MEASUREMENT OF RODENTS (MAMMALIA), ESPECIALLY THEIR SKULL, FOR TAXONOMIC PURPOSES

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(With 2 Tables and 3 Plates)

CONTENTS

I—INTRODUCTION

(a) *General*

For taxonomic purposes in rodents, especially for the separation of species and subspecies, certain body- and skull-measurements are essential. However, the exact method of measurement, and the precise points of reference between which the measurements are taken, are not readily available in the literature. Authors frequently do not give any details at all, merely mentioning the code name or abbreviated name of a particular measurement, such as : " Head 83 ; tail 95 ; molar 1½ ; etc. " Even the unit of measurement (whether in inches or millimetres) is sometimes not mentioned. As a result, comparison between the measurements of two authors becomes difficult.

Selected measurements which have been found most useful for rodents are discussed in this paper. All measurements are *vertical* distances between two parallels running through the two points of reference mentioned in each case. They are *not* merely straight-line distances between the two points of reference, nor are they taken along the curvatures of the body- or skull-parts. The measurements are best expressed in the metric system, usually in millimetres.

In many cases, indices are often more expressive as measures of differences between two allied forms than the absolute measurements themselves. They may be expressed either as a percentage of one measure against another or as a fraction expressed in the decimal system.

The measurements are best written in a tabular form (Table 1 ; also *vide* Roonwal, 1950, pp. 24-39, for an example) in which the items of measurement are given horizontally and the individual specimens listed serially vertically. Besides the actual measurements, the following particulars should invariably be given for each specimen to enable its individual identity being determined infallibly :—

1. Registration Number (in the collection registers of the institution to which the specimen belongs).
2. Name of the institution (in an abbreviated form) to which the specimen belongs.
3. Field Collection Number (if any).
4. Locality (Give exactly).
5. Sex (Either as : ♂ or M., male ; and ♀ or F., female).
6. Age (Exact age, if known). Also mention whether :

   Ad., adult ;

   Sad., subadult ; or

   Juv., juvenile.

7. State of wear of molars. Mention whether :

   N., not worn out ;
   S., slightly worn out ;
   H., half worn out ; or
   M., much worn out.

This gives an indication of the approximate age of the individual.

8. Upper incisor "index". Mention whether :

   Opi., opisthodont (bent backward) ;
   Ort., orthodont (straight or vertical) ; or
   Pro., proodont (bent forward).

For recording the indices, either a separate table may be used ; or, when the indices of the various body- or skull-parts are in terms of a single part, they may be mentioned within brackets below the actual measurement.

(b) *Skull measurements as defined by some previous authors*

In recent literature the definitions of the various skull-measurements of mammals have been provided by the following authors :—

(i) Pocock (1939, p. 23 for Primates ; and p. 203 for Carnivora).

(ii) Ellerman (1947*a*, p. 250, for Rodentia ; 1947*c*, p. 259 for the Sciuridae).

(iii) Chaworth-Musters & Ellerman (1947, p. 479, for *Meriones* : Muridae, Gerbillinae).

(iv) Roonwal (1950, pp. 2-4, for Rodentia, especially the Muridae)

The definitions of these authors are given below :—

(i) Pocock (1939, p. 23, Primates ; and p. 203, Carnivora) gave the following eleven measurements for mammalian skulls, and although they refer primarily to the Primates and the Carnivora, some of them can be used for the Rodentia as well :—

1. *Total length.—Primates :* From tip of premaxilla to end of cranium. *Carnivora :* From front edge of premaxilla to tip of occipital crest.
2. *Condylobasal length.—Primates :* From tip of premaxilla to end of occipital condyle. *Carnivora :* From front edge of premaxilla to hind border of occipital condyle.
3. *Zygomatic width.—Primates :* Across zygomata at their widest point. *Carnivora :* Greatest width across cheek-bones.
4. *Orbital width.—Primates* : Across the middle of orbits.
5. *Postorbital width.—Carnivora :* Least width behind the eyes.
6. *Interorbital width.—Carnivora :* Least width between the eyes.
7. *Maxillary width.—Primates :* Across maxilla at the base of canines. *Carnivora :* Width of muzzle just above upper canine teeth.
8. *Upper cheek-teeth.—Primates :* From front edge of canine to hinder edge of last molar.
9. *Mandibular length.—Primates :* From tip of condyle to tip of symphysis. *Carnivora :* Length of lower jaw from condyle to anterior edge.
10. pm^4 .—Greatest length of upper carnassial tooth along its outer side.
11. m_1 .—*Carnivora :* Greatest length of lower carnassial tooth.

