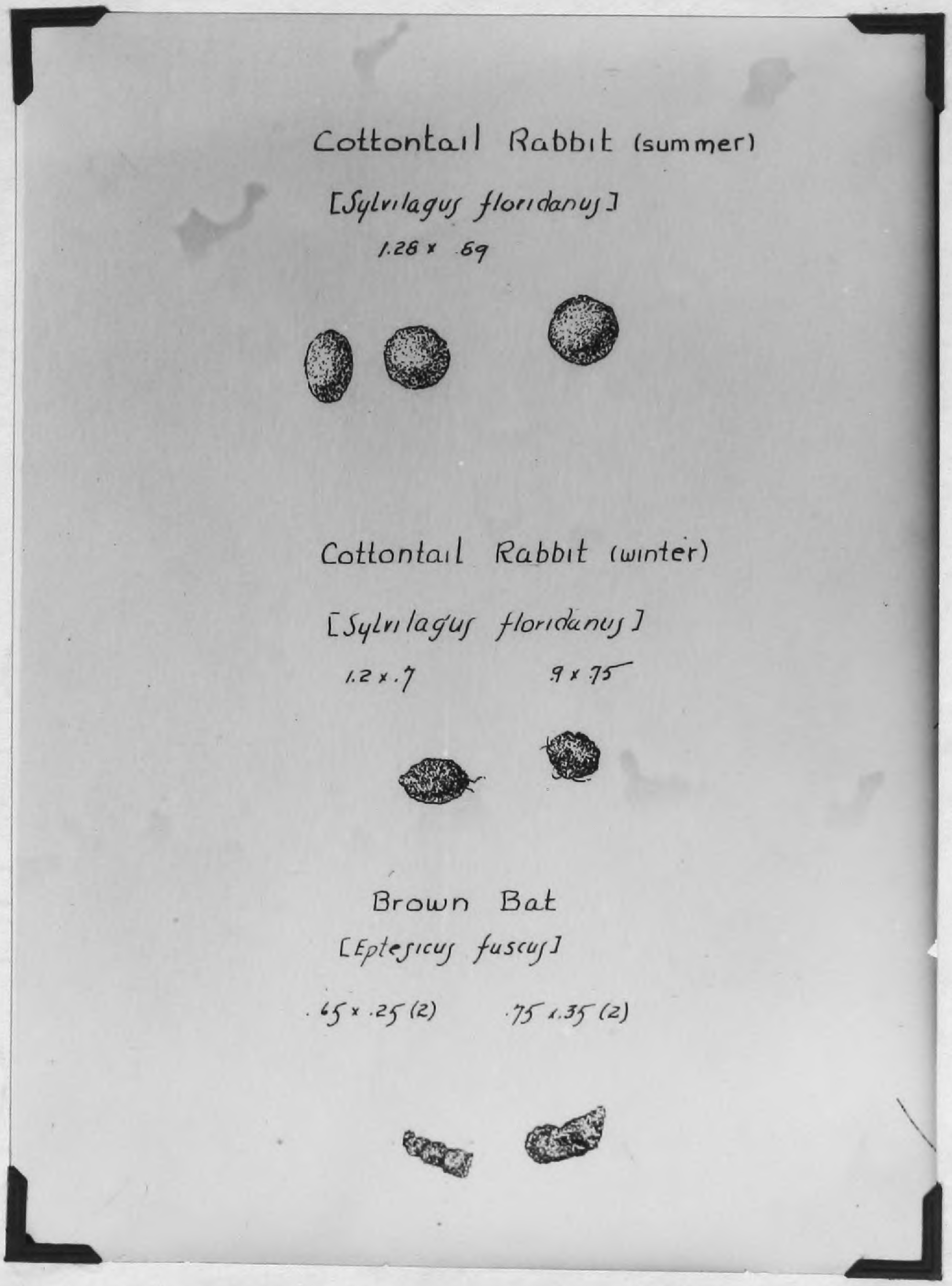

N. Fox Squirrel
(from large intestine)
[Sciurus niger]
.3 x .5(2) .3 x 6(2)
Flying Squirrel
[Glaucomys volans]
.65 x .35(2) .7 x 35(2)
Cotton Rat
[Sigmodon hispidus]
.7 x .25 (2) .5 x .25 (2)
Eastern Chipmunk
[Tamias striatus]
.8 x .35(2) .8 x .3 (2)
Eastern Woodchuck
[Marmota monax]
1.1 x 5.5(2) .8 x .5 (2)
Hoary Marmot
[Marmota caligata]
1.9 x .75 1.6 x .9
Canada Porcupine
[Erethizon dorsatum dorsatum]
.65 x 1.9 .9 x 2
DROPPINGS OF SOME RODENTS

