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Taxonomic Re-examination of the *Apodemus agrarius chejuensis*, Comparing External and Cranial Morphological Characters among Four Asian *Apodemus* Species

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In order to re-examine the taxonomic position of the Korean striped field mouse, *Apodemus agrarius chejuensis* from the Cheju Island, external value and skull characters were compared among *A. agrarius coreae* from the Korean Peninsula, *A. speciosus*, *A. argenteus*, and *A. semotus*. Skull characters of *A. agrarius chejuensis* (Cheju population) and *A. agrarius coreae* (mainland population) were fitted onto different clines. In paticular, distances between the posterior end of incisive foramina and anterior end of the first upper molar were critically different between these two subspecies. These evidences support the specific division of '*Apodemus chejuensis*' for the population inhabiting the Cheju Island from *A. agrarius* in the mainland, as proposed by Koh and Yoo(1992).

INTRODUCTION

The striped field mouse, *Apodemus agrarius*, widely distributes across the temperate region of the Eurasia (Corbet, 1978), including 22 subspecies (Musser and Carleton, 1993). This mouse is the most common species in wild rodents in Korea (Hong and Lee, 1984), showing considerable geographic variations in morphology. Thomas (1907) first described the striped field mouse in the Korean Peninsular. He did not state any critical differences in the external morphometric characters between the populations from Korean mainland and the Cheju Island, and classified the Korean striped field mouse as a single subspecies, *Micromys agrarius mantchuricus*. Thereafter, the species was assigned to a genus *Apodemus*, and the Korean population has been morphologically classified into two or four subspecies. Johnson and Jones (1955) identified two subspecies, *Apodemus agrarius pallescens* and *A. a. chejuensis*, while Kuroda (1934) and Won (1961) did *A. a. manchuria* and *A. a. coreae*. Jones and Johnson (1965) divided into four subspecies, *A. a. manchuria* in the extreme northern Korea, *A. a. coreae* in the

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major part of Korea, *A. a. pallescens* in the coastal lowlands of southern and south-western Korea, and *A. a. chejuensis* in the Cheju Island.

Tsuchiya (1984, 1985) performed cytogenetic and biochemical analyses for *Apodemus* spp. aiming to produce new experimental animals, and found transferrin polymorphism among those four subspecies. A series of papers written by Koh and colleagues, however, have been insisted that the population of the striped field mouse in the Cheju Island should be classified into another species. They found morphological difference between *A. agrarius chejuensis* and *A. agrarius coreae* (Koh, 1986) or other Asian seven subspecies (Koh, 1991). Moreover, in RFLPs analyses of mitochondorial DNA, *A. agrarius chejuensis* and *A. agrarius coreae* assigned to different subgroups (Koh and Yoo, 1992). However, there is no consensus up to this time on the classification of the population of the striped field mouse in the Cheju Island.

There are many reports on inter– and intra–specific variations in the cranial and external morphometric characters for various *Apodemus* spp., *A. agrarius*: (Haitlinger, 1962; Adamczewska–Andrzejewska, 1971, 1973; Sikorski, 1982) and *A. sylvaticus*: (Delany and Davis, 1961; Haitlinger, 1969; Delany, 1970; Gurnell and Knee, 1984) in Europe, *A. speciosus* (Imaizumi, 1962; Miyao *et al.*, 1968; Yoshida, 1983) and *A. argenteus* (Miyao and Mōri, 1968; Yoshida, 1984) in Japan, *A. semotus* (Lin *et al.*, 1992) in Taiwan. Comparing with these *Apodemus* spp., data for *A. agrarius* were constricted, especially for *A. agrarius chejuensis*. Thus, it seems to be important to show detailed morphological data of *A. agrarius* in order to clarify the taxonomic problem of *A. agrarius chejuensis* population.

The purpose of this study is to give some evidences to clarify the classification of the Cheju–Island population of the striped field mouse, by showing intra–specific and inter–specific variations in body and cranial characters. Originally, the population of *A. agrarius* in the Cheju Island had been classified to a subspecies because of their large body size compared to other *A. agrarius*. In this study, we focus on the proportional differences in morphology between *A. agrarius chejuensis* and *A. agrarius coreae*. We also compared these data with those of three other Asian species, *A. speciosus* and *A. argenteus* in Japan and *A. semotus* in Taiwan to demonstrate the inter–specific variation of Asian *Apodemus* spp. and to evaluate the differences between *A. agrarius chejuensis* and *A. agrarius coreae*.