(ii(Ellerman (1947*a*, p. 250) gave the following definitions of the ten cranial measurements used by him for Indian Rodents he further redefined (Ellerman, 1947*c*, p. 259) the ' orbit which is a new measurement used by him for the Sciuridae. Except where otherwise stated, all these measurements are " length " measurements :—

1. *Occipitonasal.*—From anterior tip of nasal to back of occiput, or to centre of top of occiput when this projects or slants backwards behind the lambdoidal region, errors, if presen tending to be on the large side.

2. *Palate.*—From the front of the incisors to the back of the palate, ignoring the spinous process if present.

3. *Diastema.*—From a point immediately behind the front incisor to a point immediately in fornt of the front cheek-tooth.

4. *Palatal foramina.*—From a point immediately in front of the foramina to a point immediately behind it.

5. *Bullae length.*—From a point immediately next to the paroccipital process to the nearest point opposite the inflated part of the bulla, not including the mastoid portion when it is swollen as happens in the Dipodidae or the Gerbillinae.

6. *Toothrow.*—Is the crown length of upper toothrow.

7. *Frontals width.*—Is the least interorbital width.

8. *Orbit* (used extensively in the Sciuridae but not elsewhere).—From the lacrymal to a point on the posterior zygomatic root just after this has left the squamosal (Ellerman, 1947*a*). In another paper Ellerman (1947*c*) defined the posterior limit as follows : " To a point on the posterior zygomatic root just after it leaves the brain case " He further added : " With a single exception which occurs in the genus *Lariscus*, I am able to place any genus of squirrel in the Palaearctic and Indo-Malayan regions by the length of this measurement, taken as a percentage against the occipitonasal length."

9. *Occiput* (used only in subterranean Rodents like the Rhizomyidae).—From the top of foramen magnum to the top of lambdoidal ridge.

10. *Condylobasal.*—From the occiput to the front of the incisor.

(ii) Chaworth-Musters & Ellerman (1947, p. 479) used the following five measurements for the genus *Meriones* (Muridae, Gerbillinae), with the same definitions as those of Ellerman (1947*a*, *vide* above), except that the " frontals width " is here called the " least interorbital width ", the two measurements being identical :—Occipitonasal length ; palate ; bullae ; toothrow ; and frontals width.

(iv) Finally, Roonwal (1950, pp. 2-4) gave definitions of nineteen skull measurements used by him for Rodents, especially the Muridae. The definitions given below in the present account are largely based on that author, with such modifications and additions as are considered necessary.

II—External Measurements of Head-and-Body

(Plate 8 ; Tables 1 and 2)

These measurements are taken on freshly killed animals before *rigor mortis* has set in and with the body-parts fully relaxed and pressed against a flat surface such as a table or a sheet of glass ; no stretching should be allowed. Four length-measurements are generally taken, *viz.*, head-and-body (H. & B.) ; tail (Tl.) ; hind-foot (H.F.) ; and ear (E). They should immediately be recorded either in the field note-book or on the back of the label (to be tied to the specimen) thus :

H. & B.	224 mm.
Tl.	186 mm.
H.F.	41 mm.
E.	23 mm.

The measurements are taken as follows :—

1. *Length of head-and-body* (Pl. 8, Fig. *b*, line FD).

From the tip of the nose to the ventral root of the tail just above the anus.

2. *Length of tail* (Pl. 8, Fig. *b*, line DT).

From the ventral root of the tail just above the anus to the tip of the tail vertebrae, excluding the end-hairs.

3. *Length of hind-foot* (Pl. 8, Fig. *c*, line NN').

From the outer, most prominent surface of the heel to the tip of the longest toe, excluding the claw or nail.

4. *Length of ear* (Pl. 8, Fig. *d*, line HH').

From the most prominent surface of the tragus to the farthest edge of the pinna.