Figure 9



Cottontail Rabbit (summer)
[Sylvilagus floridanus]
1.28 x .69
Cottontail Rabbit (winter)
[Sylvilagus floridanus]
1.2 x .7
.9 x .75
Brown Bat
[Eptesicus fuscus]
.65 x .25 (2)
.75 x .35 (2)

Figure 10

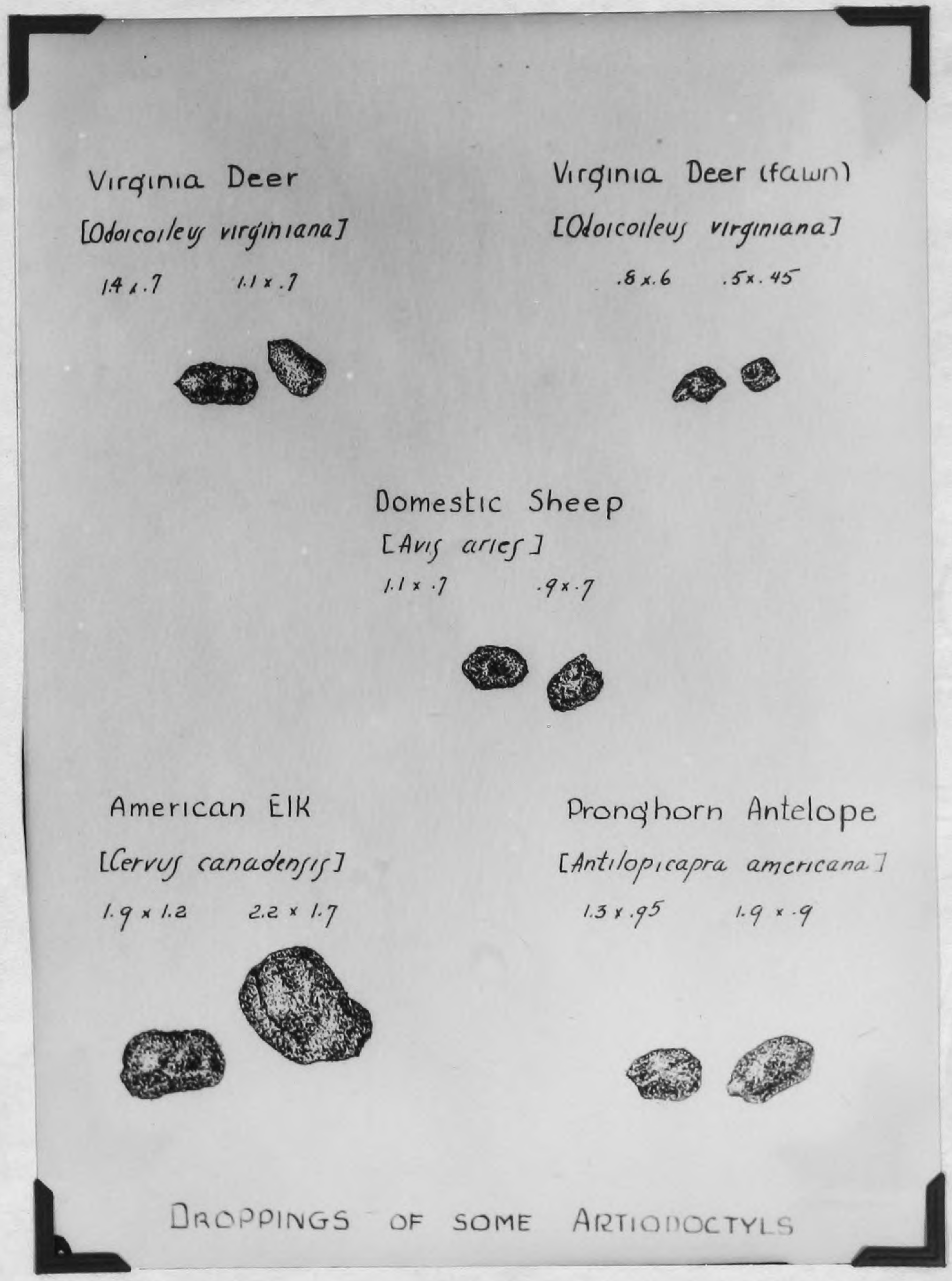

Virginia Deer
[Odoicoileus virginiana]
1.4 x .7
1.1 x .7
Virginia Deer (fawn)
[Odoicoileus virginiana]
.8 x .6
.5 x .45
Domestic Sheep
[Avis aries]
1.1 x .7
.9 x .7
American Elk
[Cervus canadensis]
1.9 x 1.2
2.2 x 1.7
Pronghorn Antelope
[Antilopicapra americana]
1.3 x .95
1.9 x .9
DROPPINGS OF SOME ARTIODOCTYLS

