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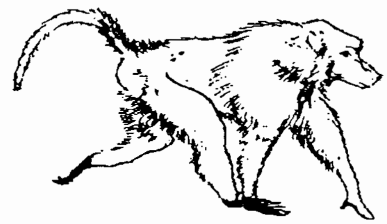
FROM THE EDITOR'S WORKSTATION



If it seems like a long time since the last issue of the CRPA/RCAP, that is not really so unless you allowed your membership to lapse, moved without telling us, or the postal system has decided that your mail should be redirected to the dead letter office. The last issue, jointly with the Canadian Journal of Anthropology Volume 5 #2, and erroneously labelled as "CRPA/RCAP Volume 5 numbers 2" - it should have read "numbers 1 and 2" - was distributed in October 1986. If you did not receive yours, and a few people did not, please advise me. You will note that your mailing label contains a box with a year number inside it. That year is the last for which you have paid your membership, and unless it says 1987 you are in arrears, the association would like you to take care of this matter expeditiously please. This issue is being distributed to all those on the 1985, 1986, and 1987 lists, but the next issue (Volume 6,#2) will only go to those who have paid up for 1987.

This issue represents the first one for which the editor has to take full responsibility in all regards. From the reviewing process through the editing and preparation of the final text and graphics, to the final layout and printing of the master copies, your humble editor has had final control, and indeed has done nearly all of the work. I thank my administrative secretary Renaté Hull who has aided me by typing five of the papers. I thank the University of Calgary Microstore for the use of their Abaton Scanner which I used to prepare the graphics in the Lang, Colquhoun, Wade and Elie papers. My wife has also had to put up the irritated state of the editor whenever the software did not do what it was ordered to do, and without whose calming influences, I might have reacted badly. This issue has, by my current estimate, consumed approximately three hundred hours of intensive work over the past four months, a large part of it during this week (it happens to be "reading week" here). However, it is now nearly done, with only the printing out of the final masters to be accomplished over this next weekend, and it can go to the printers.

Now a matter of some interest and urgency for me: I HAVE NOT ONE SINGLE ITEM OF MATERIAL SUBMITTED FOR THE NEXT ISSUE OF THIS JOURNAL! If the Review is to continue as a viable journal, this state of affairs must immediately come to an end. I have tentatively planned to produce the next issue in the early fall of this year - about six months hence. At the current rate of submission, this is unlikely, and I wonder about the possibility of even continuing the review. If you don't submit material, I can't publish it. Remember that the CRPA/RCAP is the ONLY physical anthropology journal in Canada, and while your administrators may have a different viewpoint, in Alberta the "publish or perish" ethic has assumed dominance. We have agreed upon procedures for the dismissal of inadequate performing professorial staff, and many have taken early retirement rather than face the prospect of being fired. If the "British Columbia disease" is not to spread eastwards even more, now that it has taken root in Alberta, it may be wise to take the line of least resistance and provide me with submitted papers. Some individuals may be reluctant to submit to CRPA/RCAP because they perceive it as being of low respectability, yet how is the journal to achieve a higher level of reputation unless the leading scholars of the Canadian Association for Physical Anthropology take the "risk" of publishing their work in this journal? I want this journal to succeed and to become established as one of higher repute, and I assume that as members of the association, you do so as well. Therefore your course is clear, you will each submit one paper to the editor before the end of May 1987.

On a rather different topic, I would encourage everyone who is involved with or using microcomputers to have a look at a new newsletter called "Computer Assisted Anthropology News" or simply "CAAN" which is edited by James Dow and published out of the Department of Sociology and Anthropology, Oakland University, Rochester, Michigan, U.S.A. 48063. This little journal is now into its second volume, publishing, or attempting to do so, 4 times a year. It is filled with information relevant to the use of computers in field and laboratory situations. One recent issue examined a large collection of statistical programs for the IBM compatible world, and may be of great interest to users of those machines. The most recent issue (Volume 2,#2) has an interesting article about the use of a microcomputer in the field, in the bush of Kenya, using a solar power system to charge the batteries of a Data General DG-One, as well as an in depth account of the use of E-Mail over the Mailnet/ARPANET/ BITNET set of mail networks. If you are interested in subscribing, you can either send "regular" mail to the address above or to the following e-mail addresses:

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And if anyone wishes to check the status of a paper submitted, to complain about/to the editor, perhaps even to actually submit a paper, or merely to chat, my own e-mail addresses are:

JDPaterson@UNCA-MULTICS.Mailnet
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Sincerely, Jim Paterson, Editor/Redacteur

Editorial Note: Dr Susan Pfeiffer acting on behalf of the Palaeopathology Association has requested that the following statement from the association be passed on to the membership of the CAPA/AAPC. This policy statement was passed at the Palaeopathology Association meeting in Albuquerque, May 1986.

Policy on the Preservation of Human Remains.

The Palaeopathology Association is a multidisciplinary international organization devoted to the study of the antiquity and evolution of disease, and its effect on human biological variation and cultural history. The Association is composed of physicians and other scientists in the fields of archaeology, biological anthropology, forensic medicine, pathology, radiology, orthopedic surgery, dentistry, infectious disease, nutrition, art history, and medical history.

The Association opposes any attempt to prohibit the scientific excavation and curation of archaeological human remains. Moreover, those seeking to seize the carefully maintained archaeological human remains and cultural artifacts in scientific institutions are committing serious acts against the rights of all citizens, as well as the rights of future generations.

Human remains comprise a valuable means of directly evaluating the presence or absence of specific infectious diseases, neoplasms, dietary deficiencies, congenital anomalies, dental disorders, different forms of arthritis, age-related degenerative changes, accidental and intentional trauma, and theraputic intervention. Such information is directly applicable to related groups today, and is basic to our understanding of the evolution of disease, the causes and epidemiology of cancer, the biology of skeletal growth, and humankind's accomodation and adaptation to disease both biologically and culturally.

The study of human remains from all cultures, time periods, and regions is vital to an understanding of human disease and adaptation. There is no discrimination against or bias towards any cultural or racial group. Human remains, predominantly archaeological skeletal remains, are respectfully and scientifically handled at all times, and are accessible only to serious researchers. Proper storage is critical to ensure availability of the material for future evaluation with new techniques.

The Palaeopathology Association recognizes the concerns of certain cultural groups regarding the appropriate disposition of specific human remains, but only on a well-documented case by case basis. The Association joins them in condemning the unscientific pillaging of archaeological sites by vandals or other unauthorized persons. It also seeks to minimize the inadvertant damage or destruction of such sites on federal and state lands produced by road construction, logging, mining, and grazing.

As the Palaeopathology Association's motto states: *Mortui viventes docent* — the dead are our teachers. We treat the dead with great respect and dignity, for the human remains have taught us much about human development and cultural history. Such investigations are vital to obtain knowledge applicable to all people and cultural groups.

OSTEOMETRIC DIFFERENTIATION OF MALE AND FEMALE HIP BONES: AN EXPLORATORY ANALYSIS OF SOME UNORTHODOX MEASUREMENTS

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Department of Anthropology
University of Toronto,

Abstract: This paper deals with osteometric differences between male and female hip bones. A series of mostly unorthodox measurements were made on a sample of dry hip bones from the Grant Collection, curated in the Medical Sciences Building at the University of Toronto. The data were subjected to appropriate t-test analyses in order to assess the magnitude of sexual dimorphism. Significant differences between male and female means were shown in six of the direct measurements and four indices. Females produced larger inner pelvic measurements and males produced larger outer pelvic measurements.

Resumé: Cet étude s'agit des différences ostéometriques entres les os iliaques chez les hommes et les femmes. Une séries des mésures insolites était prise d'un échantillon des os iliaques secs de la collection Grand à l'Université de Toronto. Ces résultats nous montrent quelques différences significatiques entres les hommes et les femmes pour six mésures directs et pour les quartre indices des proportions pelviennes. Les plus grandes valeurs d'intérieurs pelvienne étaient parmis les femmes, et les plus grandes d'extérieur pelvien se trouvaie chez les hommes.

Key Words: **Hip bones, sexing, pelvimetry, Forensic Osteology**

** Editorial Note: This paper was joint winner of the Oschinsky-McKern Award for the best student presentation at the 1985 meetings of the Canadian Association for Physical Anthropology at Thunder Bay, Ontario.*

Ms Lang is now a graduate student in the Anthropology Department at Trent University, Peterborough, Ontario.

INTRODUCTION

Historically, the use of osteometry has been an important tool in sex determination of the human skeleton. Metric measurements focusing on the hip bone in particular have produced reliable distinctions in this regard, as reported by Schultz (1930), Washburn (1948) and many other researchers since that time. This paper discusses the sex-discriminating effectiveness of some mainly unorthodox measurements.

The paper is structured in two parts: Part I explains the initial methods and results of the obstetric measurements while Part II describes the consequent measurements which have greater archaeological applications.

MATERIALS AND METHODS I

Measurements were applied to a sample of dry hip bones, obtained from the Grant Skeletal Collection, then housed in the Medical Sciences Building at the University of Toronto. The specimens are of known sex, age at death, and cause of death. This enables researchers to produce skeletal information against a baseline of known critical data. A sample of 45 specimens was selected from the Grant Collection: 19 females and 26 males. A forthcoming paper by Heathcote and colleagues will specify the history and composition of this collection.

Obstetric Measurement

The following measurements are ultimately based on works from researchers in the field of obstetrics, namely Caldwell and Moloy (1933) and Aiman (1976). They are modified from those developed by Heathcote and Sullivan

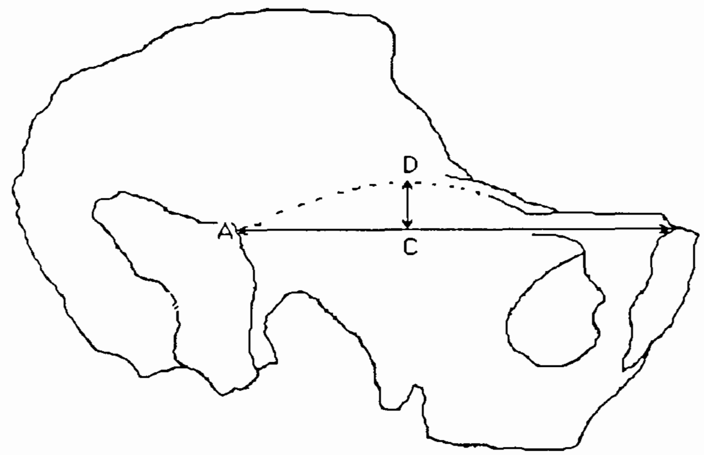


Figure 1: A-B: Maximum A-P length of Pelvic Inlet (MAXLGT)
A-C: FRACTION (along the MAXLGT chord)
C-D: SUBTENCE (to the MAXLGT chord)
Dashed line indicates the iliopectineal line
(after Bass,71)

(1978), and quantify the critical dimensions of the obstetric pelvis. Left hip bones were measured whenever possible. A standard GPM 222 mm co-ordinate caliper was used, and readings were recorded to the nearest millimeter.

