Pattern correlation of mammalian teeth as a means of identification
by Charles L Buck

A THESIS Submitted to the Graduate Committee In partial fulfillment of the requirements for the degree of Master of Science in Zoology at Montana State College
Montana State University

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Several skulls of each species were closely examined and photographs were made. Approximately fifty-five species were studied. Comparisons were made throughout.

In nearly all cases, the family could be recognized easily. In the Order Rodentia, the genera and even species could be determined by their teeth patterns. In a number of cases, the teeth pattern was altered by excessive wear and age. Caution should be exercised along this line when teeth patterns are used.

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Approved:

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Bozeman, Montana
June, 1939

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Abstract Of Thesis

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PATTERN CORRELATION OF MAMMALIAN TEETH AS A MEANS OF IDENTIFICATION

Introduction

Much work has been done on the teeth of mammals. Several phases of approach have been used in this vast field due to the great diversity of forms and structures encountered. A great amount of work has been done along the lines of structure, evolution of the teeth, homologies, and general anatomy. A person would readily understand the immensity of this field when he considers the large number of mammals in the world besides the number brought to light through paleontological records. In North America alone there are at least fifteen hundred (1500) species and sub-species today. Even though much work has been done, little specialized effort has been put for th to determine the extent in which teeth patterns may be used as a means of identification. Thus the purpose of this research is to work out a systemized study of mammalian teeth patterns and determine to what extent they may be used.

Preparation of materials

All the specimens, with the exception of one, were collected in the state of Montana. The collection represents six orders, nineteen families and fifty-one species. All together about 355 skulls were examined. My sincere appreciation is extended to M. H. Spaulding for the use of his collection in this study.

Procedure

Several sets of teeth of the same species were closely examined. The only variation found was due to age and excessive wear. Nevertheless the pattern may be easily traced from a young tooth to the older, worn tooth. Whenever possible, the set of teeth showing the most distinct pattern was selected to be photographed.

Since we are primarily concerned only about the teeth patterns, just the upper and lower right jaws were photographed. In some cases, the left jaw was photographed, when more detail could be brought out. Commercial panchromatic film was used. In the porcupine and beaver, modeling clay was inserted around the base of the teeth, hoping to bring out a sharper contrast.

Discussion

Before a comparative study is made, it would be well worth while to consider the different types of teeth, purpose of each and where each is found. The following terms apply to the molar and premolar teeth. "Brachyodont" is a term applied to teeth low crowns which cease to grow after eruption. Examples would be any of the ground squirrels. Teeth with long linear growth before the roots are formed as found in horses are known as "hypsodont". When the surfaces of the molars present blunt cones, they are termed "bunodont". These are found in the carnivores such as dogs, cats and weasels. Teeth which are lengthened out antero-posteriorly and curved as found in sheep, goat, and elk are called "selenodont". The type of tooth is usually suggestive of the animal's feeding habits but cannot always be depended upon. Tims (24) writes; "Thus the Canidae, fairly uniform as they are in dentition, have somewhat different habits: the Arctic fox, a flesh-feeder purely, has a dentition undistinguishable from the North Italian fox, which is reputed to be a vegetarian in its diet; the Canis cancrivarus of Guiana, which often possesses a fourth molar, eats small mammals, crabs, and fruit".

As the series used in this study is very incomplete, only primary or suggestive assumptions can be made. It was noted that teeth could be separated by pattern and size. In some cases of genera and species when the patterns were identical, the size separated the teeth in question. Especially in the Rodentia, the teeth patterns may be altered by excessive wear as illustrated by plate XVII. In a number of cases, the species can be identified by minute differences in teeth patterns, but these are usually lost by usage. Osgood (21) makes the following statements; "The teeth vary chiefly in size and seldom greatly. The pattern of the grinding surfaces of teeth at different stages of wear, however varies much, and in all comparisons of teeth, is to be carefully considered". In general, the species are separated by external coloration, measurements and habitat. Owens (22) writes; "Vertical folds of enamel and cement penetrate the crown of the tooth of most

Rodents and Ungulates, characterizing by their various forms the genera; but these folds never converge from equidistant points of the circumference of the crown toward its center". In the veaver/and some of the other rodents, it was noticed that the enameled surface of the incisors is of a bright orange or reddish-brown color. In some of the other rodents as the Lepus, the anterior surface is indented by a deep longitudinal groove. This character seems not to influence the food or habits of the species. It is present in one genus and absent in another of the same natural family.