Figure 11

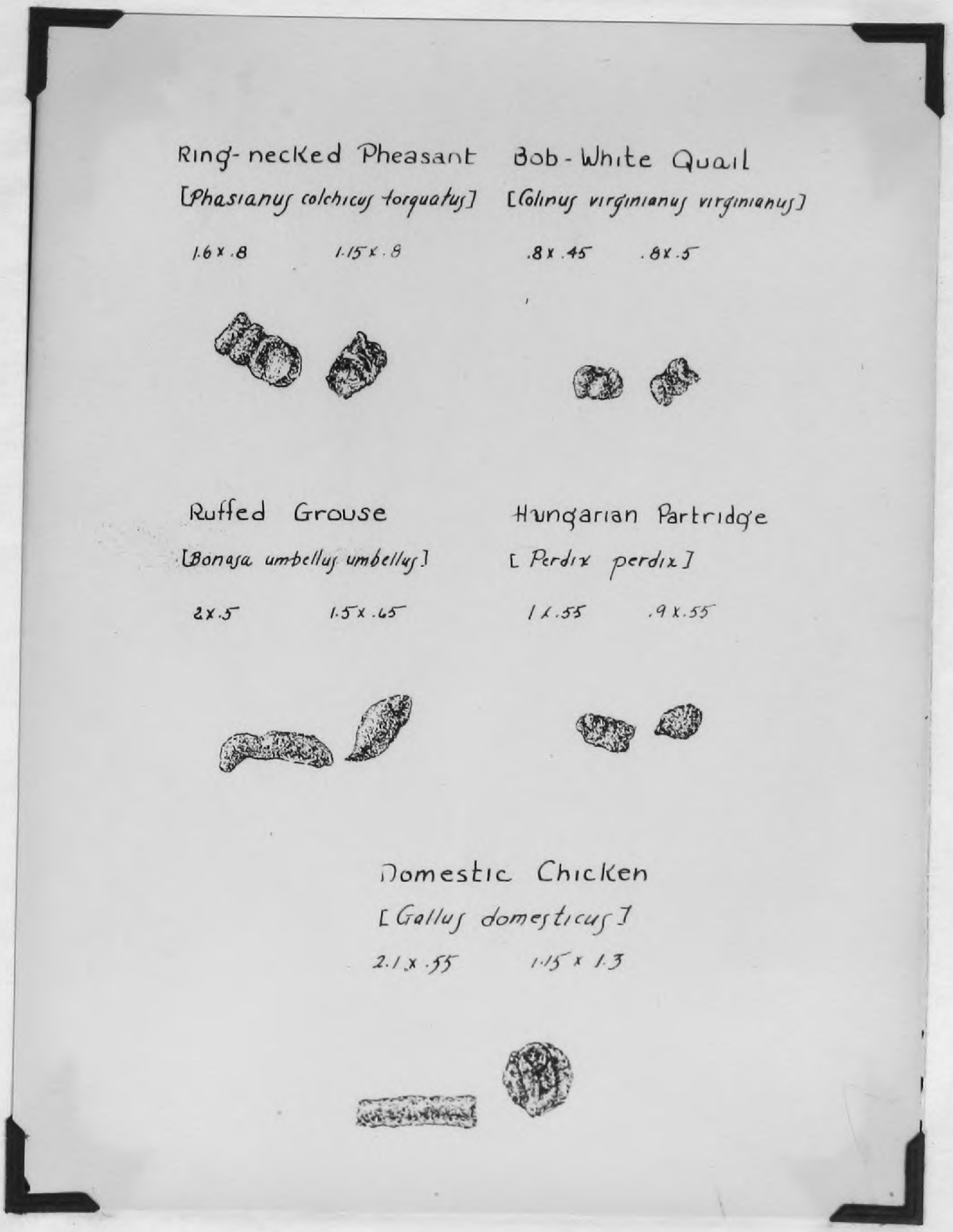

Ring-necked Pheasant
[Phasianus colchicus torquatus]
1.6 x .8
1.15 x .8
Bob-White Quail
[Colinus virginianus virginianus]
.8 x .45
.8 x .5
Ruffed Grouse
[Bonasa umbellus umbellus]
2 x .5
1.5 x .65
Hungarian Partridge
[Perdix perdix]
1 x .55
.9 x .55
Domestic Chicken
[Gallus domesticus]
2.1 x .55
1.15 x 1.3