In Figure 1, the measurement shown from point A to B is called the Maximum Length. It is the maximum anterior-posterior length of the pelvic inlet. It is fashioned from the obstetric conjugate, described by Aiman (1976). Maximum Length is measured from point A, the most anterior point on the margin of the auricular surface, where it meets the iliopectineal line, (which is the dashed line), to point B, which is the most posterior point on the superior margin of the pubic symphysis. High values for this measurement are expected to represent the longer, female A-P length. The measurement from point A to C is called the Fraction (along the Maximum Length chord). It is the point at which the greatest transverse diameter of the pelvic inlet occurs. Caldwell and Moloy (1933) have found that the greatest transverse diameter is located closer to the sacrum in females. Consequently, lower values are expected to represent females and should indicate this posterior orientation. The third measurement (from point C to D) is the Subtence and measures the greatest demidiametric breadth, from the Maximum Length chord, to the iliopectineal line, on a single hip bone. High values indicate a broader pelvic inlet, which is expected in female specimens.

In Figure 2, the measurement from point A to B is called Minimum Length; this is the minimum A-P length of the pelvic inlet. It is measured from point A, the most anterior point on the auricular surface, wherever found, to point B, the most posterior point on the median margin of the pubic symphysis. It measures the minimum A-P diameter of the superior part of the functional birth canal. Higher values should indicate the longer female length of the functional birth canal. The second measurement (from point C to D) is called Pelvic Height and is the depth of the true pelvis. It is the distance from the most superior point on the iliopubic eminence (at point C) to the most inferior point on the ischial tuberosity (point D), and is fashioned after a similar measurement from Caldwell and Moloy (1933). This measurement obtains the superior-to-inferior height of the functional birth canal on an individual hip bone. Low values would indicate the shallower depth

Figure 2:
A-B: Minimum A-P length of Pelvic Inlet (MINLGT)
C-D: Pelvic Height (PELHGT)
After Bass, 1971

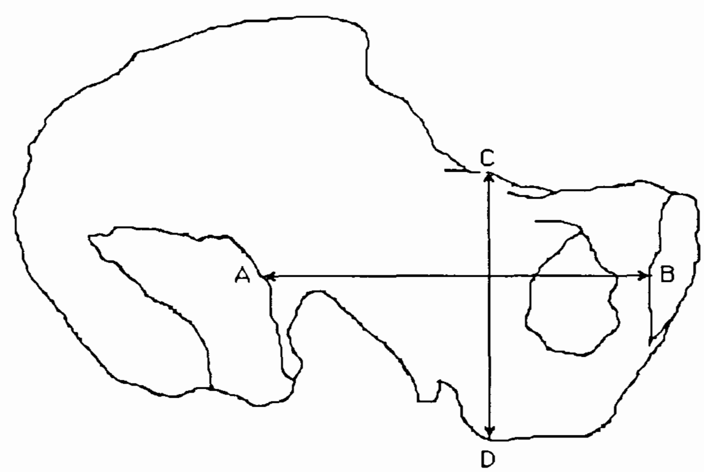


Table 1

Indices Produced From Obstetric Measurements		PROPORTIONALITY VALUES
Index 1	$\frac{\text{SUBTENCE}}{\text{PELHGT}} \times 100$	High Value = Female (broad, shallow birth canal)
Index 2	$\frac{\text{PELHGT}}{\text{MAXLGT}} \times 100$	Low Value = Female (shallow, long inlet)
Index 3	$\frac{\text{PELHGT}}{\text{MINLGT}} \times 100$	Low Value = Female (shallow, long inlet)
Index 4	$\frac{\text{FRACTION}}{\text{MAXLGT}} \times 100$	Low Value = Female (broad, long inlet)
Index 5	$\frac{\text{PELHGT2}}{\text{ACEHGT}} \times 100$	

of the female birth canal as reported by Caldwell and Moloy (1933) and others.

Four indices were developed from these measurements and are shown in TABLE 1. Index 1 is the Subtence Breadth (from the Maximum Length chord) to true Pelvic Height ratio. High values indicate a broad, shallow pelvic inlet shape, expected to represent female proportions. Index 2 is the Pelvic Height to Maximum Pelvic Length ratio. Low values indicate a shallow, long A-P pelvic inlet shape, representative of female proportions. Index 3 is the Pelvic Height to Minimum Pelvic Length ratio. Low values again indicate shallow, long A-P pelvic shape expected in females. Index 4 is the point of deepest concavity at the Fraction (along the inlet brim) to Maximum Pelvic Length ratio. Low values indicate a short fraction value (i.e. more posterior orientation for the maximum transverse diameter) with long pelvic length, indicating female proportions.

Data generated from these variables along with information on age and the sex of each specimen were entered onto a computer file, using the SOS editing package, supported by the University of Toronto's DEC 10 system. The data were sorted by sex, and using the SAS statistical package (Helwig 1978), supported by University of Toronto's mainframe IBM computer, summary statistics and t-tests results were generated. Using the SAS procedures, PROC MEANS and PROC T-TEST respectively, the male and female group mean values were compared. SAS tested for homogeneity of variance and generates alternate t-values in cases where this assumption was not met. A visual check of skewness and kurtosis indicated that the Fraction distributions were significantly non-normal in males and females. However, this was considered unproblematic, given the well known robusticity of the t-tests (Schefler 1980). Differences were considered significant at the 5% confidence level. A one-tailed t-test model was used, as it is clearly appropriate in this application, where a priori expectations are held.

RESULTS AND DISCUSSION I
Obstetric Measurements

TABLE 2 lists the results for male and female group means, their respective t-values and probabilities. In general, the mean values for all of the direct measurements and indices have met the original expectations: for example, the first variable, Maximum A-P Length, shows a higher mean value for the female group. This was expected for this measurement, as it is indicative of the longer A-P dimension of the female pelvic inlet. All group means shown here display the high and low values which were expected, according to their respective male or female group. The first three variables shown here, however, have non-significant probabilities attached to the t-values. This indicates that the Grant Collection males and females do not display substantial

SIZE differences in these regards, according to sex. The maximum A-P Length measurement shows the greater mean value for the female group to be significant at the .025 level. This indicates a strong sexual dimorphic difference for this pelvic inlet dimension. The Pelvic Height variable has the greatest mean difference for male and female groups, the difference being significant at the .001 level. The lower mean value for the female group suggests the obstetric significance of this dimension. Caldwell and Moloy (1933) suggest that the shorter pelvic height found in females, increases the chances of successful fetal passage through the constrictive boney pelvic inlet. In the event of a narrow pelvic diameter or a narrow sub-pubic angle, a short pelvic height creates a shallow pelvis which may be the determining factor in a successful fetal passage.

The first three indices listed in TABLE 2 also manifest highly significant sex differences. This reflects the proportionality differences between male and female groups, as discussed earlier. These results (on a small sample), suggest that the proportionality variables may be of value in general application, while size variables may be likely by more population-specific in sex-discriminating efficiency. However further testing on a larger sample is necessary to resolve this suggestion.

MATERIALS AND METHODS II

Archaeologically-oriented Measurements

With the permission of Dr J. Melbye at the University of Toronto, the skeletal remains from the Kleinburg Ossuary were used. The ossuary, located at Kleinburg, Ontario was excavated by Melbye in 1970 (Pfeiffer 1979). The collection has a minimum number of 270 adults and is a later Ontario Iroquoian population (F.J. Melbye, personal communication).

Dr J.E. Molto, at Lakehead University, provided access to remains from the Misner Cemetery. The Misner Collection is the skeletal remains recovered from a looted Neutral Indian Cemetery in Ontario by the Ministry of Citizenship and Culture in the fall of 1984 (Fox, 1985). The cemetery is associated with the Misner Village Site which has been dated at 1620-1625 (by trade beads). It is an historical Neutral site and contains about 65 individuals (J.E. Molto, personal communication).

On examination of both collections, the hip bones were found to be fragmented and broken, rendering most of the specimens unsuitable for measurement. Figure 3 represents the most frequent breakage points noted, and resultant

Table 2

Group Means and t-test Results for Obstetric Variables
Direct Measurements for the Functional Birth Canal

	Male				Female					
	n	x	S.D.	S.E.	n	x	S.D.	S.E.	t	Probability
MAXLGT	26	114.15	8.55	1.67	19	116.15	7.12	1.63	0.8315	0.25
FRACTION	26	47.80	9.91	1.94	18	146.61	8.70	2.05	-0.4132	0.40
SUBTENCE	26	23.88	3.86	.75	18	25.16	3.46	.81	1.1279	0.25
MINLGT	26	106.69	8.13	1.59	18	112.00	5.87	1.38	2.3705	0.025*
PELHGT	26	107.57	5.49	1.07	19	95.15	4.66	1.07	-7.9675	0.0001***
Indices										
Index 1	26	22.20	3.49	.68	18	26.31	3.61	.85	3.7815	0.0005***
Index 2	26	94.54	5.70	1.11	19	82.15	5.62	1.29	-7.2383	0.0001***
Index 3	26	101.18	6.34	1.24	18	85.67	5.63	1.32	-8.3371	0.0001***
Index 4	26	41.96	8.74	1.71	18	39.82	6.78	1.60	-0.8684	0.25

Levels of significance * ≤ .05; ** ≤ .01; *** ≤ .001

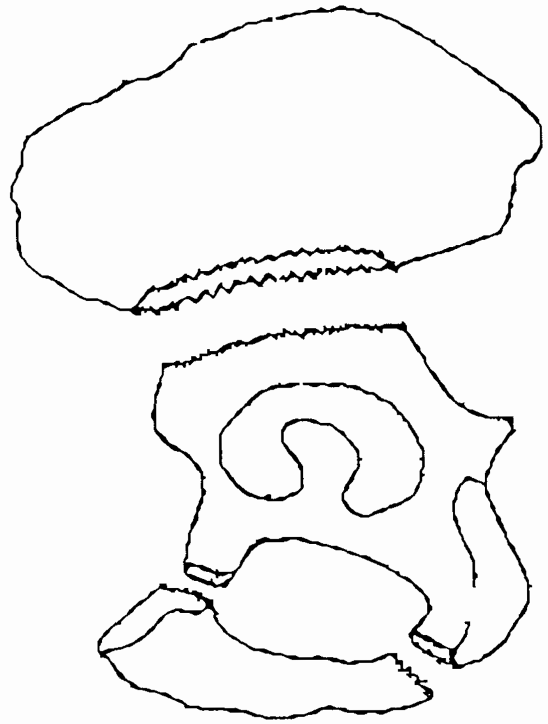


Figure 3:
The most common breakage points in ancient material. (after Taylor and Dibennardo,1984.