In discussing plate I, we find that the shrews have a very definite teeth pattern which cannot be mistaken for any other small mammal. Tims (24) writes; "The Insectivora may be divided into groups by the pattern of their molar teeth; the majority present a W-shaped pattern and also a deep pigmentation of the outer enamel". Most genera of shrews cannot be separated by teeth patterns alone. A secondary cusp is present on the canines and incisors in some genera and absent in others. In the two genera which I have examined (Sorex and Newsorex), no distinction could be found. C. Hart Merriam (16) makes the following statements: "In defining the various species, cranial characters have proved serviceable and dental characters indispensable. The most important dental characters are the size and depths of emargination of the molariform teeth and the proportions of the unicuspidate teeth". He also adds that in studying the teeth of shrews it is absolutely essential to take into account changes due to age and wear. Certain species have been known by three specific names due to change of teeth pattern caused by excessive wear and age.

The plates II to VI inclusive are teeth of mammals belonging to the order Carnivora. The families and sub-families are easily distinguishable by their respective teeth patterns. The family Ursidae is represented by the dentition of the black bear (Euarctos americanus) on plate II. Except for the size of the skull, very little can be depended upon the teeth patterns in separation of the genera. The teeth are strongly modified by food and consequently in some cases present marked variations in the same family.

The family Mustelidae is composed of several sub-families which are Mustelinae, (Martens, Weasels, and Minks). Culoninae, (Wolverines), Lutrinae (Otters), Enhydrinae (Sea Otters), Mephitinae (Skunks) and Taxidiinae (American Badgers). According to C. D. Elliot's Synopsis Of The Mammals Of North America on pp. 318-350, the above sub-families have definite teeth patterns. However within a sub-family little variation was found except in size.

The family Felidae has a definite teeth pattern; however lack of specimens prohibited much study and comparison. The molar crowns presented sharp cutting edges.

The family Canidae includes the Wolves, Coyotes and Foxes. Except for difference in size, the teeth patterns are very similar. The teeth pattern of the fox appears to be sharper and more distinct than that of the dog.

The order Rodentia forms a very large and interesting group, especially in relation to teeth patterns. There are ten families in this order, which are easily distinguishable by their respective teeth patterns. Most of the genera could also be differentiated in the same manner.

In the family Sciuridae, seven genera were represented in my collection. This family is a closely related group. In the "Revision Of The North American Ground Squirrels, North American Fauna No. 56, pp. 35, Arthur Howell divides the family into four groups namely; (1) the ground squirrels, (2) the chipmunks, (3) the tree squirrels, and (4) the flying squirrels." The different pattern forms agree very well with the above grouping.

The genus Marmota, (Woodchucks) is easily recognizable because of its size. Four skulls were observed with no variation present. Beyond the genus, little use of the teeth patterns are made. The upper molars are heavy, subquadrate, and brachydont, with heightened inner cones. On the last upper molar, the lateral cones converge posteriorly. (VII). The genus Callospermophilus (Say Ground Squirrel) is very closely related to the genus Citellus but can be separated

Fig. 1.—— Upper tooth row of *Ondatra zibethica*.