MATERIALS AND METHODS

To show inter–specific morphological variations in Asian *Apodemus*, 40 samples consisted of 20 males and 20 females were collected in the field for each of *A. agrarius chejuensis*, *A. agrarius coreae*, *A. speciosus*, *A. argenteus*, and *A. semotus*. *A. agrarius chejuensis* was captured at Mt. Halla of Cheju Island in Korea, from March to August, 1994. *A. agrarius coreae* was captured at Mt. Whangreung in Pusan in Korea from August to September, 1994. *A. speciosus* and *A. argenteus* were captured at Mt. Abura at Fukuoka in Japan in November and December, 1994, respectively. *A. semotus* was captured at the Alishan Alpine Forest Park in Taiwan in April, 1986. These samples of *A. semotus* were measured their body size and conserved in 70% alcohol. Adults were determined by the degree of wear of the upper 1 st, 2 nd and 3 rd molars based on Hikida

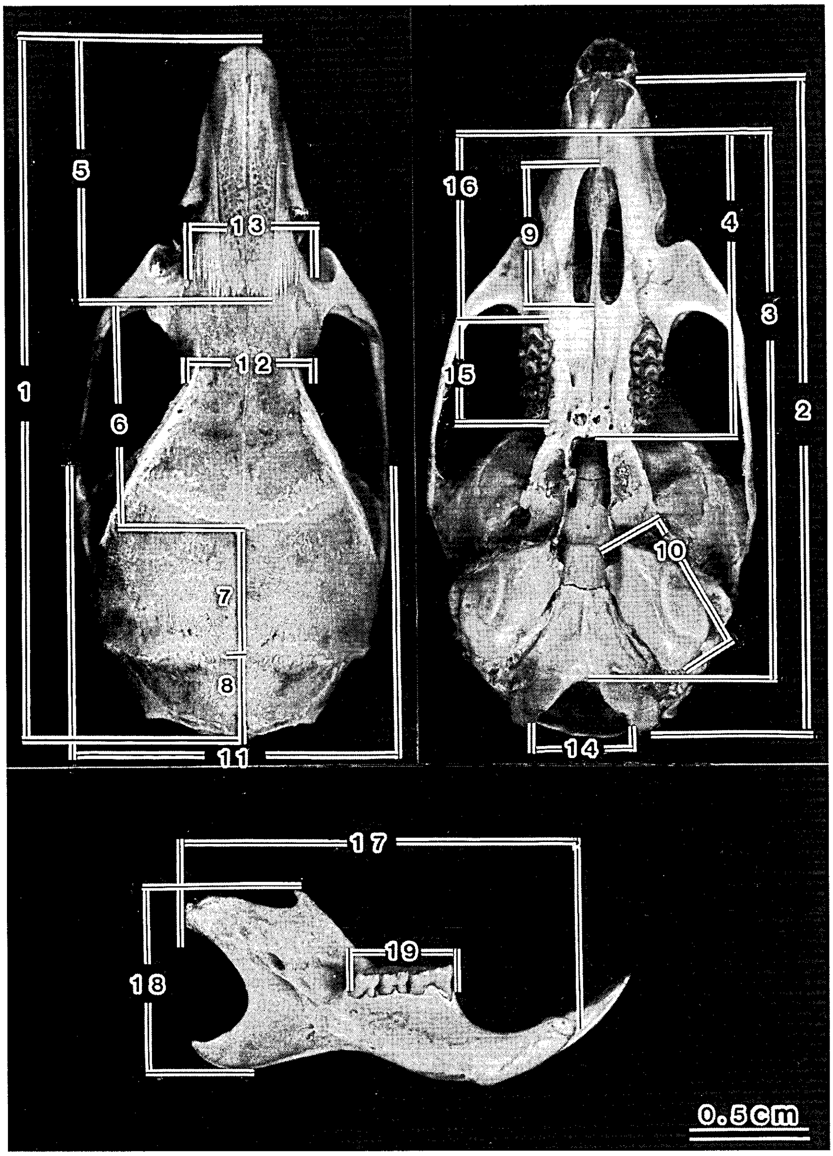

Fig. 1. The skull of genus *Apodemus* showing the the cranial and mandibular measurements. 1) Greatest length (GL); 2) Condylobasal length (CL); 3) Basilar length (BL); 4) Palatilar length (PL); 5) Nasal length (NL); 6) Frontal length (FL); 7) Parietal length (PrL); 8) Interparietal length (IL); 9) Length of incisive foramen (LIF); 10) Auditory bulla length (ABL); 11) Zygomatic breadth (ZB); 12) Interorbital breadth (IB); 13) Breadth of rostrum (BR); 14) Breadth of occipital foramen (BOF); 15) Length of upper molar series (LUM); 16) Length of upper diastema (LUD); 17) Length of mandible (LM); 18) Height of mandible (HM); 19) Length of lower molar series (LLM).

and Murakami (1980). To show external morphological characteristics, five variables were measured for each specimen: weight, head and body length, tail length (from the anus to the end of the tail), hind foot length (without claws) and ear length. After external morphometry, we prepared cranial specimens and measured 19 parts of skull (Fig. 1) with digital Vernier calipers to the nearest 0.01 mm. In addition, sexual dimorphism in size is also considered as a specific characteristics.

Results are expressed as mean 1±SD. The differences of averages in body and cranial measurements were tested by ANOVA. To show the proportional difference, partial lengths of body were regressed on total length (head and body length) and those of skull were regressed on the greatest length of the skull. We estimated the slopes and Y–intercepts of regression lines for each species/subspecies. The slopes of these lines were compared by t–test between all dyad combinations of examined five species/subspecies. When there was no significant differences, we tested the Y–intercepts (Zar, 1998). Differences between each part of the body and skull size of males and females were compared by unpaired t–tests.