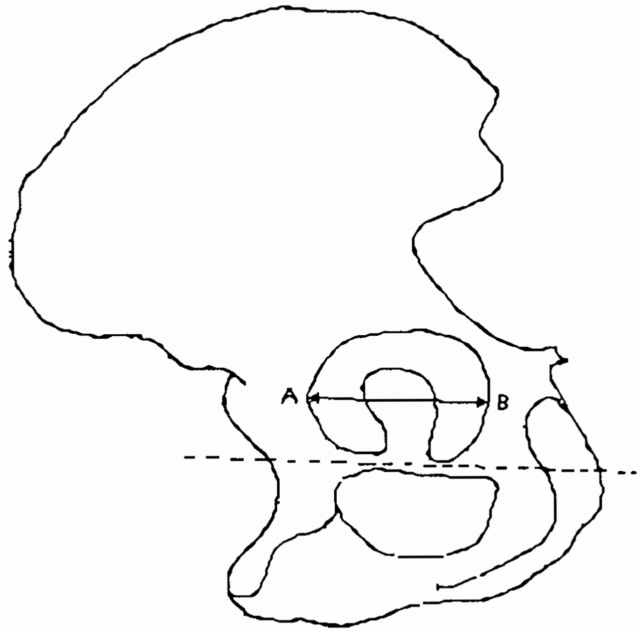


Figure 4:
A-B: Acetabular Height (ACEHGT)
Dashed line represents angle of the spiral border of the Obturator Foramen. (after Taylor and Dibennardo, 1984)

preserved portions of the hip bone. Subsequent measurements were designed which would be applicable to a portion of the hip bone most likely to survive burial, weathering, looting or other effects imposed on ancient material, and would also distinguish sexual dimorphism and encompass the greatest sample size, in order to adequately represent the collections. To this end, four extra measurements were developed which focused on the central portion of the hip bone.

The following measurements are variations of measurements applied in the field of physical anthropology. A 170 mm Helios dial caliper was used and readings were recorded to the nearest one-tenth of a millimeter.

The measurement illustrated in Figure 4 is the Acetabular Height. It is modified from a similar measurement used by Genoves (1956). It is the maximum diameter of the acetabulum (from point A to B) and is measured from a superior-inferior plane, parallel with the axis of the spiral margin border of the obturator foramen, indicated by the dashed line. It follows the general axis of the body of the ischium as does a similar measurement by Day and Pitcher-Wilmott (1975).

Acetabular Depth, is the deepest point on the non-articular surface of the acetabular floor: Figure 5 demonstrates the points from which the Acetabular Depth will be taken. The caliper needles rest on the points which are actually the Acetabular Height. Figure 6 demonstrates the use of Vitrex profile gauge (model #A921942) to measure the Acetabular Depth. The gauge is placed on the points of the acetabular rim, determined for Acetabular Height. The needles of the gauge are depressed onto the acetabular floor, and the gauge removed. The depressed needles take the shape of the acetabular depression, including its point of deepest concavity (Figure 7). This point is measured from the profile needles, with the dial calilper as shown. The profile gauge was found to be a more accurate instrument for use in depth measurement here, rather than trying to estimate the deepest point, using the central arm of a co-ordinate caliper.

The next measurement (Figure 8) is the Co-

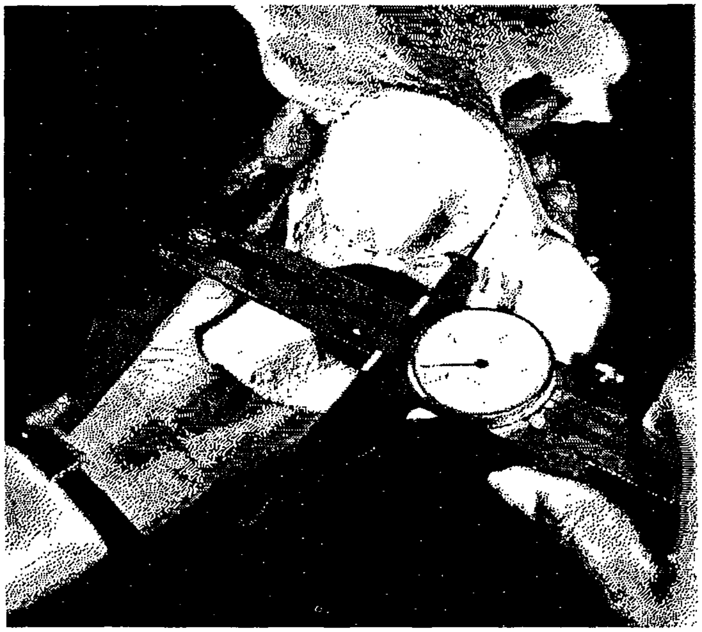
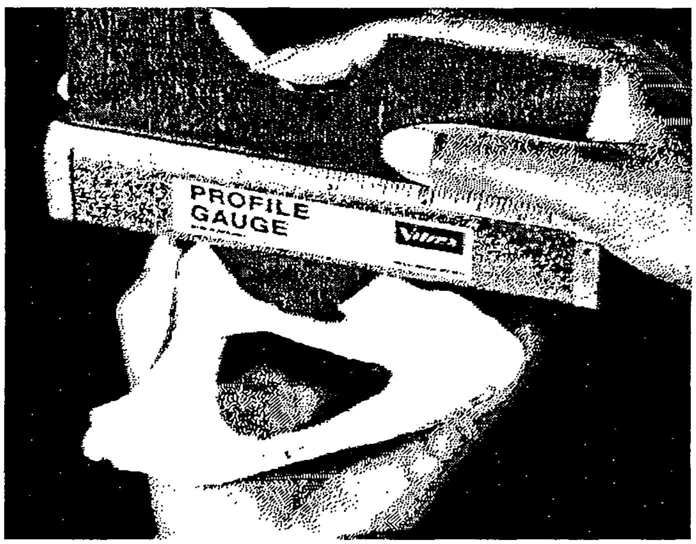


Figure 5 (above):
The points from which the Acetabular Depth is taken. It is the same as the Acetabular Height.
Figure 6 (below):
The use of a contour guage to measure Acetabular Depth.
Figure 7 (right):
The point of deepest concavity on the acetabular floor is measured from the contour guage with a dial caliper.

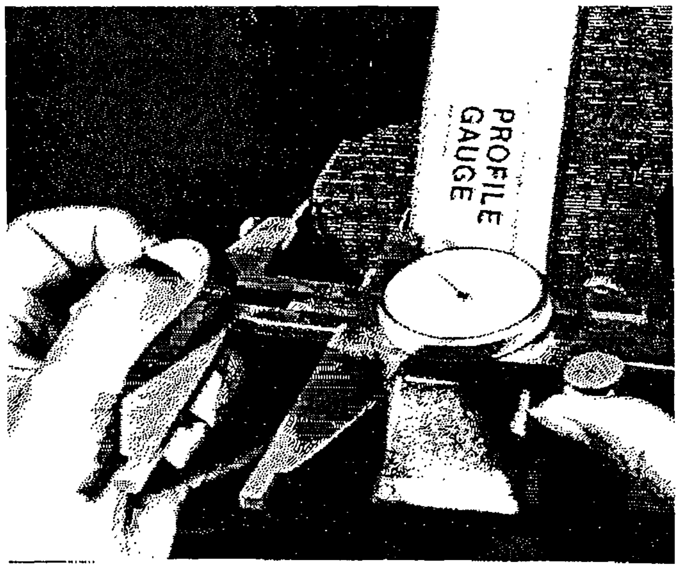
tylo-Sciatic Breadth at Midpoint. It is from a similar measurement of Sauter (1954-55 in Olivier 1969); modified by Heathcote and Sullivan (1978). It measures the minimum breadth from



the acetabular rim (point A), to the border of the greater sciatic notch (point B).

The final measurement is the Second Pelvic Height (Figure 9). The purpose of this measurement is to obtain a pelvic depth reading in cases where the most inferior point of the ischial tuberosity may be broken off or damaged, preventing the use of the first pelvic height measurement. It is a depth reading of the true pelvis, taken from the most superior point on the iliopubic eminence (point A), to the ischial tuberosity, (point B) in a vertical plane, parallel to the spiral margin border of the obturator foramen, which is indicated by the dashed line (Figure 9).

These measurements were applied to the same sample selected from the Grant collection. The specimens were grouped according to sex once more and subjected to the same statistical



procedures and tests, in order to assess their significance. Acetabular Height for males and Acetabular Depth for females showed non-normal distributions. Again, these distributions were not transformed, given the robusticity of the t-test.

RESULTS AND DISCUSSION II

TABLE 3 lists the results computed for the second set of measurements. All four direct measurements show significant male-female differences. Mean values for the male group are higher in all four cases. For Acetabular Height, Acetabular Depth and Cotylo-Sciatic

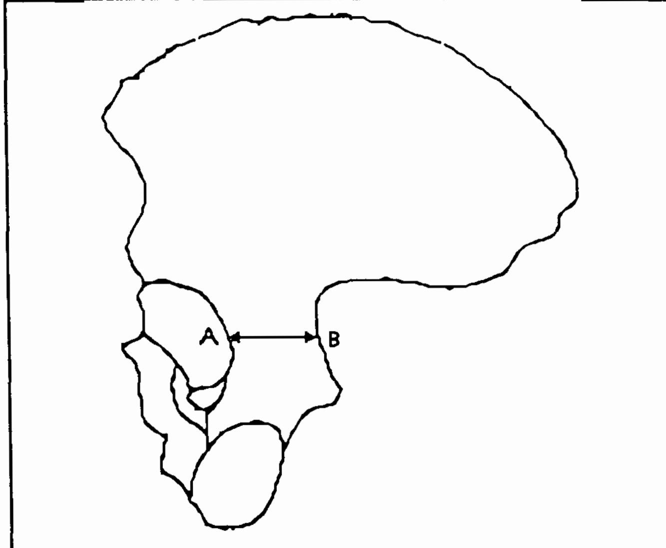


Figure 8:
A-B: Cotylo-sciatic Breadth at midpoint (COTBTH).
(after Day and Pitcher-Wilmott, 1975.)