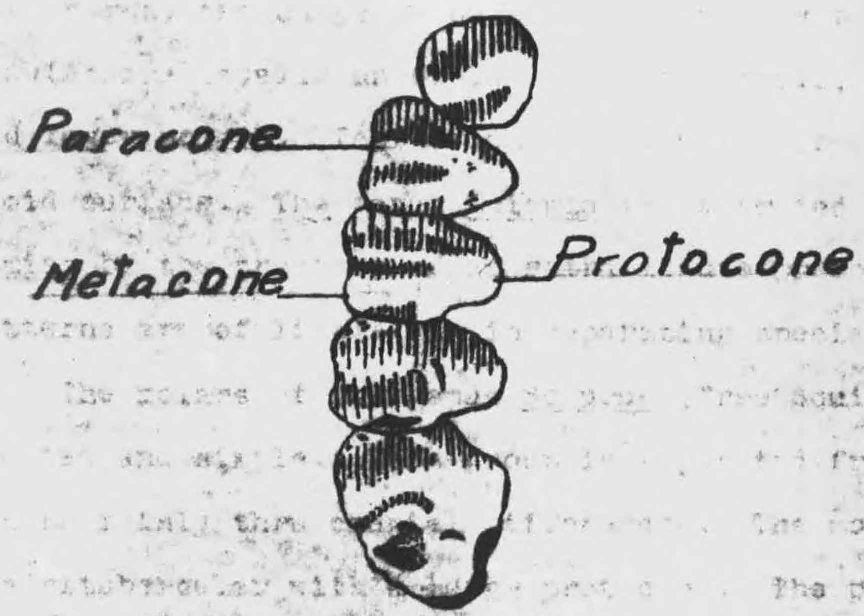

Fig. 2.—Upper tooth row of *Citellus richardsonii*

from the latter by the fact that paracone and the metacone are intercepted at a sharper angle at the base by the protocone. The first upper premolar of the genus Callospermophilus is much smaller than in the genus Citellus. The angles formed by the paracone, metacone and protocone tend to be rounded out. A large number of Citellus species were examined but no distinctions could be made. The Cynomys (prairie dogs) can be easily distinguished from the Citellus in that the teeth are relatively much larger. The molariform teeth with protocone are much more hypodont; and the crown of the last upper molar with well developed mesostyle and accompanying additional transverse ridge (pl. X).

The chipmunk genera (Tamias and Eutamia) are easily separated from the others. The molars are weak and with very low crowns, the cusps on outer border widely spaced. Metaconules are usually undeveloped or very small, on both upper and lower molars. Teeth when worn usually present a smooth ovoid surface. The genus Eutamia is separated from the genus Tamias by the presence of an extra minute premolar. Teeth patterns are of little use in separating species.

The molars of the genus Sciurus (Tree Squirrels) are low crowned and simple. This group is separated from the other genera mainly through cranial differences. The molar crowns are quadritubercular with a large protocone. The pattern of the genus Glaucomys (Flying Squirrels) is quite different from other genera of this family in that the cusps on the outer side of the upper tooth row are higher and are without subsidiary cusplets; the fourth premolar is subquadrate and nearly as large as the first molar, with the parastyle ridge rising to form a cusp.

The family Heteromyidae is represented by Dipodomys ordii (kangaroo rat). The crowns are smooth but the exterior margins of enamel follow definite contours. According to Elliot, the different genera have different exterior contours. The three skulls of the above species which I examined showed no variations.

The family Geomyidae (Pocket Gophers) are represented by two species of the genus Thomomys. The patterns are similar in type to the Kangaroo Rat but of much larger size and follow different contours. Bailey (2) writes; "Throughout the genus Thomomys there is a surprising uniformity of tooth form and enamel pattern in the molariform teeth; while many minute variations furnish distinctive specific characters, the necessity of studying them with lens renders them inconvenient for general use, and they rarely serve to separate closely related forms". Of the two species examined, there is a distinct difference in the shape of the last molars on both upper and lower jaws.

The family Castoridae takes in all the beavers with the exception of the mountain beavers. Only one species was studied and no variations were found in the patterns. Because of its size and type of pattern it could not be mistaken for any other mammal.

The upper molars which are subequal have a flat crown with one inner and two outer enamel folds.

Only one species was examined belonging to the family Erethizontidae (Porcupine). Usually three cavities are left on the outer and one on inner side of the upper teeth due to wearing away of the cement. The teeth are somewhat larger than those found in the Castoridae (pl. XV).

The family Cricetidae which includes the native rats and mice, is a large and important one and offers much diversity in teeth patterns. For the most part, the molar crown patterns composed of tubercles arranged in two primary longitudinal rows, or made up of angular figures. The first two genera that will be considered are <u>Onychomys</u> (Grasshopper Mice) and <u>Peromyseus</u> (White-footed Mouse). Both have the tubercle arranged in two primary longitudinal rows. The teeth of the <u>Peromyseus</u> are somewhat larger, the tubercles higher and more sharply defined than those possessed by the <u>Onychomys</u> (pl. XXI). However with wear the teeth patterns change constantly. The genus <u>Neotoma</u> (Wood Rats) consist of three subgenera under which seventy species and subspecies are recognized. Goldman (5) writes; "In tracing the relationships of the species, color and size are of much less importance than cranial modifications. Besides the general form of the skull, the chief characters of taxonomic value are the following: Comparative size of anterior and posterior molars; depth and arrangement of reentrant angles in molar crown; and, length of molariform tooth rows". He also lists some cranial characters used. The crowns of the teeth are prismatic and flat. The enamel folds are not closely crowded and the reentrant angles are very long. In this genus the first and second upper molars have the enamel loops individed and the third lower molar with two transverse enamel loops (not S-shaped as in all the other genera of the subfamily Neotominae). One must be careful of the change brought about by excessive wear as illustrated by pl. XVII.