Figure 12

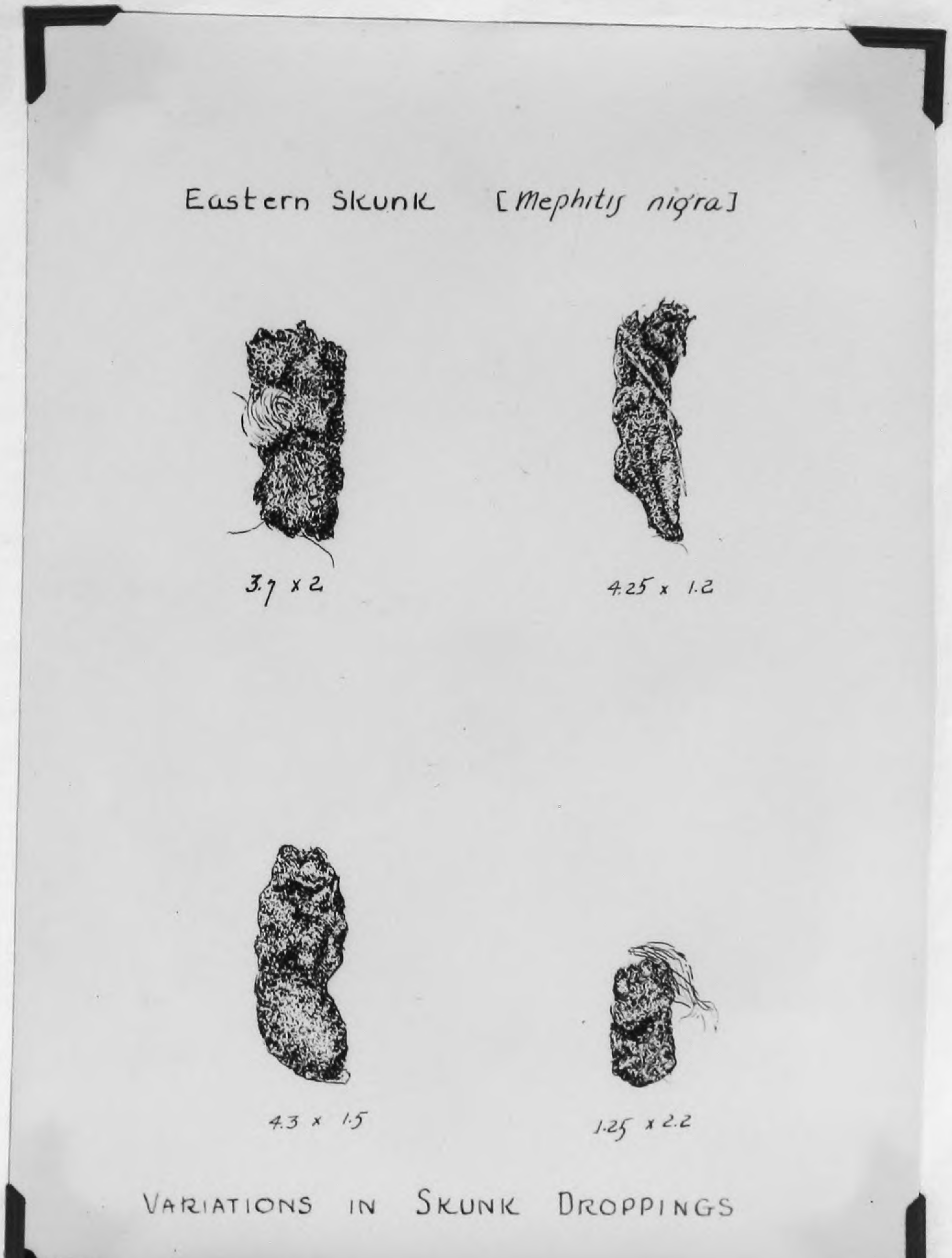

Eastern Skunk [Mephitis nigra]
3.7 x 2
4.25 x 1.2
4.3 x 1.5
1.25 x 2.2
VARIATIONS IN SKUNK DROPPINGS