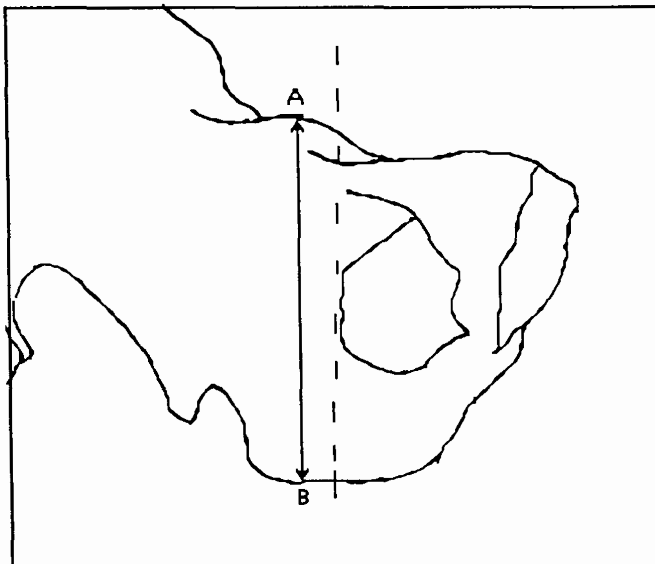


Figure 9:
A-B: Second Pelvic Height (PELHGT2)
Dashed line represents the spiral margin border of the Obturator Foramen.(after Bass, 1971)

Breadth, these higher values indicate that males have larger measurements dealing with the inner structures of the pelvis. This was also shown in the first set of obstetric measurements, which dealt with the inner pelvis and where female group means were consistently higher. This pattern has also been observed by Reynolds (1945, 1947) in infants and pre-adolescents.

The Second Pelvic Height measurement is a variation of the first Pelvic Height variable and therefore has the same obstetric significance discussed earlier.

Index 5 is the ratio between the Acetabular Height and the Second Pelvic Height. Again, the female group displays a significant lower value. This index may be the best sex-determinator in the present study, reflecting as it does, the influences of locomotion, smaller female stature, proportionality and obstetrics.

The entire battery of nine measurements was applied to specimens in the archaeological collections, whenever possible. Due to the preservational condition of the specimens, the measurements concerning the central portion of the hip bone were most applicable in most cases. Presentation and interpretation of these results will be presented in a forthcoming paper.

CONCLUSIONS

TABLE 4 lists those variables which were found to have statistically significant differences between male and female group means, when applied to the Grant Skeletal Collection. These results were based on a small sample, and may be population-specific. As indicatd earlier, proportionality variables (indices) may well be proven by further research to be more generally powerful sex discriminators than size variables. These results may be useful in instances of recovery of skeletal material from archaeological sites because four of the measurements: Acetabular Height and Depth measurements, the Cotylo-Sciatic Breadth and the Second Pelvic Height, were specifically developed for application on damaged material.

Index 2 and 3 compare well with percentage results from other studies. Washburn (1948) reports the Ischium-Pubis Index to average 15% higher in females in the Hamman-Todd Collection. The Acetabular-Pubis Index, developed by Schulter-Ellis and Hayek (1984), produces black male averages 14.5% higher than black females and white males 17.6% higher than white females for the Terry Skeletal Collection. In the present study, the Maximum Length-Pelvic Height Index averages 15% higher in males, and the Minimum Length-Pelvic Height Index averages 18% higher in males for the Grant Collection. Therefore, these latter two indices appear to have promise for application in forensic and anthropological studies. It is hoped that other researchers will

Table 3

Group Means and t-test Results for the Central Portion of the Hip Bone Measurements with Greater Archaeological Application

	Male				Female					
	n	x	S.D.	S.E.	n	x	S.D.	S.E.	t	Probability
ACEHGT	25	55.22	3.05	.61	19	48.20	2.91	.66	-7.7009	0.0001***
ACEDTH	21	29.00	3.80	.82	18	26.64	2.93	.69	-2.1426	0.025*
COTBTH	24	40.57	4.05	.82	19	37.25	5.47	1.25	-2.2811	0.025*
PELHGT2	26	107.40	6.28	1.23	19	96.14	4.35	1.00	-6.7047	0.0001***
Index 5 (PELHGT2-ACEHGT)	25	51.73	1.81	.36	19	50.17	2.89	.66	-2.0516	0.025*

Level of significance: * ≤ .05; ** ≤ .01; *** ≤ .001

Table 4

Table of Significant Results

Direct Measurements

	Male				Female					
	n	x	S.D.	S.E.	n	x	S.D.	S.E.	t	Probability
Minimum A-P length pelvic inlet	26	106.69	8.13	1.59	18	112.00	5.87	1.38	2.3705	0.025*
Pelvic Height	26	107.57	5.49	1.07	19	95.15	4.66	1.07	-7.9675	0.0001***
Acetabular Height	25	55.22	3.05	.61	19	48.20	2.91	.66	-7.7009	0.0001***
Max Acetabular Depth	21	29.00	3.80	.82	18	26.64	2.93	.69	-2.1426	0.025*
Cotylo-Sciatic Breadth	24	40.47	4.05	.82	19	37.25	5.47	1.25	-2.2811	0.025*
2nd Pelvic Height	26	107.40	6.28	1.23	19	96.14	4.35	1.00	-6.7047	0.0001***
Indices										
Index 1	26	22.20	3.49	.68	18	26.31	3.61	.85	3.7815	0.0005***
Index 2	26	94.54	5.70	1.11	19	82.15	5.62	1.29	-7.2383	0.0001***
Index 3	26	101.18	6.34	1.24	18	85.67	5.63	1.32	-8.3371	0.0001***
Index 5	25	51.73	1.81	.36	19	50.17	2.89	.66	-2.0516	0.025*

Level of significance: * ≤ .05; ** ≤ .01; *** ≤ .001

find merit in applying them, to identify sex of human skeletal remains in the fields of human osteology and in forensic studies.

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Dominance and "Fall-fever": The Reproductive Behaviour of Male Brown Lemur (*Lemur fulvus*)

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Abstract: It has consistently been reported that, based on agonistic interactions, (Lemur fulvus) social behaviour is characterized by an apparent absence of hierarchical social dominance relationships. Also striking is the "package" of behavioural changes and fluctuations exhibited by adult males during breeding season (termed here, "fall-fever"). During the 1984 (Northern Hemisphere) breeding season, over 300 hours of focal animal observations were conducted on two adult males in a semi-freeranging (L. fulvus) troop. Using a comprehensive ethogram, the role of the "fall-fever" behavioural fluctuations in the reproductive behaviour of adult males was investigated. Despite several previously published reports, it was found that hierarchical social dominance relationships played an important part in male (L. fulvus) reproductive behaviour. This paper presents a chronological profile of the social interactions of the study's focal animals over the first 120 hours of observation, following one male's social demise and expulsion from the study troop and his troop-mate's ascendancy to the role of the troop's lone breeding male.

Résumé: Measuré par interaction agressifs, le comportement social de Lemur fulvus est rapporter à manque la parenté du dominance hierarchique social. De plus remarquable est un "paquet" de changements et fluctuations des comportements des adulte mâles de Lemur fulvus pendant le temps de procréation (le terme ici "fall-fever"). Durant le "fall-fever" de 1984 (Hemisphere Nord), plus de 300 heures d'observations des animaux focal sont fait. Les animaux focal sont deux adulte mâles d'un troupe de Lemur fulvus qui vivant dans une cloture de habitat naturel. En employant une ethogramme compréhensive, le rôle de changement des comportements procréatifs de ces deux animaux a été observer.

Contre les rapports d'autre recherche, j'ai trouvé que le parenté du dominance hierarchique social est un composant essential dans les comportements procréatifs des mâles de L. fulvus. Cet article présente un profil chronologique des interactions sociaux des animaux focal pendant les premiers 120 heures d'observation. On suivre l'aliénation d'un mâle et son explusion finalement de troupe en mene temps qu'on voit l'ascension de son camarade jus qu'au rôle de seul procréateur de troupe.

Key Words: ***Lemur fulvus*, hierarchical social dominance relationships, "fall-fever", reproductive behaviour.**

INTRODUCTION

Alison Jolly was essentially saying it 20 years ago, and it is still an accurate assessment today; that is, that: (1) prosimian primates are under-represented in the primate literature, (2) the Superfamily Lemuroidea - the most extensive branch of the strepsirhine primate suborder - remains largely unstudied, and (3) our knowledge of even "well-studied" lemuroid species is based on only a few populations. Indeed, while *Lemur fulvus*, the brown lemur, is one prosimian which is relatively well repre-

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sented in the primate literature, we still know extremely little about the behaviour or ecology of this species.

One aspect of *L. fulvus* social behaviour that has consistently been reported in the literature is the apparent, and significant, absence of hierarchical social dominance relationships (Vick & Conley, 1976; Vick, 1977; Tattersall, 1977b; Harrington, 1974, 1975; Sussman, 1974, 1975; Sussman & Richard, 1974; Hornshaw & Colquhoun, 1983; Kavanagh, 1983). Normal social interactions in *L. fulvus* troops are generally perceived as amicable and gregarious, with sitting in contact with, and grooming, other animals being by far the most commonly social behaviours. I was interested in determining alternate behavioural indices to agonistically determined "dominance", to gauge how adult males gained and maintained access to estrous females. Accordingly, the ethogram for this study included 39 behavioural states, spanning the entire range of *L. fulvus* social behaviour: from behaviours that occurred year round (e.g., grooming, sitting with), to behaviours that showed seasonal peaks and were primarily associated with the breeding season (e.g. clasping, mounting and, anogenital sniffing and grooming). To my knowledge, this study represents the first intensive investigation of male *L. fulvus* reproductive behaviour (cf. Chandler, 1975; Boskoff, 1978a, b & c), and the first published report to quantitatively establish hierarchical social dominance relationships in a *L. fulvus* social group. This article is a preliminary report of the expulsion of a breeding age male from his social group, as measured by several social parameters. Behavioural fluctuations involved in his troop-mate's ascendancy to sole breeding male in the troop will also be briefly considered.