Genus *Evotomys* (Red-bodied Mouse) also has triangular flat crowns. The front upper molar has five exterior and interior triangles; middle upper molar with four while the back upper molar has seven triangles, three exterior and four interior. Beyond genus, teeth patterns are of little value. Genus *Microtus* (Meadow Mice) embraces many forms which are difficult to differentiate. The molar patterns are flat and triangular, similar to Genus *Evotomys*. This genus is composed of nine subgenera which are separated by teeth patterns along with certain other characters. Then the subgenus *Microtus* is again divided into ten groups using teeth patterns along with other characters. It is very obvious then that teeth patterns are quite important in separating species and subspecies in this genus, (pl. XIX). Again caution should be exercised in using teeth patterns. Several specimens should be examined to avoid the danger of being led astray by abnormal molar patterns, for even the widest ranges of subgeneric differences are sometimes covered by individual variation or abnormal teeth pattern. Because of the great number of variations in this genus no attempt will be made to separate the subgenera. They usually vary in the number of closed triangles in certain molars. A general character common to the genus is that the inner and outer reentrant angles are nearly equal.

Genus Fiber (Muskrats) has a rather constant tooth pattern. The molars have a flat crown with triangles and loops formed by the enamel folds. The teeth are similar to the Microtus but comparatively much larger. The upper molars are described as follows: m1 with anterior loop and four closed triangles; m2 with anterior loop and three closed triangles; m3 with anterior and posterior loops and two or three closed triangles. The lower molars crowns are as follows: m1 normally with large anterior loop deeply cut by two reentrant angles; five closed triangles, and posterior loop; m2 with four closed triangles and posterior loop; m3 with three or four closed tiangles and posterior loop.

The family Muridae is represented by the species Mus musculus (House Mouse). This small group do not have any premolars. The molar crowns of the genus Mus consist of a transverse series of tubercles, three in a series longitudinally. Some forms in this family present crowns with enamel folds.

The family Zapodidae (Jumping Mice) was formerly composed of five genera which now are grouped into the one genus Zapus. This genus then is divided into five subgenera. The crown surface presents a complex, folded pattern (pl. XX). The subgenera are differentiated by the presence or absence of the upper premolar and the degree to which the enamel folds are crowded. To this extent, it is remarkably accurate.

The next order Lagormorpha includes the Hares, Rabbits and Conies. The molar patterns are quite simple and similar in this group. The family Ochotonidae (Conies) can be distinguished from the family Leporidae (Hares and Rabbits) by its much smaller size and the lower molars are deeply grooved on the sides causing the salient angles to be very prominent. Beyond this point, the molar patterns are very uniform and difficult to use. In this order, external and skull characters are of much more taxonomic value.

The order Artiodactyla contains the even-toed hoofed mammals. Two families (Cervidae and Bovidae) were represented in the collection studied. The molars have broad crowns and ridged grinding surface. As very few skulls were examined, the writer could make but limited proven distinction. Skull characters were much more obvious in determining the genus. The teeth varied much in the amount of wear which also hindered definite conclusions. The buffalo (Bison bison) can be separated from the other genera by its large rectangular molar crown and the crescent ridges well apart.

The horse, belongs to the order Perissodactyla and family Equidae. This animal has a very definite molar pattern. In the worn tooth there are two islands of cementum upon a general field of dentine bounded by tortuous lines of enamel. Tims (24) states: "The pattern of grinding thus produced are very constant for allied species, so that an individual tooth of a herbivore may sometimes be correctly referred to its genus and always to its family."

Keys

Suggestive keys will be made for the teeth patterns studied in this paper. It must be remembered that these mammals are the more common forms found in the State of Montana and by no means a complete series. Characters used will be the size, type of teeth and enamel pattern.

Key To The Orders

A_1 Molar teeth large, crowns broad with ridged grinding surfaces; hypsodont or selenodont type; size - - 20mm. - 35mm.

B_1 Molar teeth nearly square; hypsodont -- Perissodont.

B_2 Molar teeth lengthened antero-posteriorly - Artiodactyla.

A_2 Molar teeth mostly small to medium in size, great diversity in pattern.

B_1 Molar teeth, bunodont, presenting blunt cones through out; well developed canines; wide range in size -- Carnivora.

B_2 Molar teeth not bunodont and without well developed canines.

C_1 Supporting incisors present; upper molars twice as wide as long or nearly so --Lagomorpha

C_2 Supporting incisors absent.

D_1 Teeth with relatively flat crowns -----------------Rodentia

D_2 Teeth sharply pointed and minute in size -----------Insectivora

Order Carnivora

Key To Families

A_1 Teeth, crushing type or shearing type.