RESULTS

1. Body size comparisons

Using head and body length as an index of body size, we found that there are significantly different among the five species/subspecies (ANOVA, F=102.9, $d.f.$=4, 195, $p<$ 0.0001). *A. speciosus* (111.94±8.21 mm) was the largest species, followed by *A. agrarius chejuensis* (103.07±7.38 mm), *A. semotus* (101.59±3.99 mm), *A. agrarius coreae* (88.47±12.00 mm) and *A. argenteus* (80.45±4.83 mm). In post–hoc tests, there were significant differences between all dyads species/subspecies ($p<0.0001$) with the excep-

Table 1. Statistical differences(t -test, Zar, 1984) among regression lines of three body measurements and the greatest length of the skull against the head and body length in five species and two subspecies of *Apodemus*. Differences of the regression coefficients (R) and the Y-intercepts(I) are shown for dyad with p<0.05. Y-intercepts were tested for dyad with equal regression coefficients

Dyad	Body weight (g)	Tail length (mm)	Hind foot length (mm)	Ear length (mm)	Greatest length of skull (mm)
A. a. chejuensis : *A. a. coreae*	I	I	I	I	I
A. a. chejuensis : *A. speciosus*	R	I	I	I	ns
A. a. chejuensis : *A. argenteus*	I	I	I	I	R
A. a. chejuensis : *A. semotus*	I	I	I	I	R
A. a. coreae : *A. speciosus*	R	R	I	R	R
A. a. coreae : *A. argenteus*	I	I	I	I	I
A. a. coreae : *A. semotus*	I	I	I	I	R
A. speciosus : *A. argenteus*	R	I	I	I	R
A. speciosus : *A. semotus*	I	I	ns	I	R
A. argenteus : *A. semotus*	R	ns	I	ns	R

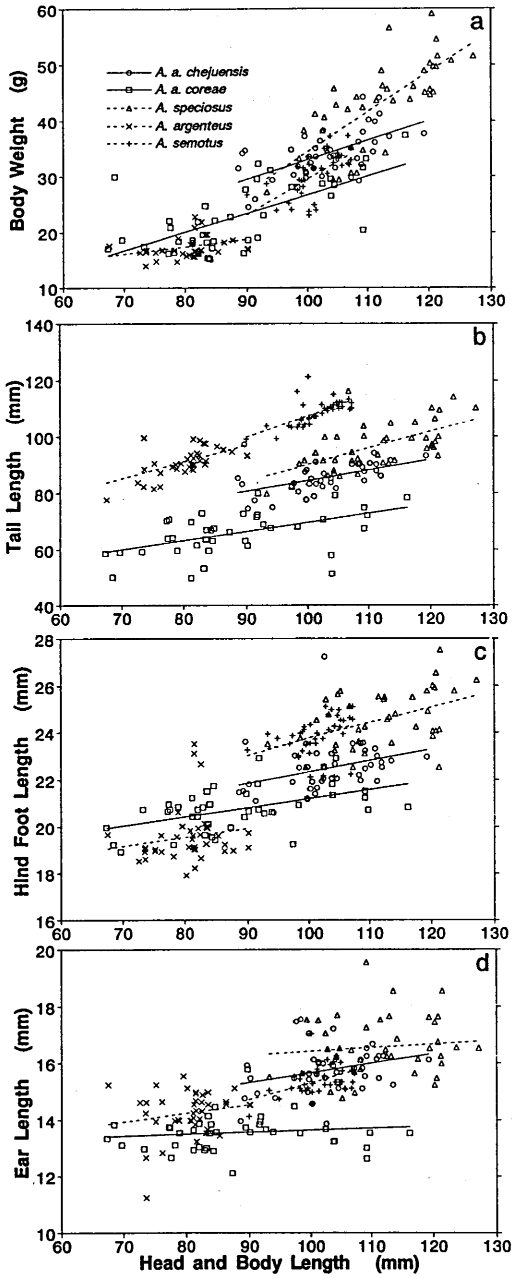

Fig. 2. The relationships of the difference between a) body weight; b) tail length; c) hind foot length; d) ear length against head and body length of the external morphological traits in *Apodemus*.

tion between *A. agrarius. chejuensis* and *A. semotus* (p=0.40). The head and body length of *A. agrarius. chejuensis* was 16.5% longer than that of *A. agrarius. coreae*. Similar tendency was observed in body weight (Table 1), in which *A. agrarius. chejuensis* (34.11±4.34 g) was 48.9% heavier than *A. agrarius. coreae* (22.91±6.00 g).

Most of the regression lines of the tail lengths, hind foot lengths and ear lengths on head and body lengths (Fig. 2) were significantly different among five species/subspecies (Table 1). That indicates the proportions of these body parts were different among the species/subspecies, including between *A. agrarius chejuensis* and *A. agrarius coreae*. Especially, the tail and ear were remarkably short in *A. agrarius coreae*, that is known as common characteristics in *A. agrarius*.

In sexual dimorphism in body size, generally male-dominant dimorphism was found in *Apodemus* spp. (Table 2). *A. semotus* indicated the greatest male-dominant dimorphism in all measurements, while *A. speciosus* indicated low sexual dimorphism. However, *A. argenteus* alone indicated female-dominant sexual dimorphism. Between *A. agrarius chejuensis* and *A. agrarius coreae*, there was not so clear difference in sexual dimorphism in body size.