METHODOLOGY

The fieldwork for this study was conducted at the Duke University Primate Center (DUPC), in Durham, North Carolina. Among major primate research centers, DUPC is unique in housing only prosimian primates. The prosimian colony at DUPC is the largest and most diverse in the world, numbering well over 500 animals and representing 5 Families, 11 genera, 20 species and nearly 30 different sub-species. It is also the largest breeding colony of endangered primate species in the world (Simons,). The study period spanned the 1984 (Northern Hemisphere) breeding season, from mid-October 1984 to late January 1985. The first 120 hours of observations, conducted from October 22 to November 25, 1984, are reported on here.

The study troop, nicknamed "Ursula's troop", was composed of 9 animals (Figure 1).

This particular troop is unique among captive populations of (*L. fulvus*). Since Ursula's troop was formed over 15 years ago (on October 14, 1970), troop membership has been regulated mainly by natural means (births, deaths and expulsions from the troop). Breeding males have occasionally been replaced to prevent inbreeding. Ursula's troop is the single most studied lemuroid social group. Adult female "Ursula", the troop's present matriarch, was just a juvenile of 1 1/2 years when the troop was first formed. Today, she is the single most studied lemuroid, having been the subject of behavioural observations for virtually her entire life.

On August 4, 1981, Ursula's troop was released into a fenced, forested "natural habitat enclosure". At 4856 m^2 (1.2 acres), it approaches the 7285-9663 m^2 (1.8-2.4 acre) home range reported by Sussman (1977b) for wild *L. fulvus* in Madagascar. Conditions in the enclosure allowed for the observation of the troop in a natural-type environment; at the same time I was consistently able to make detailed observations at close range (i.e., within 2 metres of the troop). Ursula's troop shared the enclosure with a family group of 7 ruffed lemurs (*Varecia variegata variegata*), largest member of the Lemuridae, and an adult pair of mongoose lemurs *L. mongoz*. Since the completion of this study, Ursula's troop has been re-located to a larger, 36,185 m^2 (8.2 acre) natural habitat enclosure which they share with 9 ruffed lemurs and a troop of 23 ring-tailed lemurs *L. catta*. Both natural habitat enclosures offer near ideal conditions for achieving the kind of lab/field study complementarity called for by Doyle & Martin (1974).

Data acquisition during the focal animal observation sessions included: frequency, duration and sequence of behaviours, whether the focal animal directed or received the behaviours, the other animal(s) involved in the interactions, and the animal/condition that ended the interactions. Observation sessions were conducted daily, on a sliding schedule to cover the entire day-light period. As a rule, observation sessions were conducted within 24 hours of

Figure 1:

A qualitative social ordering of Ursula's troop, based on observation of inter-individual social dynamics during the 1984 breeding season. Ages given for the animals represent their ages at the start of the study. Age classes: infant animals are those aged less than 1 year, juveniles, 1- 2 1/2 years; adults, over 2 1/2 years (after Vick & Conley, 1976:127). Arrows represent the approximate range of priority within the troop for the adult males over the study period.

Ursula: adult female, age 15 years, 6 mos; troop matriarch

Orsco: adult female,age 3 yrs, 6 mos,; 2nd ranking female, eldest daughter of Ursula

Mischa: juvenile female,age 2 yrs., 7 mos,; 3rd ranking female, youngest daughter of Ursula -approaching co-dominance with Orso.

Swanhild: adult female, age 3 yrs., 6 mos,; subordinate female - unrelated to Ursula's matriline; expelled from troop March 24/85.

Cub: Ursula's female,age 7 mos.

Osa: Orso's female infant, age 7 mos,; expelled from troop early Aug. '85.

Ucamari: Swanhild's female infant, age 7 mos,; expelled from troop Jan.22/85.

Balder: adult male, age 5 yrs., 3 mos,; troops breeding male; dominant to Mischa, at least co-dominant with Orso.

Bjorn: adult male, age 3 yrs., 6 mos,; subordinate, male - as the period of Bjorn's social demise continued, he was kept from interacting with troop members by Balder,and increasingly peripheralized; expelled from troopNov. 22/84.

Bor: adult male, age 3 yrs., 5 mos,; peripheral male - expelled from troop Sept. 7/84; reintroduced to enclosure and expelled a second time, Oct. 2/84.

each other. Up until the expulsion incident involving one of the study's focal animals, an average of two hours of observations was conducted daily on both focal animals.

RESULTS AND DISCUSSION

Laura Vick (1985) has summarized 15 years of data on expulsion episodes in two *L. fulvus* troop's (including Ursula's troop), housed at DUPC; she used a sample of 76 animals (Figure 2). It is in the context of this significant review that I'd like to set the present report. We are interested here with the expulsion frequencies for September to November, a period just prior to, and including, the first half of the Northern Hemisphere breeding season. A tenth troop member, a young adult male named "Bor", was expelled from Ursula's troop at the start of September. DUPC records show that Bor had been observed as being peripheral to the troop just prior to the expulsion incident. An attempt to reintroduce him into the troop early in October again ended in his expulsion; Bor was also wounded during this second ex-

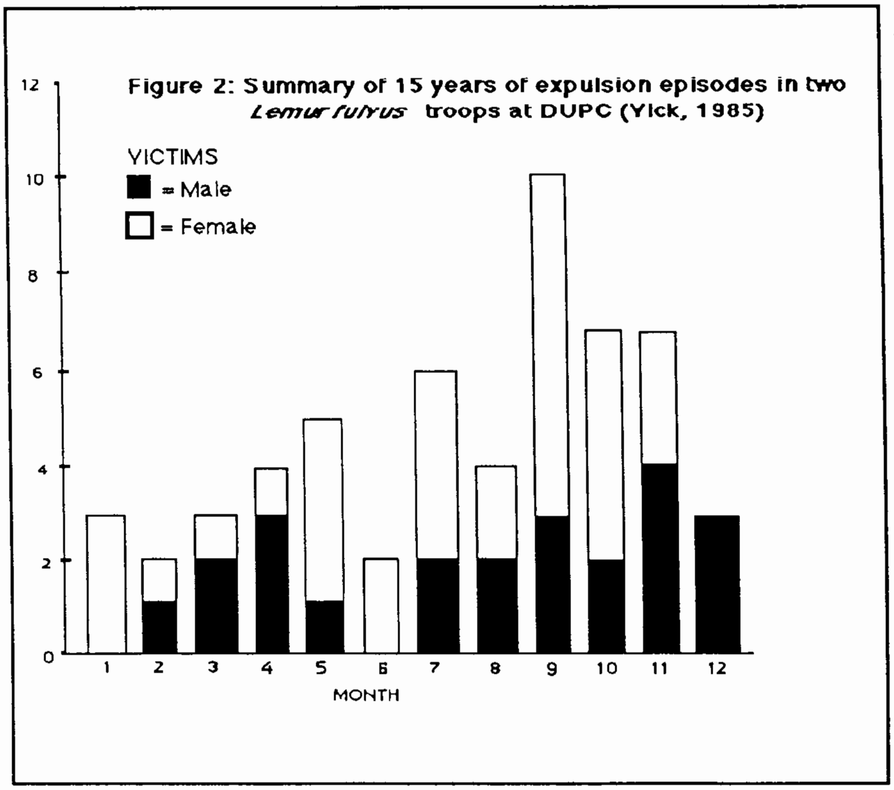


Figure 2: Summary of 15 years of expulsion episodes in two *Lemur fulvus* troops at DUPC (Yick, 1985)

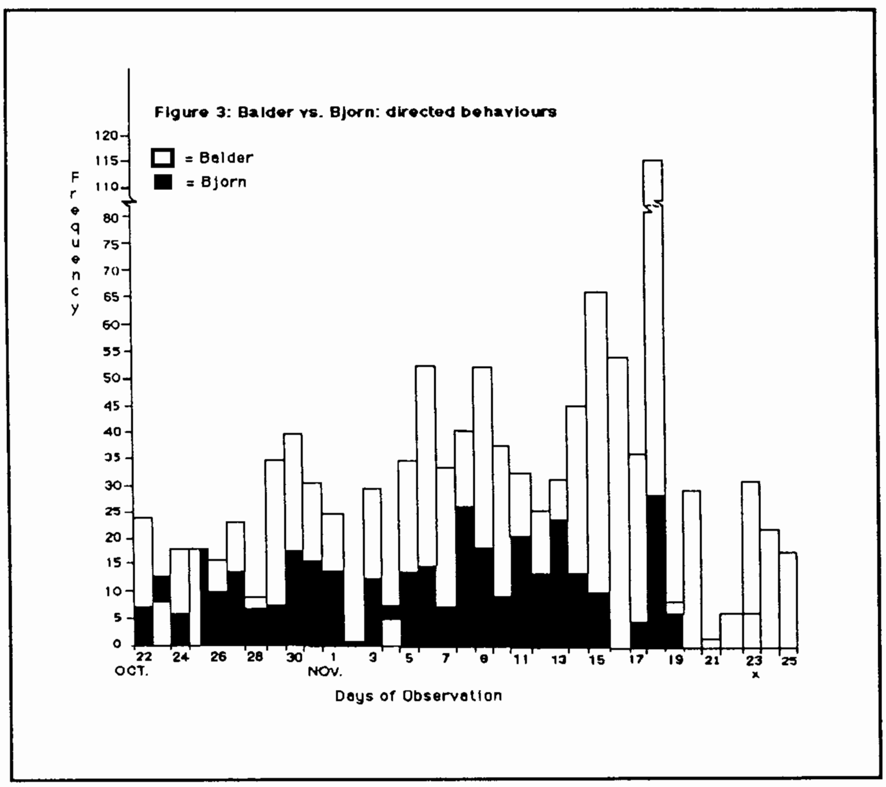


Figure 3: Balder vs. Bjorn: directed behaviours

pulsion incident. While Bor wasn't actually included in my study, his expulsion must be considered in order to understand the course that interactions between the troop's remaining males took. With Bor's explusion, there were suddenly just two adult males left in the troop: adult male "Balder", who, at age 5 years, 3 months at the start of the study, had bēen the breeding male in the group for the two previous years; and young adult male "Bjorn", who at 3 1/2 years was the same age as the expelled Bor and was entering the breeding season as an adult for the first time.