III—Skull Measurements

(Plates 9 and 10; and Tables 1 and 2)

Rodent skulls being rather small, their measurements are best taken under a large magnifying lens of *ca.* 12-15 cm. diameter and mounted on a revolving stand and magnifying about 2 to 3 times. Vernier callipers with a dial graduation reading upto 0.1 mm. should be used. About 19 skull measurements (Roonwal, 1950, pp. 2-4) are generally taken. In addition, Ellerman (1947*a*, p. 250; and 1947*c*, p. 259) has used a few

other measurements which have been found to be of taxonomic value in certain families. These 21 measurements, with their definitions, are given below :—

TABLE 1.—*Example of a Table to be used for recording the measurements of the skulls of rodents for taxonomic purposes. Bandicota bengalensis bengalensis* (Gr. & Hardw.). Skull measurements (in mm.).

Abbreviations used :

(i) Molars.—N., not worn out ; S., slightly worn out ; H., half worn out ; M., much worn out.

(ii) Upper incisor index.—*Opi.*, opisthodont ; *Ort.*, orthodont ; *Pro.*, proodont.

(iii) Age.—*Ad.*, adult ; *Sad.*, subadult ; *Juv.*, juvenile.

(iv) Institutions.—A. M. N. H., American Museum of Natural History ; Z. S. I., Zoological Survey of India.

Sl. No.	Registration No	Institution	Field Collection No.	Locality	Sex	Age	State of wear of molars	Upper incisor index	Occipito-premaxillary length	Condylo-basal length	Occipitonasal length	Greatest zygomatic width	Cranial width	Etc.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	11200	Z.S.I.	N 1/9·10·45	Imphal (Manipur, Assam)	♂	Ad.	M	Opi.	42·5	42·0	44·6	20·1	16·6	Etc.
2.	F. 1.28.58	A.M.N.H.	283	Kalewa (W. Burma)	♀	Ad.	H	Opi.	45·3	44·5	45·8	21·5	16·8	Etc.

1. *Occipito-premaxillary length* (Pl. 10, Fig. *a*, line PB).

From the most forward point of the premaxilla to the hindmost point of the occipital surface.

2. *Condylobasal length* (Pl. 10, Fig. *a*, line PO).

From the most forward point of the premaxilla to the hindmost point of the occipital condyle.

Ellerman (1947*a*, p. 250) defined this measurement as follows :— "From the occiput to the front of the incisor." In our opinion the definition given by us is preferable as it is independent of the condition of the incisors whose character, especially with regard to their forward or backward bending, is often variable.

3. *Occipitonasal length* (Pl. 10, Fig. *a*, line AB).

From the most forward tip of the nasals to hindmost point of the occipital surface, or to the centre of the top of the occiput when this projects backwards behind the lambdoidal region. (This is generally the greatest length of the skull.)

4. *Greatest zygomatic width* (Pl. 9, Fig. *a*, line ZZ').

Greatest width across the outer surfaces of the two cheekbones (zygomatic arches) measured at right angles to the long axis of the skull.

5. *Least interorbital width* (Pl. 9, Fig. *a*, line XX').

Least width of the frontal bone between the orbits, as viewed from above.

This is the "frontals width" of Ellerman (1947*a*, p. 250).

6. *Cranial width* (Pl. 9, Fig. *a*, line YY').

Greatest width of cranium just above the squamosal roots of the zygomatic arches.

7. *Occipital breadth* (Pl. 9, Fig. *a*, line RR').

Width of the occipital region just above the external auditory meatus and in front of the mastoid processes of the periotic.

8. *Median depth of occiput* (Pl. 10, Fig. *b*, line KK').

Vertical median height of the occiput from the highest surface of the occipital crest to the lowest surface of the foramen magnum.

9. *Postmolar length* (Pl. 10, Fig. *a*, line WO).

From the hindmost point of the occipital condyle of one side to the hindmost point of the base of the last molar, or m_3 of that side where it emerges from the maxilla.

10. *Auditory length* (Pl. 10, Fig. *a*, line EO).

From the most forward surface of the tympanic bulla to the hindmost oint of the occipital condyle of that side.

11. *Length of tympanic bulla* (Pl. 10, Fig. *a*, line EE').

Maximum length of the tympanic bulla proper from a point immediately next to the paroccipital process to the opposite point on the inflated bulla, excluding the spinous processes and the mastoid portion when swollen, as happens in the Dipodiae and the Gerbillinae.

12. *Length of nasals* (Pl. 9, Fig. *a*, line AA').