Table 2. Sexual dimorphism in five measurements of body size in four species and two subspecies of *Apodemus*. Larger sexes are shown with the significant levels(t-test, *$p<0.05$, **$p<0.01$, ***$p<0.001$)

	Body weight (g)			Head and body length (mm)		
	male	female	larger sex	male	female	larger sex
A. a. chejuensis	36.80±3.63	31.42±3.19	male***	105.53± 7.91	100.61±6.04	male*
A. a. coreae	27.68±4.66	18.15±2.12	male***	93.89±12.45	83.05±8.87	male**
A. speciosus	45.58±7.91	40.26±6.97	male*	115.14± 6.94	108.74±8.28	male*
A. argenteus	16.64±1.33	18.38±2.07	female**	79.03± 4.08	81.87±5.19	
A. semotus	32.98±2.81	28.11±3.22	male***	103.34± 4.60	99.84±2.26	male***

	Tail length (mm)			Hind foot length (mm)		
	male	female	larger sex	male	female	larger sex
A. a. chejuensis	87.85±3.85	83.49±5.56	male**	22.60±0.68	22.37±1.41	
A. a. coreae	67.85±9.44	64.12±5.72		21.01±1.09	20.51±0.72	
A. speciosus	98.95±7.32	95.34±8.54		24.58±1.26	24.55±1.22	
A. argenteus	90.53±4.89	92.23±5.54		19.22±0.41	19.91±1.53	
A. semotus	110.64±4.36	106.61±3.74	male**	24.32±0.75	23.48±0.68	male***

	Ear length (mm)		
	male	female	larger sex
A. a. chejuensis	15.78±0.76	15.74±0.89	
A. a. coreae	13.72±0.78	13.41±0.53	
A. speciosus	16.75±0.96	16.38±1.15	
A. argenteus	13.85±0.85	14.66±0.51	female**
A. semotus	15.60±0.61	15.22±0.31	male*

2. Interspecific comparison of cranial size

Comparing the external appearance of the skull specimens, the skulls of *A. agrarius chejuensis* and *A. speciosus* were characterized by their large size. There was a pair of

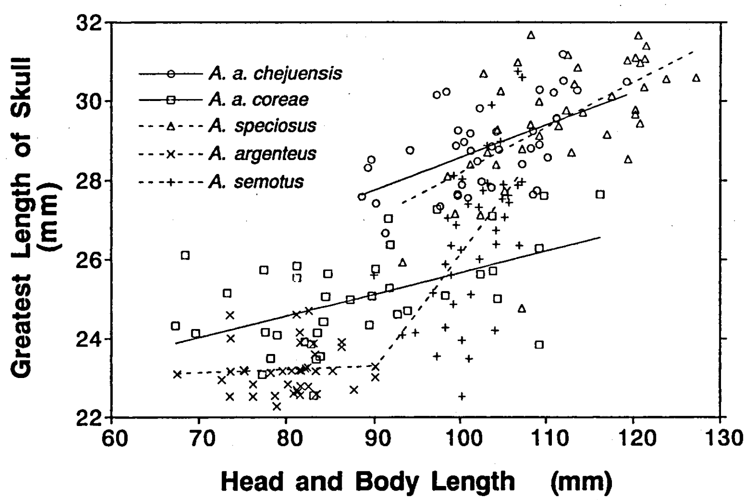

Fig. 3. The relationship between the greatest length of the skull and the head and body length in *Apodemus*.

Table 3. Sexual dimorphism (*t*-test) in 19 measurements of skull in two subspecies of *Apodemus agrarius* and other three *Apodemus* species. Values indicate the remainders which subtracted female average values form male ones

Measurements	*A. a. chejuensis*	*A. a. coreae*	*A. speciosus*	*A. argenteus*	*A. semotus*
GLS: greatest length of skull	0.74ns	1.31***	0.28ns	-0.02ns	1.95***
CL: condylobasal length	0.75*	0.97**	0.34ns	-0.19ns	1.66**
BL: basilar length	0.58ns	1.28***	-0.07ns	-0.18ns	1.48*
PL: palatilar length	0.27ns	0.54***	0.15ns	-0.08ns	1.05**
NL: nasal length	0.42*	0.48***	-0.09ns	0.26ns	1.33**
FL: frontal length	0.00ns	0.56**	-0.21ns	0.12ns	0.12ns
PrL: pariental length	0.10ns	-0.06ns	-0.05ns	0.06ns	0.31ns
IL: interpariental length	0.14ns	0.15ns	0.14ns	0.04ns	-0.03ns
LIF: length of incisive foramen	0.23ns	0.09ns	0.13ns	-0.04ns	0.41**
ABL: auditory bulla length	-0.03ns	0.02ns	0.07ns	-0.04ns	0.30*
ZB: zygomatic breadth	0.21ns	0.55***	-0.02ns	-0.20*	0.63*
IB: interorbital breadth	0.08ns	0.03ns	0.06ns	0.05ns	0.21*
BR: breadth of rostrum	0.06ns	0.05ns	0.08ns	0.03ns	0.26*
BOF: breadth of occipital foramen	-0.06ns	-0.19*	0.30ns	-0.02ns	-0.02ns
LUM: length of upper molar series	-0.05ns	0.05ns	0.11ns	0.04ns	0.24*
LUD: length of upper diastema	0.22ns	0.44**	0.34ns	-0.02ns	0.68**
LM: length of mandible	0.36ns	0.81***	0.15ns	0.12ns	0.99**
HM: height of mandible	0.21ns	0.68***	-0.06ns	-0.01ns	0.51*
LLM: length of lower molar series	-0.11ns	-0.03ns	0.08ns	0.11*	0.25*