When I began observations in mid-October, Bjorn was still interacting with all troop members. However, Bjorn also appeared to be peripheral to the troop in several respects. He would withdraw from feeding situations after retrieving food items. He would often be the last to join in troop progressions (lagging up to 10 metres behind the others), and he would often sleep by himself rather than huddled with other troop members.

An appreciation of the social dynamics involved in the process of Bjorn's demise within the troop, and his eventual expulsion, can best be gained by considering several social parameters. A direct comparison of Balder's and Bjorn's social activity levels in terms of "directed behaviours" (behavioural interactions initiated by Balder and Bjorn, respectively - Figure. 3), shows clearly that Balder was a much more socially active animal than was Bjorn. Some key dates to note here are: November 13 - a date that was pivotal in the process of Bjorn's expulsion, and will be considered in detail shortly; November 15 to 18 - the peak period of activity levels for Balder towards both Bjorn and the troop's adult females, (this will be shown for several behavioural parameters), November 20 - the last date of observed activity between Balder and Bjorn; November 21 -

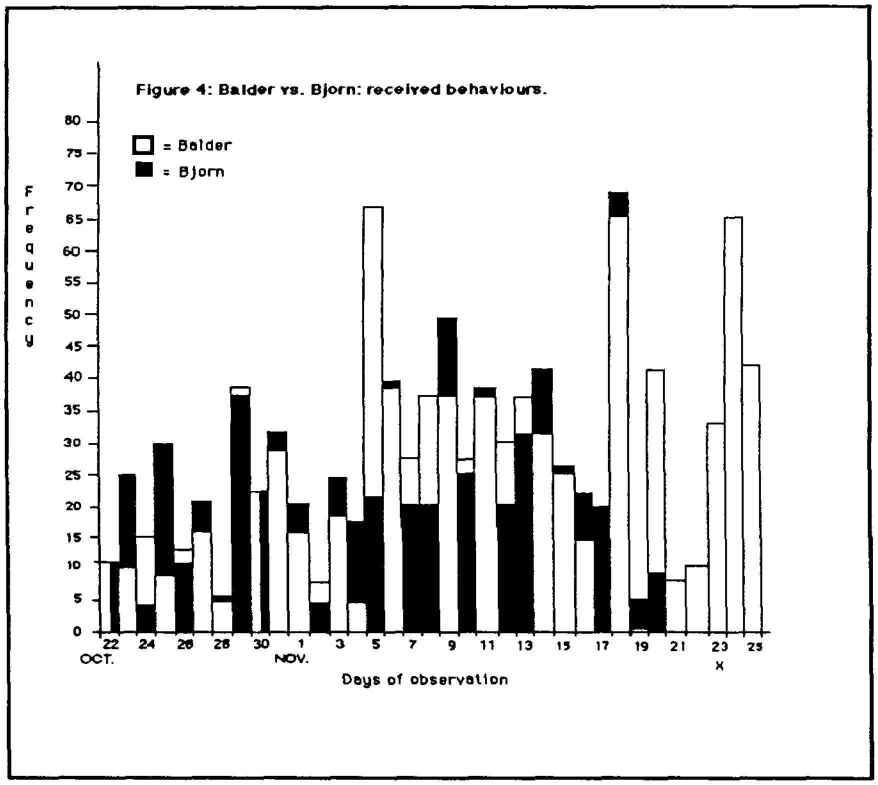


Figure 4: Balder vs. Bjorn: received behaviours.

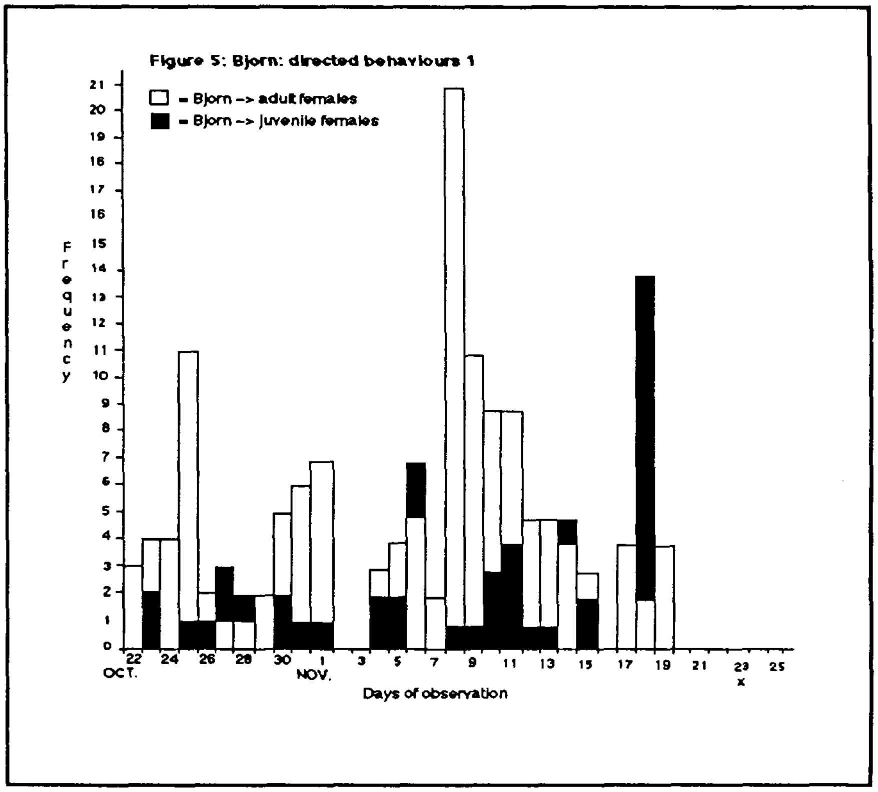
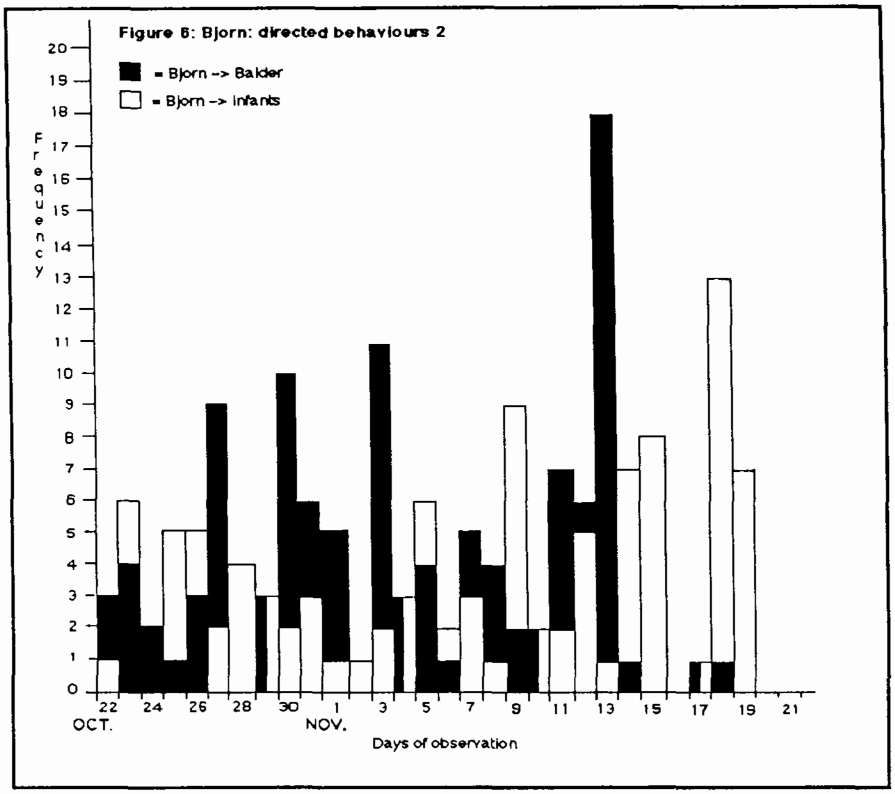
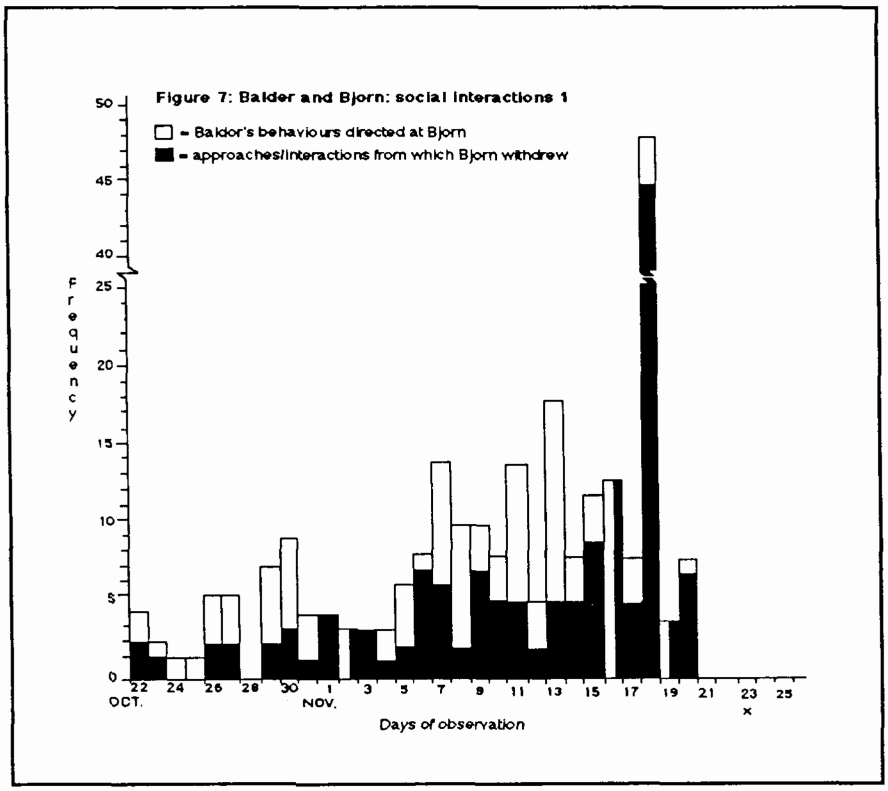


Figure 5: Bjorn: directed behaviours 1

the last date of observations on Bjorn, at which point he was peripheralized well over 50 metres from the rest of the troop; he approached the troop as close as 20 metres while remaining under cover but was not observed to interact with any troop member. November 22 - Bjorn was not sighted (denoted by "/"); November 23 - Bjorn was found outside the enclosure with a deep gash to the back of his hand (denoted by "X"). This was the same type of injury that Bor had suffered in the reintroduction attempt, and one that is consistent with wounds inflicted by the canine teeth during the downward slashing head-thrust attack reported for the species (Vick & Conley, 1976:136). For November 4 and 19 (rain) and November 21 (cold), the weather was largely responsible for the depressed activity levels.