B_1 True molars with broad, flat tuberculated crowns ----Ursidae

B_2 True molars with a large compressed sharp blade with two subequal lobes, without inner cusp; upper carnassial (posterior premolar), very large with a tri-lobed blade and a small inner tubercle. ------------------------------Felidae

A_2 Teeth, crushing-shearing type.

B_1 Upper carnassial with strong blade, the middle lobe conical, pointing backwards, the anterior lobe nearly obsolete; lower carnassial with bilobed blade, compressed, the posterior lobe the larger, with two cusps and a raised lingual border. -------------------------------------Canidae

B_2 A single tubercular molar tooth on either side of both jaws; in upper molar the inner tubercular portion longest in the antero-posterior direction -----------------------Mustelidae

Order Rodentia

Key To The Families

A_1 Molars rooted.

B_1 Molars tubercular.

C_1 First upper premolar small if present; crowns relatively flat; size of tooth $1\frac{1}{2}$mm-4mm x $1\frac{1}{4}$mm-5mm ------------Sciuridae

C_2 Molar crown composed of tubercles arranged in two longitudinal rows. --Cricetidae

C_3 Three molars on each side; tubercles arranged in three longitudinal rows ------------------------------------Muridae

B_2 Molars flat.

C_1 Reentering of enamel folds in crown, usually one inner and two outer; crowns subequal and somewhat square; size-6mm x 7mm ---Castoridae

C_2 Tooth (worn) shows three parallel cavities and one salient angle on inner side; tooth more or less rounded--size 8mm x 8mm --Erethizontidae

C_3 Molar crowns flat with complex, folded pattern premolar may not be present; tooth row - 4mm long ----------Zapodidae

A_2 Molars rootless.

B_1 Molars made up of angular figures ------------------Cricetidae

B_2 Molars not made up of angular figures and crown smooth

C_1 Posterior upper and lower molars with definite groove or salient angles --Geomyidae

C_2 Posterior molars without definite groove or salient angles ---Heteromyidae

Conclusions

As the collection was very incomplete and restricted in range, only general conclusions could be made.

The extent to which teeth patterns may be used for identification varies in the different orders of mammals. Some mammals are very constant in the teeth pattern while abnormality may enter in others. It is therefore quite essential to check a number of the same species. It was also noted that teeth patterns vary as a result of wear and age. The degree of variance differed in the different mammals. In some cases, when the teeth pattern was very similar to that of another mammal, they were differentiated by a distinct difference in size.

In nearly all cases, the family could be recognized by the pattern, and in many instances to genus and even species. In the order Carnivora the families and in a few instances the genera, could be easily determined. The order, Rodentia with its large number of mammals could be quite accurately determined to genus by their teeth patterns. Orders Insectivora, Perissodactyla and Artiodactyla were recognizable to families and in a few cases to genera.

Undoubtedly with a complete series and a sufficient number of each species, a very fine study could be made and a suitable key produced.

Bibliography

1. Anthony, H. E. 1928 Field Book Of North American Mammals pp.327, 448, 458, 465.

2. Bailey, Vernon 1915 Revision Of The Pocket Gophers Of The Genus Thomomys. North American Fauna No. 39, pp.17, 32 pl. II.

3. Bailey, Vernon 1900 Revision Of The American Voles Of The Genus Microtus. North American Fauna No. 17. pp.5-80, fig. 1-17, pl. III, V.

4. Elliot, D. G. 1901 A Synopsis Of The Mammals Of North America. fig.12-91.

5. Goldman, E. A. 1910 Revision Of The Wood Rats Of The Genus Neotoma. North American Fauna No.31 pp.13, 20; pl. I-VIII.

6. Hollister, N. 1916 A Systematic Account Of The Prairie Dogs. North American Fauna No.40. pp.10, 11, 12 pl. II, IV, VI.

7. Hollister, N. 1911 A Systematic Synopsis Of The Muskrats. North American Fauna No. 32. pp.14; pl. IV, V.

8. Howell, A. H. 1924 Revision Of The American Pikas. North American Fauna No.47. pp.7; pl. V, VI.

9. Howell, A. H. 1929 Revision Of The American Chipmunks. North American Fauna No. 52. pp. 11, 12, 26; pl. VII-X.

10. Howell, A. H. 1915 Revision Of The American Marmots.

Bibliography-cont.

North American Fauna No. 57. pl. XI-XV.

11. Howell, A. H. 1938 Revision Of The North American Ground Squirrels. North American Fauna No. 56. pp. 34-57; pl. XVII-XXXII.