*p<0.05, **p<0.01, ***p<0.001, ns: statistically non-significant (p>0.05) lateral processus in the posterior part of the skull in *A. speciosus* only. The rostrum of *A. agrarius chejuensis* was long and narrow, while that of *A. speiosus* was long and wedge–shaped constricted at the center. The skull of *A. semotus* was intermediate size. The skulls of *A. agrarius coreae* and *A. argenteus* were small. In *A. argenteus*, the rostrum was long and a braincase was relatively flat.

In order to carry out interspecific comparisons of relative cranial size, we estimated the regression lines of the greatest length of the skull on the head and body length. *A. agrarius chejuensis* and *A. speciosus* showed similar distribution, forming a group with relatively large skull (Fig. 3), and the estimated regression lines were not different, while there were significant differences in the linear regression between other dyads (Table 3). The regression coefficient was greatest in *A. semotus*, because of their large variation in

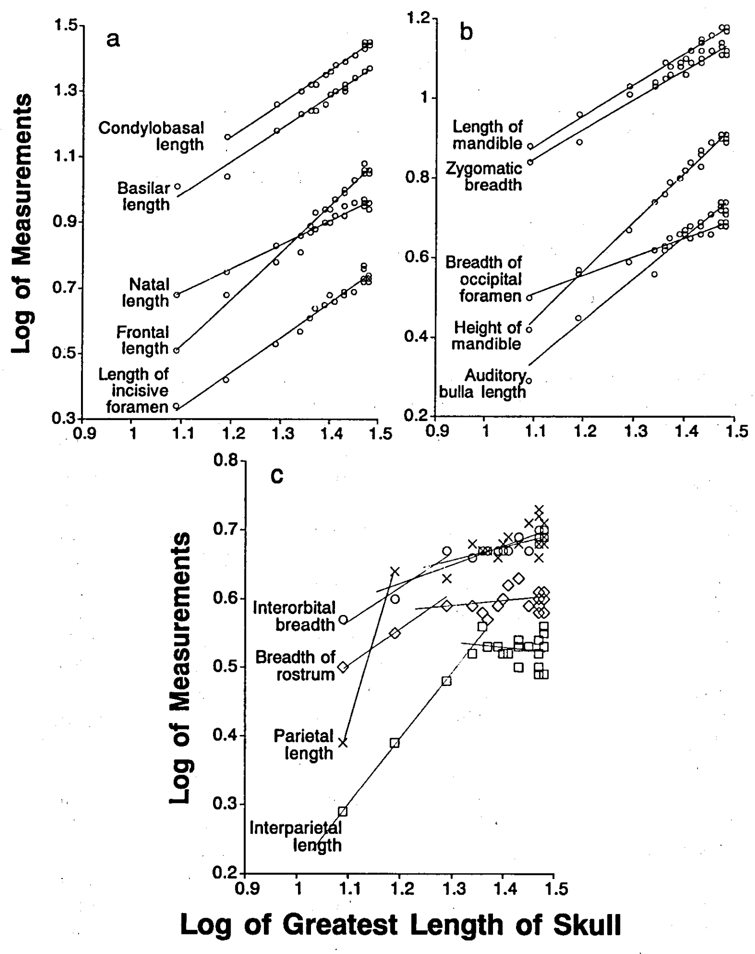

Fig. 4. Relative growth of the 14 skull measurements against the greatest length of the skull in *Apodemus agrarius chejuensis*.

skull size. The regression line of *A. agrarius. coreae* was significantly different from that of *A. agrarius chejuensis* (Table 3), showing proportional difference in skull size relative to body size. *A. argenteus* constituted a smallest skull group with small variation (Fig. 3).

Comparing the percentages of 18 lengths to the greatest length of the skull between *A. agrarius chejuensis* and *A. agrarius coreae*, 14 parts were relatively longer in *A. agrarius coreae* than in *A. agrarius chejuensis* (Fig. 4 and Table 3). In the remaining parts, basilar length, nasal length and length of upper diastema were longer in *A. agrarius chejuensis*, showing relatively longer rostrum in this subspecies.