Direct comparison of Balder's and Bjorn's social activity levels in terms of "received behaviours" (behavioural interactions were not initiated by the two males - Figure 4), does not present as clear a picture of Bjorn's status, on first inspection, as did the social parameter "directed behaviours". However, a consideration of the age-class composition of these received interactions reveals a somewhat different picture (Table 1). Changes in the proportional make-up of Bjorn's social interactions with the various age-class groups within the troop, in terms of both directed and received behaviours, are clear. There was a decrease in Bjorn's overall activity both towards and from the adult females. The sustained mean value for Bjorn's directed activity towards the troop's juvenile female during the third calendar period is largely explainable by a single 8-minute interaction. Also noticeable is an increasing upper limit in the daily percentage involvement values for Bjorn towards the adult females, despite a decrease in the mean involvement value in the third calendar period.





Thus, despite an overall reduction in interactions with the adult females, Bjorn was still making the occasional concerted attempt to maintain proximity to, and interact with, the adult females.

The reduced level in Bjorn's interactions with the adult females was due primarily to the increasing levels of social interaction Bjorn was receiving from Balder (in terms of both the percentage range and mean values). The pivotal November 13-14 boundary is mirrored in the dramaticallay reduced values for both the percentage range and mean of Bjorn's behaviours towards Balder and the adult females. There is a consistent trend in Bjorn's gravitation towards the troop's infants, despite a progressive decrease in their activity towards him. Bjorn's social situation eventually reached the point where, on some days of observation, 100% of Bjorn's directed behaviours involved the troop's infants.

Looking at the frequency distributions of Bjorn's directed behaviours towards the adult and juvenile female age-class groups (Figure 5), there are several key dates to note. Peaks of activity towards the adult females on October 25 and November 8 included both anogenital sniffing and grooming - increased levels of these behaviours are characteristic of the breeding season. From November 8 on, however, there are trends of decreasing activity towards the adult females, and increasing activity towards the troop's juvenile female. The peak in activity towards juvenile female "Mischa" on November 18 included anogenital sniffing and grooming, clasping and attempted mounts, all occurring over an 8-minute period. Bjorn's observed interactions on November 19 were all with adult female "Swanhild". Over the last two days that Bjorn was in the enclosure, he was not observed to direct any behaviours towards either the adult females or the juvenile female.

An examination of the frequency distributions of Bjorn's activity towards Balder and the troop's infants (Figure 6), shows Bjorn increasing levels of activity towards Balder up to the critical date of November 13. Thereafter, there

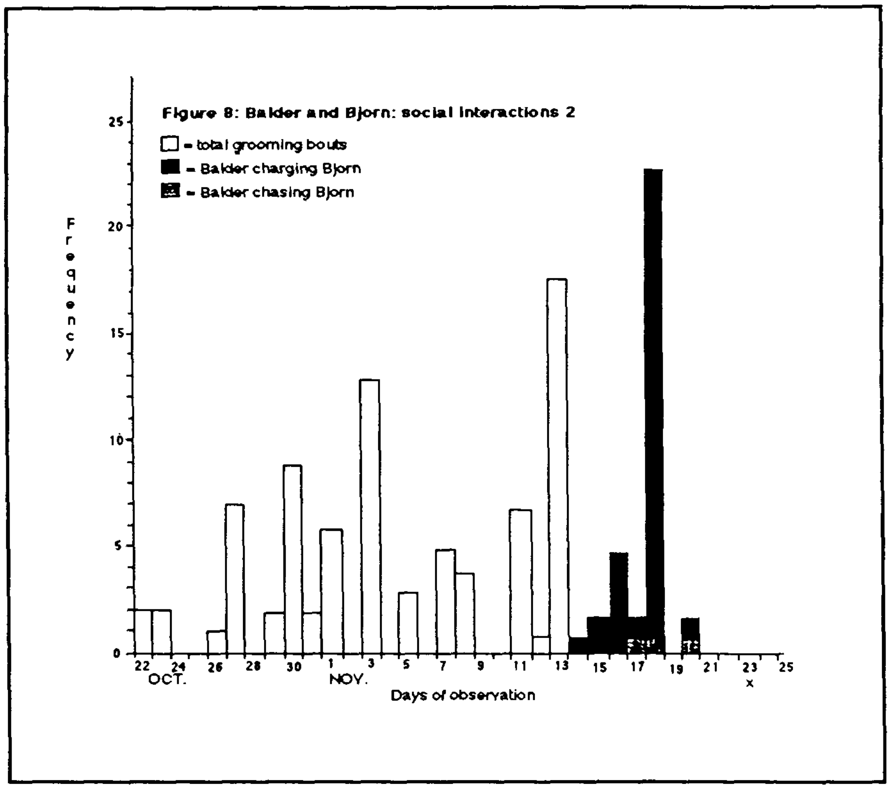


Figure 8: Balder and Bjorn: social interactions 2

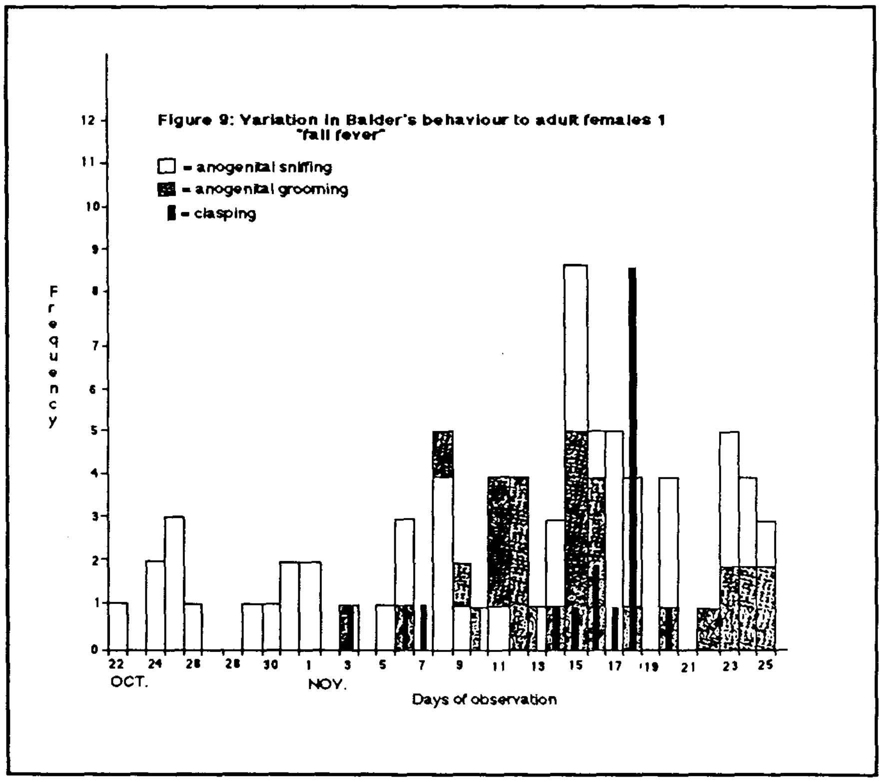


Figure 9: Variation in Balder's behaviour to adult females 1 "fall fever"

is a dramatic decrease in Bjorn's activity towards Balder, and a concomitant increase in activities directed towards the troop's infants, peaking on the key date of November 18. Of the 13 interactions Bjorn was observed to direct towards the infants that day, 8 of them involved "Ucumari", the infant female of Swanhild. On November 19, all 7 of Bjorn's observed behaviours directed towards the infants involved Ucumari. Interestingly, Ucumari was the next animal after Bjorn to be expelled from the troop; this occurred practically two months to the day after Bjorn's expulsion, on January 22, 1985. Ucumari's mother, Swanhild, was expelled another two months after that, on March 24, 1985. Thus, on the last date that Bjorn was observed to direct behaviours towards other troop members (November 19), the interactions were all with animals (Swanhild and Ucumari), that were also low in the troop's social order.

Looking in particular at the interactions between Bjorn and Balder, Bjorn's social slide towards expulsion is dramatically illustrated. Prior to the critical date of November 13, Bjorn did not withdraw from more than 50% of his interactions with Balder (Figure 7).

Over the period of October 22 to November 1, the mean percentage value for interactions with Balder from which Bjorn withdrew was 24.5. Over the period of November 2 to 13, this mean value nearly doubled, increasing to 48.0%. From November 14 on, however, there was a dramatic increase in Bjorn's withdrawal response to behaviours directed at him by Balder. The mean value for interactions with Balder from which Bjorn withdrew jumped to 83.0%, or nearly 3.4 times greater than the mean withdrawal value for the October 22 to November 1 period. November 18 was notable for the sheer raw frequencies of both the behaviours that Balder directed towards Bjorn, and interactions be-

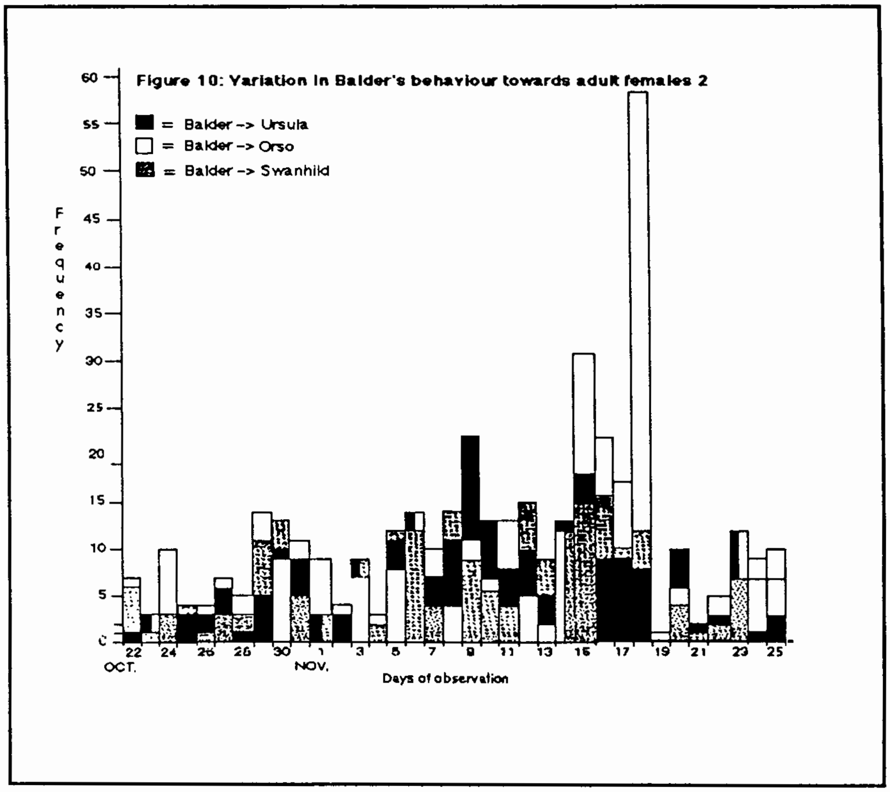


Figure 10: Variation in Balder's behaviour towards adult females 2

tween the two from which Bjorn withdrew (45 of 48).