12. Loomis, F. B. 1926 The Evolution Of The Horse

13. Merriam, C. Hart 1890 Annotated List Of Animals, With Description Of New Species. North American Fauna No. 3. pp. 43-86.

14. Merriam, C. Hart 1895 Revision Of The Pocket Gophers. North American Fauna No. 8. pp. 23, 24, 69-88; fig. 18-44; pl. XIV, XVII.

15. Merriam, C. Hart 1889 Description Of Fourteen New Species And One New Genus Of North American Mammals. North American Fauna No. 2. pp. 27-45.

16. Merriam, C. Hart 1895 Synopsis Of The American Shrews Of The Genus Sorex. North American Fauna No. 10. pp. 57-88; pl. X.

17. Merriam, C. Hart 1918 Review Of The Grizzly And Brown Bears Of North America. North American Fauna No. 41; pp. 13.

18. Merriam, C. Hart 1896 Synopsis Of The Weasels Of North America. North American Fauna No. 11. fig. 6-14; pl. I-V.

19. Nelson, E. W. 1909 The Rabbits Of North American. North

Bibliography-cont.

American Fauna No. 29. pl. 13.

20. Osborn, Henry F. 1907 Evolution Of Mammalian Molar Teeth.

21. Osgood, Wilfred H. 1909 Revision Of The Mice Of The American Genus Peromyscus. North American Fauna No. 28. pp. 15, 33; pl. VII, VIII.

22. Owens, Richard 1868 Comparative Anatomy And Physiology Of The Vertebrates, Vol. III pp. 370.

23. Preble, E. A. 1899 Revision Of The Jumping Mice Of The Genus Zapus. North American Fauna No. 15. pp. 9-37; fig. 1-3; pl. I.

24. Tims, Henry 1923 Tommes Dental Anatomy. pp. 331-477.

And other issues of the North American Fauna.

Explanation To Plates

Plate I

1. *Sorex personatus* ----------------lower jaws----------------x11

2. *Sorex personatus* ----------------upper right---------------x11

3. *Neosorex palustris* --------------lower left----------------x10

4. *Neosorex palustus* ---------------upper right---------------x10

Plate II

1. *Euarctos americanus* -------------lower left-----------------x1

2. *Euarctos americanus* -------------upper left-----------------x1

Plate III

1. *Mustela longicanda* --------------lower left----------------x6½

2. *Mustela longicanda* --------------upper left----------------x6½

3. *Mustela nigripes* ----------------lower left-----------------x4

4. *Mustela nigripes* ----------------upper left-----------------x4

Plate IV

1. *Taxidea taxis* -------------------upper right----------------x2

2. *Taxidea taxis* -------------------lower right----------------x2

3. *Lynx c. canadensis* --------------upper right----------------x2

4. *Lynx c. canadensis* --------------lower right----------------x2

Plate V

1. *Alopex* --------------------------upper right----------------x1

2. *Alopex* --------------------------lower right----------------x1

Plate VI

1. *Canis* ---------------------------upper right----------------x1

2. *Canis* ---------------------------lower right----------------x1

Plate VII

1. Marmota flaveventris nosophora --upper right------------------x4

2. Marmota flaveventris nosophora --lower left------------------x4

3. Callospermaphilus lateralis -----upper left------------------x9

4. Callospermaphilus lateralis -----upper left------------------x9

Plate VIII

1. Citellus colombianus ------------upper right----------------x7½

2. Citellus colombianus ------------lower right----------------x7½

3. Citellus colombinus --upper left-(showing milk tooth)

Plate IX

1. Citellus richardsonii------------upper right-----------------x7

2. Citellus richardsonii------------lower right-----------------x7

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4. Citellus armatus ----------------lower right----------------x7½

Plate X

1. Cynomys ludovicianus ------------upper left-----------------x5

2. Cynomys ludovicianus ------------lower right----------------x5

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4. Eutamias minimus pallidus -------lower right---------------x16