Figure 13

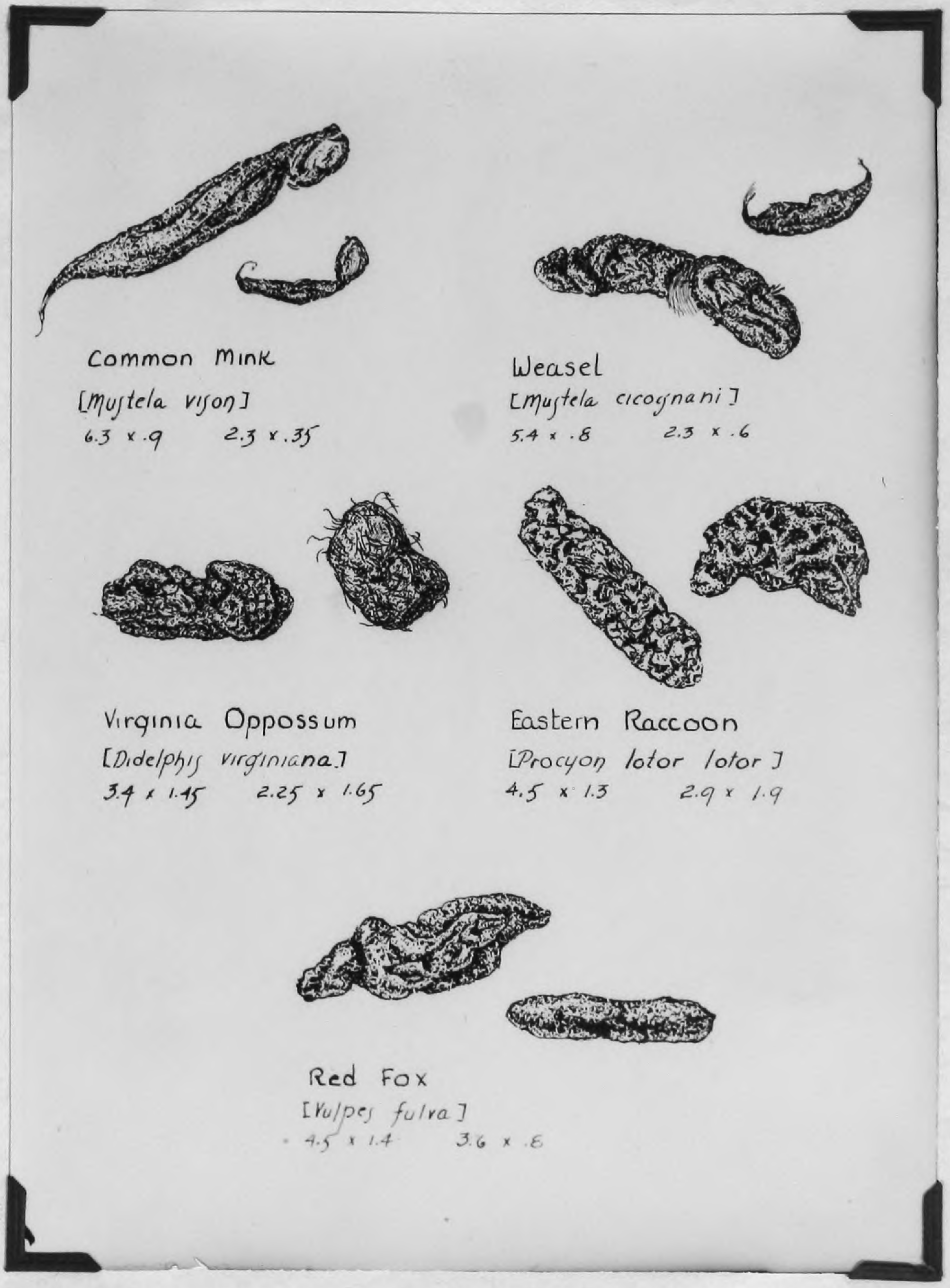

Common Mink
[Mustela vison]
6.3 x .9 2.3 x .35
Weasel
[Mustela cicognani]
5.4 x .8 2.3 x .6
Virginia Oppossum
[Didelphis virginiana]
3.4 x 1.45 2.25 x 1.65
Eastern Raccoon
[Procyon lotor lotor]
4.5 x 1.3 2.9 x 1.9
Red Fox
[Vulpes fulva]
4.5 x 1.4 3.6 x .8

Figure 14

C B A

E D

G F

Figure 15