Table 4. Measurements (mm, mean±SD) of the skull in two subspecies of *Apodemus agrarius* and three other *Apodemus* species

Measurements	*A. a. chejuensis*	*A. a. coreae*	*A. speciosus*	*A. argenteus*	*A. semotus*
GLS: greatest length of skull	28.82±1.07	25.04±1.26	29.54±1.54	23.22±0.61	26.58±1.95
CL: condylobasal length	26.65±1.16	23.32±1.21	27.33±1.38	21.71±0.57	24.52±1.88
Ratio to GLS	92.47%	93.12%	92.50%	93.52%	92.24%
BL: basilar length	22.34±1.03	19.39±1.16	23.31±1.20	17.73±0.60	20.07±1.90
Ratio to GLS	77.50%	77.43%	78.90%	76.37%	75.48%
PL: palatilar length	12.52±0.58	10.94±0.53	13.15±0.72	9.80±0.32	11.27±1.18
Ratio to GLS	43.43%	43.69%	44.50%	42.23%	42.40%
NL: nasal length	11.07±0.62	9.35±0.47	11.42±0.88	7.97±0.51	10.46±1.53
Ratio to GLS	38.39%	37.33%	38.66%	34.32%	39.34%
FL: frontal length	8.93±0.51	8.33±0.60	9.19±0.46	7.76±0.35	7.98±0.67
Ratio to GLS	30.98%	33.26%	31.10%	33.42%	30.01%
PrL: parietal length	5.06±0.31	4.65±0.29	5.40±0.33	5.00±0.31	4.82±0.58
Ratio to GLS	17.55%	18.56%	18.26%	21.55%	18.14%
IL: interparietal length	3.34±0.33	3.18±0.34	3.70±0.37	3.26±0.25	3.36±0.33
Ratio to GLS	11.60%	12.68%	12.52%	14.05%	12.65%
LIF: length of incisive foramen	5.31±0.38	4.64±0.33	5.61±0.35	4.38±0.21	5.02±0.50
Ratio to GLS	18.44%	18.54%	18.99%	18.87%	18.88%
ABL: auditory bulla length	5.39±0.24	4.97±0.24	5.83±0.29	4.70±0.44	4.78±0.44
Ratio to GLS	18.71%	19.86%	19.73%	20.26%	17.99%
ZB: zygomatic breadth	13.31±0.54	12.08±0.50	14.62±0.65	11.57±0.31	12.57±0.91
Ratio to GLS	46.18%	48.23%	49.50%	49.84%	47.28%
IB: interorbital breadth	4.92±0.21	4.46±0.21	4.98±0.20	4.19±0.23	4.60±0.29
Ratio to GLS	17.07%	17.80%	16.85%	18.03%	17.29%
BR: breadth of rostrum	4.48±0.26	4.17±0.22	4.54±0.33	3.57±0.15	4.17±0.39
Ratio to GLS	15.55%	16.67%	15.35%	15.38%	15.70%
BOF: breadth of occipital foramen	4.82±0.21	4.48±0.28	5.27±0.48	4.97±0.52	4.66±0.28
Ratio to GLS	16.71%	17.88%	17.84%	21.39%	17.53%
LUM: length of upper molar series	4.17±0.18	3.99±0.15	4.41±0.22	3.69±0.15	3.96±0.38
Ratio to GLSs	14.46%	15.95	14.93	15.88	14.91%
LUD: length of upper diastema	8.15±0.41	6.82±0.49	8.04±0.61	6.14±0.33	6.89±0.77
Ratio to GLS	28.29	27.22	27.21%	26.47%	25.93%
LM: length of mandible	14.47±0.64	12.64±0.72	15.98±0.86	12.12±0.44	13.90±1.21
Ratio to GLS	50.22%	50.50%	54.11%	52.19%	52.29%
HM: height of mandible	7.68±0.36	6.43±0.46	7.69±0.60	6.20±0.32	6.93±0.66
Ratio to GLS	26.65%	25.70%	26.02%	26.72%	26.06%
LLM: length of lower molar series	4.19±0.24	3.93±0.17	4.50±0.23	3.64±0.14	4.04±0.36
Ratio to GLS(%)	14.54%	15.70%	15.23%	15.69%	15.20%

To evaluate the proportional differences among five species/subspecies, we compared regression lines of 18 lengths of the skull against the greatest cranial length. *A. speciosus* had many characters demonstrating significant differences compared to other species/subspecies with differences in 14 to 16 parts (Table 4). In contrast, *A. a. chejuensis* showed sereral characters indicating significant differences compared to other species/subspecies (Table 4). Significant differences were observed between *A. agrarius chejuensis* and *A. argenteus* in 6 parts, between *A. agrarius chejuensis* and *A. semotus* in 7 parts, and between *A. agrarius chejuensis* and *A. agrarius coreae* in 8 parts. Thus, there is no evidence indicating skulls of *A. agrarius chejuensis* and *A. agrarius coreae* were similar shape.

Pronounced sexual dimorphism in cranial measurements was observed in *A. agrarius coreae* and *A. semotus*, in which the males were larger than females, while the others show little dimorphism (Table 5). Thus, the skull of *A. agrarius coreae* was sexually dimorphic, different from *A. agrarius chejuensis*.