Maximum length of nasals along the antero-posterior axis.

13. *Greatest combined width of nasals* (Pl. 9, Fig. *a*, line SS').

Greatest width of nasals measured at right angles to their antero-posterior axis.

14. *Length of anterior palatine foramina* (Pl. 9, Fig. *b*, line UV).

Maximum length along the antero-posterior axis of the foramina. Ellerman (1947*a*, p. 250) defined this measurement as follows :—From a point immediately in front of the foramina to a point immediately behind it.

15. *Greatest combined width of anterior palatine foramina* (Pl. 9, Fig. *b*, line JJ').

Maximum width of the two anterior palatine foramina, at right angles to the antero-posterior axis.

16. *Length of upper molars or "cheek tooth row"* (Pl. 10, Fig. *a*, line CC').

Maximum total length of all the upper molars (excluding the premolars) on the crowns.

17. *Length of diastema* (Pl. 10, Fig. *a*, line GG').

From a point on the ventro-lateral side of the premaxilla where it meets the back or posterior edge of the first incisor, or i_1, to the most forward point of the base of the first tooth present in the premolar-molar series of that side where it emerges from the maxilla.

Ellerman (1947*a*, p. 250) defined this measurement as follows :—From a point immediately behind the front incisor to a point immediately in front of the front cheek-tooth.

18. *Palatal length* (Pl. 9, Fig. *b*, line PP').

From the hindmost edge of the palate, excluding the palatal spine when present, to the most forward point of the premaxilla in front of the incisors.

This is the same as that of Ellerman (1947*a*, p. 250 who defined this measurement as follows :—From the front of the incisors to the back of the palate ignoring the spinous process if any. Roonwal (1950, pp. 2-4) defined this measurement upto the back of the incisors as follows :—From the hindmost edge of the palate, excluding the palatal spine when present, to the most forward point of the premaxilla on the ventro-lateral side where it meets the back or posterior edge of the first incisor or i_1.

TABLE 2.—*Reference points to the lines in the illustrations (Plates 8-10) indicating the various measurements of the body and the skull of a Rodent.*

Name of measurement	Reference points to the lines	Plate and and Figure No.
1. Occipito-premaxillary length	PB	10*a*
2. Condylobasal length	PO	10*a*
3. Occipitonasal length	AB	10*a*
4. Greatest zygomatic width	ZZ′	9*a*
5. Least interorbital width	XX′	9*a*
6. Cranial width	YY′	9*a*
7. Occipital breadth	RR	9*a*
8. Median depth of occiput	KK′	10*b*
9. Postmolar length	WO	10*a*
10. Auditory length	EO	10*a*
11. Length of tympanic bulla	EE′	10*a*
12. Length of nasals	AA′	9*a*
13. Greatest combined width of nasals	SS′	9*a*
14. Length of anterior palatine foramina	UV	9*b*
15. Greatest combined width of anterior palatine foramina.	JJ′	9*b*
16. Length of upper molars (or length of " cheek-teeth row ").	CC′	3*a*
17. Length of diastema	GG′	3*a*
18. Palatal length	PP′	2*b*
19. Mandibular length	MM′	3*c*
20. Length of occiput	KQ	3*b*
21. Length of orbit	LL′	2*a*
22. Length of head-and-body	FD	1*b*
23. Length of tail	DT	1*b*
24. Length of hindfoot	NN′	1*c*
25. Length of ear	HH′	1*d*

19. *Mandibular length* (Pl. 10, Fig. *c*, line MM').

From the hindmost point of the mandibular condyle to the most forward point of the mandible on the ventro-lateral side where it meets the posterior edge of the first incisor or i_1.

In addition to the measurements listed above, Ellerman (1947*a*, p. 250; and 1947*c*, p. 259) has given two other measurements of rodent skulls which are of taxonomic value and are listed below.

20. *Length of occiput* (Pl. 10, Fig. *b*, line KQ).

From the top of the foramen magnum to the top of the lambdoidal ridge. (This measurement is of importance in the family Rhizomyidae.

21. *Length of orbit* (Pl. 9, Fig. *a*, line LL).

From the anterior end of the lacrymal where it meets the zygomatic arch to a point on the postzygomatic root just after it has left the squamosal. (This measurement is of importance in the family Sciuridae.)