Scale on photograph is equivalent to 5 cms. Miscellaneous droppings: A - Weasel, B - Porcupine, C - Red squirrel, D - Ruffed Grouse, E - Pheasant, F - Opposum, G - Sheep.

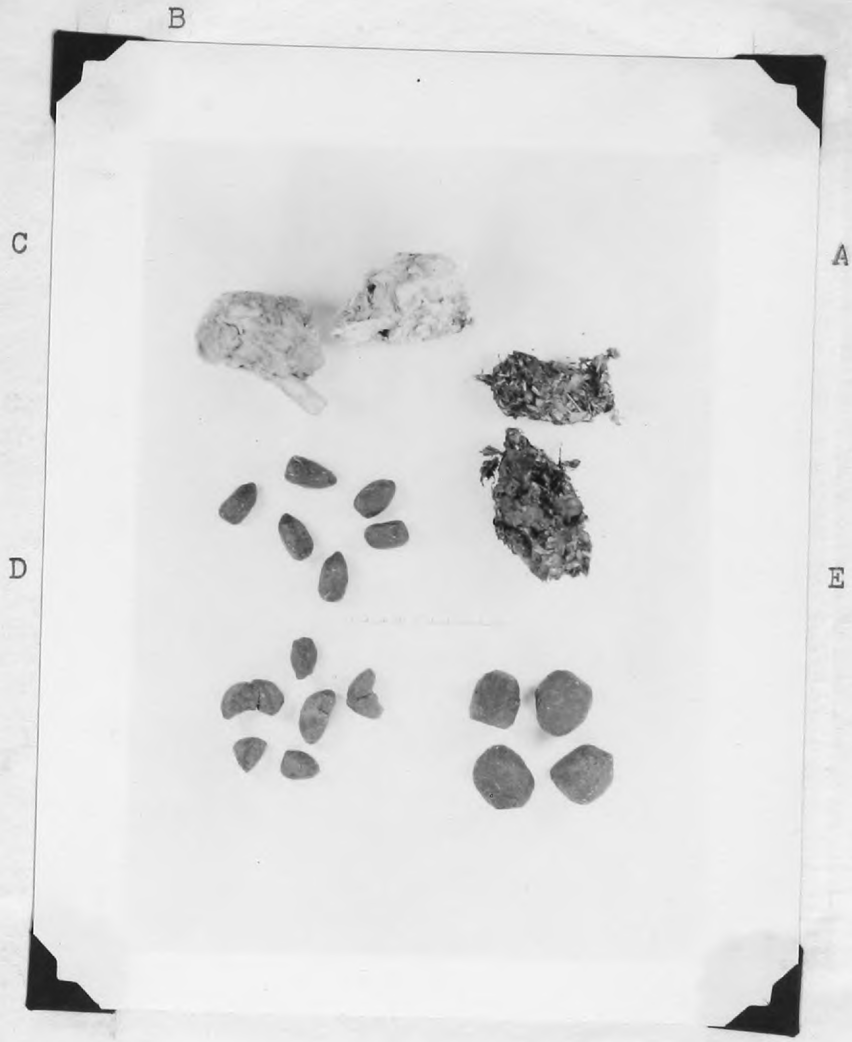


Figure 16

Scale on photograph is equivalent to 5 cms. Miscellaneous droppings: A - Raccoon, B - Coyote, C. - Deer, D. - Antelope, E - Elk.