Plate XI

1. Eutamius amoenus luteventris ----upper right---------------x16

2. Eutamius amoenus luteventris ----lower right---------------x16

3. Eutamius umbrinus ---------------upper right---------------x16

4. Eutamius umbrinus ---------------lower right---------------x16

Plate XII

1. Sciurus hudsonicus ventorum -----upper right---------------x11

2. Sciurus hudsonicus ventorum -----lower right---------------x11

Plate XIII

1. Glaucomys savrinus bangsi -------upper right---------------x10

2. Glaucomys savrinus bangsi -------lower right---------------x10

3. Dipodomys ordii -----------------upper right---------------x17

4. Dipodomys ordii -----------------lower right---------------x17

Plate XIV

1. Thomomys fucus ------------------upper right---------------x12

2. Thomomys fucus ------------------lower right---------------x12

3. Thomomys talpoides ballatus -----upper right---------------x14

4. Thomomys talpoides ballatus -----lower right---------------x14

Plate XV

1. Castor canadensis ---------------upper right---------------x2½

2. Castor canadensis ---------------lower right---------------x2½

3. Erethizon dorsatum --------------upper right---------------x2½

4. Erethizon dorsatum --------------lower right---------------x2½

Plate XVI

1. Onychomys leucogaster missouriensis --upper left----------x18

2. Onychomys leucogaster missouriensis --lower right---------x18

3. Peromycus maniculatus artemisiae -----upper left----------x18

4. Peromycus maniculatus artemisiae -----lower right---------x18

Plate XVII

1. Neotoma cinerea orlestus --------upper right---------------x9

2. Neotoma cinerea orlestus---------lower right----------------x9

3. Neotoma cinerea orlestus (worn)--upper right----------------x10

4. Neotoma cinerea orlestus (worn)--lower right----------------x10

Plate XVIII

1. Neotoma cinerea cinerea ---------upper right----------------x9

2. Neotoma cinerea cinerea ---------lower right----------------x9

3. Evotomys gapperi ----------------upper left----------------x16

4. Evotomys gapperi ----------------lower right---------------x16

Plate XIX

1. Microtus haydeni ----------------upper right---------------x12

2. Microtus haydeni ----------------lower right---------------x12

3. Microtus mordax -----------------upper right---------------x12

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1. Mus musculus --------------------upper right---------------x19

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1. Ondrata zibethica ---------------upper right----------------x6

2. Ondrata zibethica ---------------lower right----------------x6

3. Ochotona princeps ---------------upper right----------------x10

4. Ochotona princeps ---------------lower right----------------x10

Plate XXII

1. Sylvilagus nuttalli grangeri ----upper left-----------------x5

2. Sylvilagus nuttalli grangeri ----lower right----------------x5

3. Sylvilagus audoboni bailevi -----upper right----------------x6

4. Sylvilagus auduboni bailevi -----lower right----------------x6

Plate XXIII

1. Cervus canadensis ---------------upper left----------------x1

2. Cervus canadensis ---------------lower right---------------x1

Plate XXIV

1. Odocoileus virgineanus ----------upper right---------------x1

2. Odocoileus virgineanus ----------lower left----------------x1

Plate XXV

1. Bison bison----------------------upper right---------------x1

2. Ovis canadensis -----------------upper right---------------x1

Plate XXVI

1. Oreamos americanus --------------upper left----------------x1

2. Oreamos americanus --------------lower right---------------x1

Plate XXVII

1. Domestic sheep-------------------upper right---------------x1

2. Horse----------------------------upper right---------------x1

1.

2.

3.

4.

Plate I

1.

2.

Plate II

1.

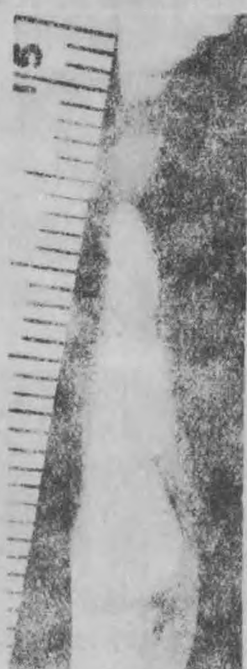
2.

3.

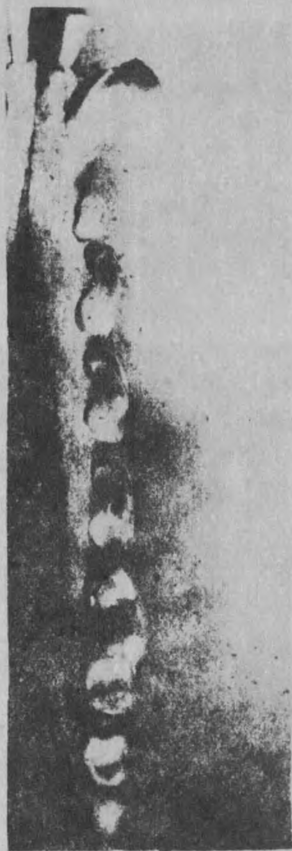
III

1.

3.



1.



2.

Plate V

1.

2.

Plate VI

1.

2.

3.

4.

Plate VII

1.