Table 5. Statistical differences (*t*–test) among regression lines of two subspecies of *Apodemus agrarius* and other three *Apodemus* species for each of 18 skull characters against the greatest length of the skull (GLS). CH=A. *a. chejuensis*, CO=A. *a. coreae*, SP=*A. speciosus*, AR=*A. argenteus*, SE=*A. semotus*. Differences of the regression coefficients (R) and the Y–intercepts (I) are shown for dyad with $p<0.05$, Y–intercepts were tested for dyad with equal regression coefficients. Cite Table 3 for the abbreviations of skull characters

Dyad	CL	BL	PL	NL	FL	PrL	IL	LIF	ABL	ZB	IB	BR	BOF	LUM	LUD	LM	HM	LLM
CH : CO	R			R	I				R		I		I				I	I
CH : SP	R	R	I			I	I	I	I	I			I	I	I	I	I	I
CH : AR	R			I		I						I		I				I
CH : SE				I	I				R			R			I	I		R
CO : SP		I	I	I	R	I	R	I	R	I	I		I	I		I		I
CO : AR			I	I		I					I	I	I	I		I	I	I
CO : SE		I	R	R	I		I		R		R	R		I	I	I		R
SP : AR	I	I	I	I			I	I		I	I	I	I	I		I	I	I
SP : SE	I	I	I	R	I	I	I		R	I	R	R	R	R	R	I		R
AR : SE	R	I	I		I	I			R	I			I		I		I	

3. Form of the upper and lower molars in the genus *Apodemus*

The upper and lower molars of the *Apodemus* spp. were generally obtuse type with three processus constituted several cusps arraying on each molar (Fig. 5). The anterocone of the upper 2nd and 3rd molars is small and the anterolingual conule, consisting of three constrictions, is continuous, forming the shape of a mountain, and the basic form was the same as the upper 1st molar. In addition, the distances between the line linking posterior points of the incisive foramen and the line linking the anterior points of the right and left of the upper first molar teeth differs between *A. agrarius chejuensis* and *A. agrarius coreae*, being obviously longer in the former (Fig. 6; *A. agrarius chejuensis*: 1.11 ± 0.21; *A. agrarius coreae*: 0.21 ± 0.11; *A. speciosus*: 1.16 ± 0.19; *A. argenteus*: 0.88 ± 0.18; *A. semotus*: 0.79 ± 0.12). There was significant differences among the dis-

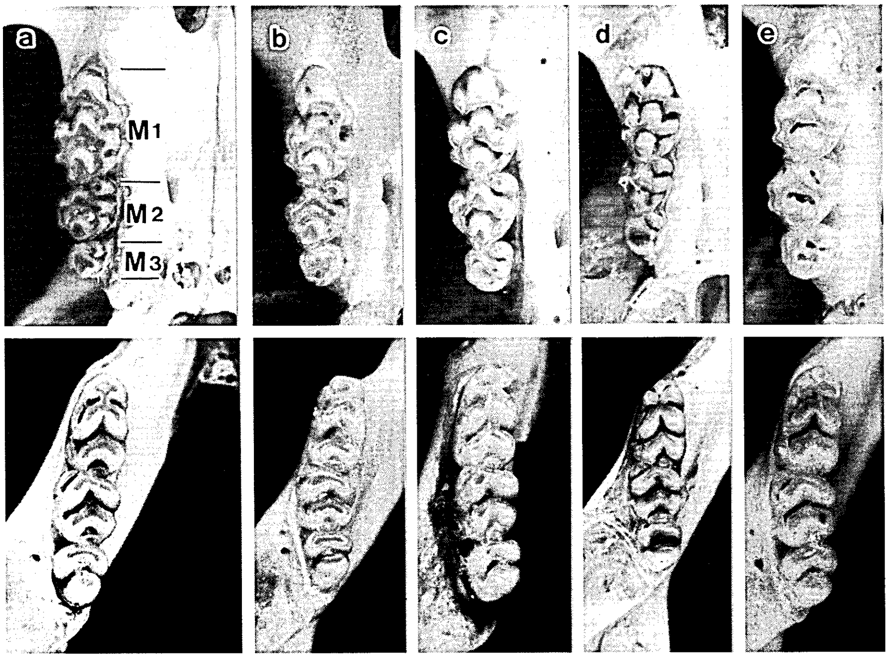

Fig. 5. Right sides of upper (upper photographs) and lower (lower photographs) molar teeth of males specimens in genus *Apodemus*. a) *A. agrarius chejuensis*; b) *A. agrarius coreae*; c) *A. speciosus*; d) *A. argenteus*; e) *A. semotus*. M1, the first upper molar; M2, the second upper molar; M3. the third upper molar. ×8.5.