A B

C E

F^1 F

Figure 17

Scale on photograph is equivalent to 5 cms. A - House Mouse, B - E. White-footed Mouse, C - Cottontail Rabbit (Winter), E - Skunk, F - Red Fox, F^1 - Red Fox fed largely on bones.

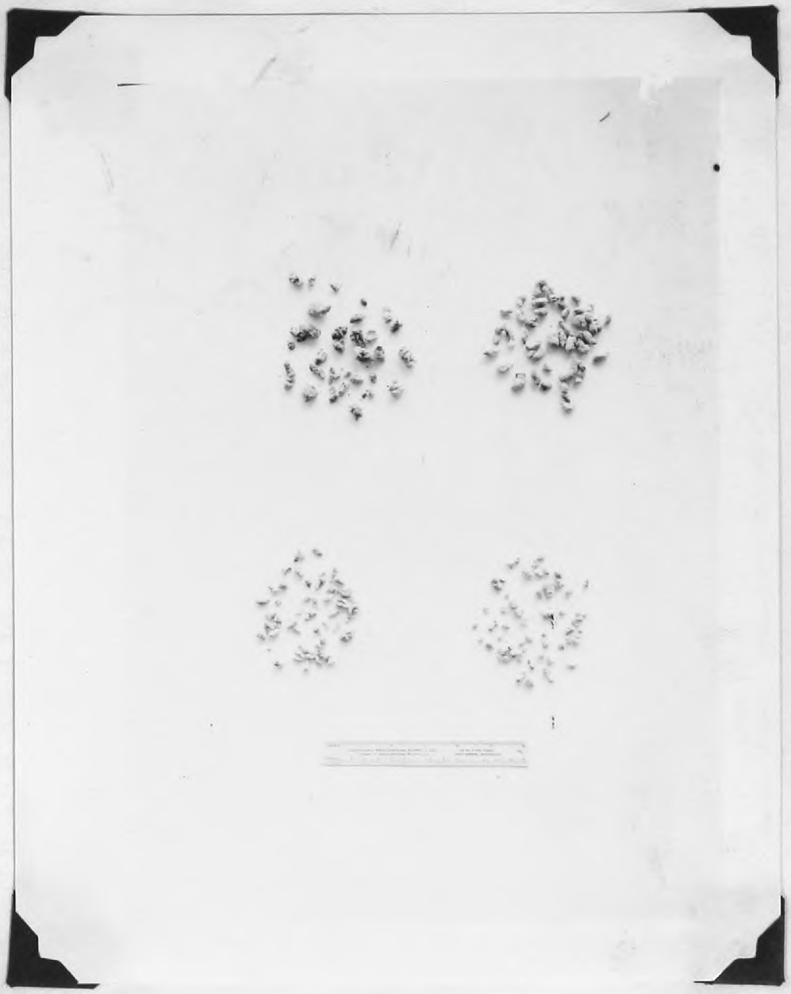
A B

C D

Figure 18

Miscellaneous Droppings: A - Guinea Pig, B - Domestic Sheep, C - Domestic Chicken, D - Domestic Pigeon.

A B



C D

Figure 19

Bird Droppings; A - Ring-necked Pheasant, B - Ruffed Grouse, C - Hungarian Partridge, D - Bob-White Quail.

Figure 20

Deer Pellets illustrating resistance to weathering. Pellets were placed in exposed location in hardwood forest area on Dec. 15, 1939. Picture was taken April 15, 1939. A one-inch layer of forest litter served to protect the pellets very successfully against any deterioration.

Figure 21

Barn Owl pellets illustrating resistance to weathering. Pellets were placed in a Scotch Pine stand on Dec. 15, 1939. Picture was taken April 15, 1939. A scanty covering of oak leaves from adjoining area and a small amount of coniferous needles kept the pellets in good condition.

Figure 22

A comparison in size of the pellets of the Great Horned Owl and the Red-shouldered Hawk. (Larger pellet is that of the Great Horned Owl.)

Figure 23

Variations in sizes in pellets of the Barn Owl. Note the mice skulls and bones in the center pellets.

Figure 24

Pellets of the Short-eared Owl collected April 16, 1939 near nest in the vicinity of the Ann Arbor Golf Course.

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← Barcode, preceding