2.

3.

Plate VIII

1.

2.

3.

4.

Plate IX

1.

2.

3.

4.

Plate [illegible]

1.

2.

3.

4.

Plate XI

1.

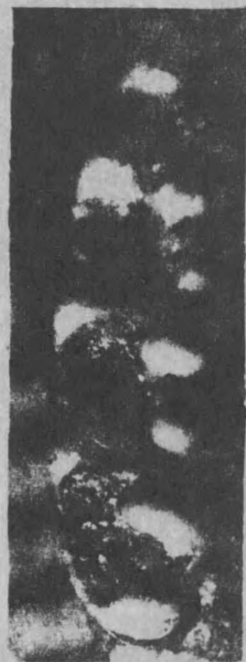
2.

3.

4.

Plate XII

1.



2.

3.

4.

Plate XIII

1.

2.

3.

4.

Plate XIV

1.

2.

3.

4.

Plate XV

1.

1.

2.

3.

Plate XIII

1.

2.

3.

4.

Plate XVIII

1.

2.

3.

4.

Plate XIX

1.

2.

3.

4.

Plate [illegible]

1.

2.

3.

4.

Pla[illegible]

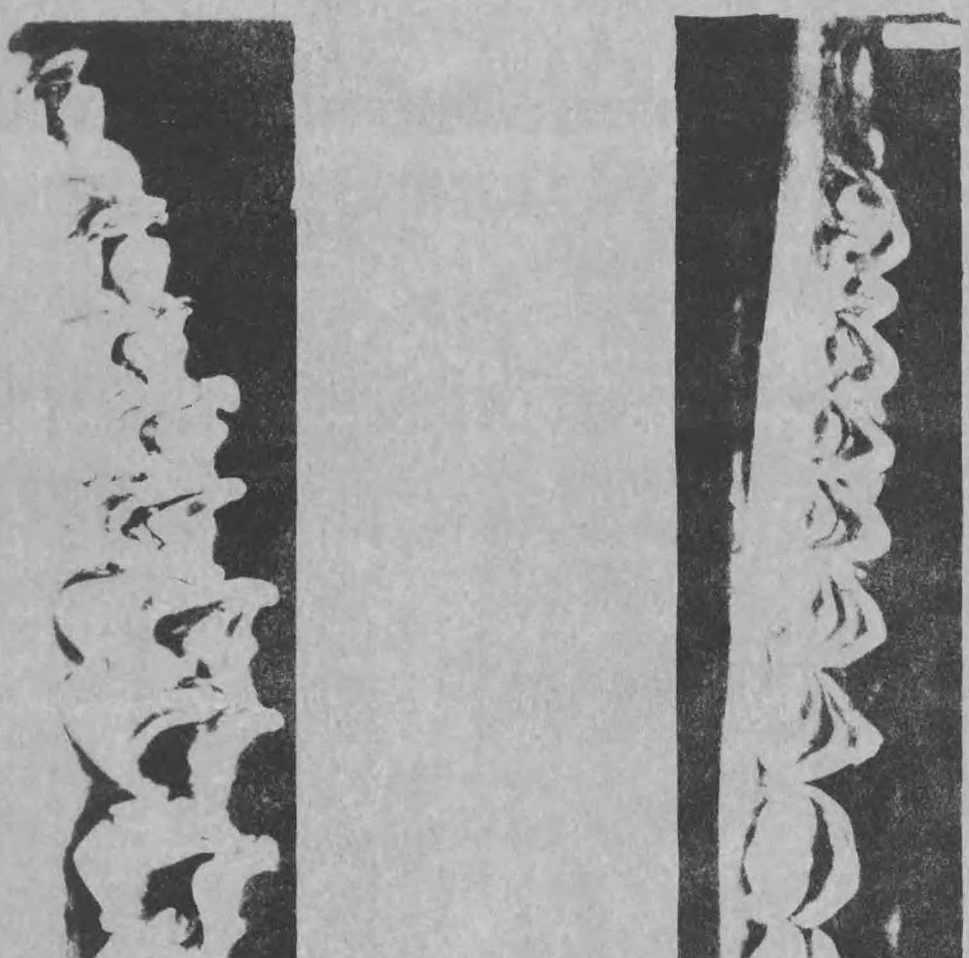
1.

2.

3.

4.

Plate II



2.

P[illegible]

2.

[illegible] XIV


2.

Plate XXVII

Buck, Charles L
Pattern correlation of mammalian teeth as a means of identification.

	NAME AND ADDRESS
	[redacted]

[redacted]