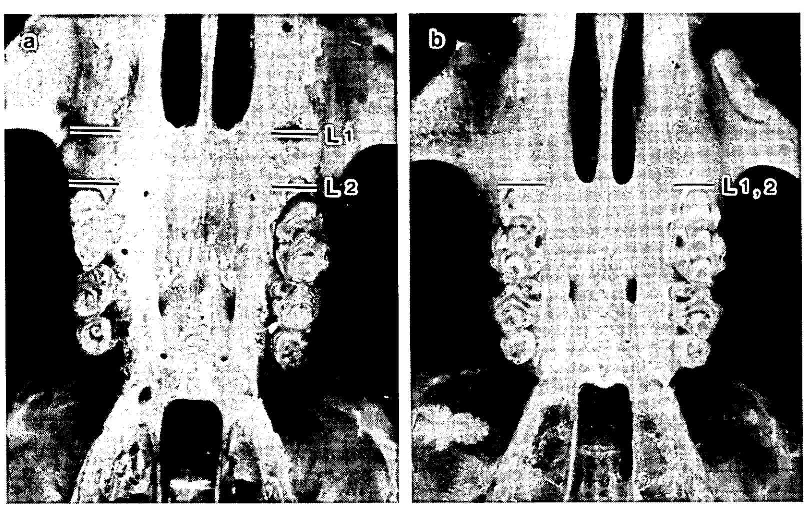

Fig. 6. Comparison of the distances between the line linking the anterior points of right and left incisive foramina (L1) and the line linking the posterior points of right and left first molar teeth (L2) of the upper jaw in a) *Apodemus agrarius chejuensis* and b) *A. agrarius coreae*. Note that two lines overlap each other in *A. agrarius core*ae. ×8.5.

tances of all of the species/subspecies (ANOVA, F=189.4, $d.f.$=195, $p<0.001$). The distance was significantly smaller in *A. agrarius coreae* and *A. semotus* than in the other species/subspecies (post hoc–test, $p<0.001$).

DISCUSSION

The degree of sexual dimorphism in the genus *Apodemus* differs between the subspecies and species and different results were obtained for *A. agrarius*, a Eurasian species which is reported to have little morphological variation (Haitlinger, 1962) and *A. agrarius coreae*, native to the Korean mainland, reported to have no sexual dimorphism (Koh, 1983). In other words, the significant differences that were observed between *A. agrarius chejuensis* and *A. agrarius coreae* in head and body length, body weight, tail length, hind foot length and ear length as well as the fact that each showed regression on different lines are good indications of the differences between the two subspecies. In addition, it can also be said that, while tail length is a sexual dimorphic character of *A. agrarius chejuensis*, the fact that the *A. agrarius coreae* did not indicate a significant difference in sexual dimorphism and the fact that the *A. a. coreae* has a lower tail ratio than *A. agrarius chejuensis* reflect differences in the living environments of these two subspecies and are interesting characters. *A. agrarius chejuensis* which inhabits Cheju Island, is large both in body and cranial size compared to the subspecies *A. agrarius coreae* and coincides well with corresponds well with the Island rule. *A. agrarius coreae* also differed in size, though basically it was expected to be much the same as *A. agrarius chejuensis*. As inferred from research (Yoon *et al.*, submitted for publication) relating to biogeography, group genetic structure and speciation relating to *A. agrarius* native to Korea, *A. agrarius* in Korea is thought to originate in *A. agrarius chejuensis*. The two subspecies are therefore thought to have been subjected to the influence of different environmental and natural enemy factors as well as genetic relationships, causing each to evolve in different directions. In addition, dimorphism is clear in the case of the forest–dwelling *A. semotus* in terms of body size, while little was found in the case of *A. argenteus*, which is thought to reflect the different ways of life of the various species, resulting in differences in morphological expression.

Comparing the results of the Formosan wood mouse, *A. semotus* (Lin and Shiraishi, 1992), which has close affinity to the relative growth of the skull in *A. agrarius chejuensis*, there were general similarities in the growth rate coefficient and the initial growth index of each part; however, the growth rate coefficient of the breadth of the rostrum and interorbital breadth was greater in the former, while that of the zygomatics breadth and breadth of occipital foramen was smaller. In addition, it has been reported in research involving *A. speciosus* (Hiraiwa *et al.*, 1958), *A. agrarius* (Tanaka, 1942) and *A. semotus* (Lin and Shiraishi, 1992) that the growth of the interorbital breadth and interparietal length is slower than that of the other parts; however, the growth rate coefficient of the breadth of rostrum and interorbital breadth is large in the case of *A. agrarius chejuensis* and the fact that, even when an adult, they continue to grow for a longer time than in in other *Apodemus* species is thought to be a characters of this species.

Interspecific differences in rodent crania are observed in those parts directly related to the molars and masticatory muscle, which take a form that enables adaption to the unique feeding habits of the animal species. The species of genus *Apodemus* have various feeding habits, such as *A. flavicollis* and *A. sylvaticus* of Europe (Hansson, 1971), *A. speciosus*, *A. agrarius chejuensis*, *A. a. coreae* and *A. semotus*, which feed on seeds and insects, and *A. argenteus*, which is insectivorous. Based on the results of a comparison of the parts of the skull between species, significant differences were found in the relationship that are greater between the two subspecies *A. agrarius chejuensis* and *A. agrarius coreae* than *A. argenteus* and *A. semotus*. Furthermore, it is thought that the distance between a line connecting the left and right rear extremities of the incisive foramen and a line connecting the left and right front extremities of the upper first molars, which is different between *A. agrarius coreae* and *A. agrarius chejuensis*, originates in the fact that the upper diastema is longer in *A. agrarius chejuensis* than in other species. Thus, in the taxonomic relationship between *A. agrarius coreae* and *A. agrarius chejuensis*, judging from the fact that there are various differences in the cranial characters, the distance between the rear extremities of the incisive foramen and front extremities of the upper first molars and the various characters of the external morphology, we have concluded that there are significant morphological differences between these two subspecies and that they have an extremely distant taxonomic relationship.

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