IV—INDICES

A number of indices may be used according to one's choice. Those which have been found most useful for taxonomic purposes are listed below. As stated earlier, indices may be expressed either as a percentage of one measurement in terms of another or as a proportion of the other which is regarded as unity. For external body-measurements, indices are best expressed in relation to the combined length of head-and-body (minus the tail). Skull indices are best expressed in relation to the occipitonasal length which is generally the greatest length of the skull, but sometimes the condylobasal length may be used with advantage. The indices used are defined below :—

(*a*) *External body indices.*

1. *Tail Index.*

Tail length/Length of head-and-body.

2. *Hindfoot Index.*

Length of hindfoot/Length of head-and-body.

3. *Ear Index.*

Length of ear/Length of head-and-body.

(*b*) *Skull indices.*

1. *Upper incisor Index.*

This differs somewhat from the other indices in the sense that it is expressed qualitatively instead of quantitatively since the tooth-angles are difficult to measure accurately. Three conditions of the upper incisors are met with in the Rodentia, and are indicated as follows :—

Proodont : Teeth projected forwards.

Orthodont : Teeth more or less straight or vertical.

Opisthodont : Teeth bent backwards.

2. *Nasal Index.*
Length of nasal/Occipitonasal length.

3. *Nasal-width Index.*
Combined width of nasals/Occipitonasal length.

4. *Tympanic bulla Index.*
Length of tympanic bulla/Occipitonasal length.

5. *Palatal Index.*
Length of palate/Occipitonasal length.

6. *Zygomatic Index.*
Width of zygomatic arch/Occipitonasal length.

7. *Orbital Index.*
Length of orbit/Occipitonasal length.

8. *Molar teeth Index.*
Length of molar teeth/Occipitonasal length.

9. *Postmolar Index.*
Postmolar length/Occipitonasal length.

10. *Anterior palatine foramina Index.*
Length of anterior palatine foramina/Occipitonasal length.

11. *Diastema Index.*
Length of diastema/Occipitonasal length.

12. *Least interorbital width Index.*
Least width of frontals/Occipitonasal length.

13. *Cranial width Index.*
Cranial width/Occipitonasal length.

14. *Occipital breadth Index.*
Occipital breadth/Occipitonasal length.

15. *Median depth of occiput Index.*
Median depth of occiput/Occipitonasal length.

16. *Mandibular Index.*
Mandible length/Occipitonasal length.

V—SUMMARY

1. The more important body and skull-measurements, and their indices, for Rodents (Mammalia) which have been found useful for taxonomic purposes are discussed.

2. The measurements used by the previous workers are first listed. This is followed by a list, with definitions and illustrations, of 4 external body measurements and 21 skull measurements.

3. The value of indices of these measurements is discussed and 19 indices (3 of the external body measurements and 16 of the skull) are defined.

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VII—ABBREVIATIONS USED IN THE PLATES

abd. m. 1, 2., ist and 2nd abdominal mammae respectively.

als., alisphenoid.

an., anus.

ang., angular process.

apf., anterior palatine foramina.

ao., auditory orifice.

B., body.

boc., basioccipital.

bsph., basisphenoid.

bul., tympanic bulla.

cl., claw.

cond., condyle.

cor., coronoid process.

E., ear.

fl., forelimb.

fm., foramen magnum.

fr., frontal.

H., head.

H. & B., Head-and-body.

ham., hamular process.

he., heel.

H.F., hind foot.

hl., hindlimb.

i., incisor tooth.

int., tr. n., intertragal notch.

iof., infraorbital foramen.

ip., interparietal.

lac., lacrymal.

m_1-m_3, 1st to 3rd molars respectively.

mal., malar bone.

mast., mastoid.

max., maxilla.

mou., mouth.

n., nostril.

nas., nasal.

nl., nail.

oc., occipital condyle.

orbs., orbitosphenoid.

pal., palatine.

Par. parietal.

pmx., premaxilla.

poc., paroccipital process.

ppf.; posterior palatine foramina.

pt., pterygoid.

so., supraoccipital.

sq., squamosal.

th.m_1-$_3$, , 1st-3rd thorasic mammae respectively.

Tl., tail.

tr., tragus.

vag., vagina.

vib., vibrissae.

zyg., zygomatic arch.

zyg. m., zygomatic process of maxilla.