The frequency distributions of total grooming bouts, charging and chasing between Balder and Bjorn provide the starkest picture of the process of Bjorn's social demise and expulsion (Figure 8).

Grooming bouts between the two occurred regularly up to November 13, often lasting for several minutes at a stretch; for example, grooming observed on November 13 occurred during a 13-minute grooming bout between the two. Balder began charging Bjorn early on the morning of November 14. The "charge" was a distinctive behaviour that differed dramaticallay from anything seen in approach-withdrawal interactions between the two up to that point. Balder would execute sudden rushes towards Bjorn, often coupling this rapid approach with a bipedal, skipping component occurring in the first couple of strides towards Bjorn. Balder's charging of Bjorn rapidly escalated after November 14, peaking on the key date of November 18 when Balder was observed to execute 23 charges at Bjorn. Minor chases (i.e., covering only 10 to 20 metres), were observed on November 17 and 18. The major expulsion chase occurred on November 20; it lasted 1 1/2 minutes and saw Balder chase Bjorn around the entire periphery of the enclosure. Following this incident Bjorn retreated to the opposite end of the enclosure, well over 50 metres from the rest of the troop. On November 21, Bjorn maintained this spatial separation from the rest of the troop. November 22, Bjorn was not sighted, and November 23 he was found outside the enclosure, his expulsion final and complete.

Table 1.

Percentage Involvement (Range of Daily Percentages and Percentage Means Over Each Calendar Study Period) of the Various Age-Class Groups in Bjorn's Social Interactions.

Age-Class	Oct. 22 - Nov. 1			Nov. 2 - Nov. 13			Nov. 14 - Nov. 21		
		X			*X*			*X*	
Balder									
Bjorn directed	0.0	**31.20**	64.3	0.0	**34.70**	84.6	0.0	**3.81**	20.0
Bjorn received	0.0	**29.87**	52.3	16.7	**38.18**	66.7	19.0	**47.26**	80.0
Adult females									
Bjorn directed	7.1	**34.84**	66.7	0.0	**37.46**	90.0	0.0	**24.99**	80.0
Bjorn received	0.0	**16.64**	36.7	0.0	**18.98**	44.4	0.0	**11.90**	33.3
Juvenile female									
Bjorn directed	0.0	**9.60**	28.8	0.0	**12.94**	46.7	0.0	**12.78**	48.3
Bjorn received	0.0	**3.63**	18.2	0.0	**5.58**	18.2	0.0	**6.72**	20.0
Infants									
Bjorn directed	0.0	**25.83**	57.1	3.7	**30.59**	100.0	0.0	**37.64**	100.0
Bjorn received	36.4	**49.70**	84.4	9.5	**39.36**	59.1	0.0	**24.05**	47.6

As Balder was displacing Bjorn more and more from the rest of the troop, he was also paying more and more attention to the troop's three adult females. A look at Balder's behaviour towards the adult females in the troop shows variation in anogenital sniffing anogenital grooming and clasping (Figure 9).

Balder was not observed to anogenital groom any of the females until November 3. Frequencies of both anogenital sniffing and grooming increased rapidly thereafter. Anogenital sniffing and grooming both peaked on November 15, followed by a peak in clasping on November 18. Balder achieved increased frequencies of activity towards the troop's adult females, even while increasing his activity towards Bjorn over the same November 15 to 18 period. This is a good reflection of Balder's frenetic state over this period - the whole behavioural package of complex that I've labelled "fall-fever". The separate peaks for anogenital sniffing and grooming, and clasping, reflects a separate physiological and behavioural estrous in the females. That is, the physiological estrous is monitored by Balder, as shown by the increasing levels of anogenital sniffing and grooming. The peak in clasping reflects the brief behavioural estrous, when the females are receptive to male mounting attempts (i.e., November 18). The period of November 15 to 20 is the likely time of conception for infants born to Swanhild (March 19, 1985), and to Ursula (March 20, 1985), as brown lemurs have an average gestation period of 120 days. As previously mentioned, November 19 was a cold, rainy day and the weather was primarily responsible for the sudden punctuation in activity levels on that date. Had November 18 been inclement, Balder may have been denied any reproductive opportunities until the females cycled and again entered estrous towards the end of December.

A breakdown of Balder's behaviours directed at the adult females (Figure 10), shows that Balder exhibited a pronounced preference towards "Orso"; she accounted for an average of 42.60% of Balder's observed behaviours directed at the troop's adult females. Ursula accounted for an average of 30.68%, and Swanhild an average of 29.24% of Balder's observed directed behaviours involving the adult females. Balder's behaviour towards Orso over the period of November 15 to 18 clearly shows her status as his preferred partner. During this brief period of extreme activity, Orso accounted for an average of 54.26% of Balder's observed directed behaviours towards the adult females (range: 46.81% - 74.22%). Swanhild accounted for an average of 25.32% (range: 15.37%- 34.12%), of Balder's directed behaviours towards the adult females over the same period. The directed behaviour frequency peak towards Orso on November 18 was mirrored by similar peaks in late December and January; these peaks occurred approximately one estrous cycle apart. Also evident is the trend of a general increase in activity by Balder towards the adult females, peaking over the key period of November 15 to 18. Again, this is a good reflection of Balder's "fall-fever".

SUMMARY AND CONCLUSIONS

As a step towards expanding the sparce lemuroid literature, a study of male Lemur fulvus reproductive behaviour was conducted. Specifically, the role of "fall-fever" behavioural fluctuations in the reproductive behaviour of adult males was investigated in order to determine alternate behavioural indices to agonistically determined "dominance", to gauge how adult males gained and maintained access to estrous females in the reported absence of hierarchical social dominance relationships. Despite several previously published reports, the emerging view of *L. fulvus* social behaviour (Boskoff, 1978c; Jolly, 1984; Vick, 1983, 1985; this study), is that hierarchical social dominance relationships are in fact present, that they are indeed discernable, and that they are most easily identified by a broad consideration of several behavioural indices. As Katharine Boskoff has noted, agonistic criteria alone, "... are not especially useful for describing *L. fulvus* social organization." (1978c:66), indicating that an adequate analysis of *L. fulvus* society must involve an extensive range of criteria. In this particular *L. fulvus* troop, however, during the 1984 breeding season, it was ultimately an escalation of aggressive behaviours that saw Balder peripheralize and expel Bjorn, leaving Balder as "king of the enclosure" (as it were), with the uncontested access to three fecund adult females.

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Growth Remodeling of the Human Femur

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Abstract : Several immature human femora aged 6 months to 5 years obtained from an archaeological site were surface replicated and then thin sectioned at multiple sites to examine bone growth remodeling.Metaphyseal reduction at the proximal and distal ends of these bones is present in all bones but not around the entire circumference of the shaft.Lateral periosteal growth also contributes to the overall size of the metaphysis,even at early stages of growth.Some bones,though not all,show evidence of cortical drift of the femoral shaft that is either postero-medial or medial.These drift directions agree with present biomechanical stress models for the femur.However, the present study indicates that femoral growth remodeling does not follow a rigid pattern but instead is variable.

Resumé: Plusiers des fémurs humains immaturs âgés de six mois à cinq ans déterrés d'un site archéologique était reproduits. Les répliques étaient préparées en coupes minces aux lieux multiples pour examiner le rémodelage en croissance ossieuse. Tous les os montraient une réduction métaphyséale aux bouts proximales et distales, bien qu'elle n'incluait pas le circonférence entière. La croissance périostéale latérale contribue aussi à la taille métaphyséale. Accordant avec les paradigmes des forces biomécaniques, la direction de l'apposition osseuse soit postéro-médiale ou médiale. Ces résultats nous montrent que le rémodelage en croissane fémorale est très variable.

Key Words : **Growth, Bone Remodeling, Human Femur**

INTRODUCTION

The general pattern of growth remodeling or what is also termed skeletal modeling of mammalian long bones has been characterized by several authors.Growth remodeling is a sculpting process that maintains normal bone macro-architecture throughout maturation by coordinating patterns of addition and removal of bone from periosteal and endosteal surfaces.For example,the cortex of long bone metaphyses is produced by endosteal cancellous compaction resulting in endosteal deposition and periosteal resorption to allow for progressive incorporation of the flared metaphsyeal end of the bone into the thinner shaft (Enlow,1962).Therefore, cortical growth takes place by resorption on the periosteal surface and deposition on the endosteal surface.This is called the V principle of growth.

In addition, Enlow(1968) and Frost(1973) have established that during growth,diaphyseal shafts may undergo cortical drift,a combination of deposition and resorption on opposite sides of the same cortical plate to move the surfaces of the shaft through tissue space.This activity produces or reduces characteristic bone curvatures and is presumably related to local histogenetic and biomechanical influences.

So far, however, there is little information on the particular distribution of these growth patterns over the surfaces of specific human long bones except for the fetal and neonatal periods.In addition,information on the range of variability of remodeling patterns in normal and abnormal human bones is sparse.Only a few workers have attempted to assess inter-individual variability of growth remodeling of the human craniofacial skeleton (Kurihara,et al,1980;Tommasone,et al,1981).

Ideally, comprehensive studies of bone growth remodeling should follow a longitudinal design.The best available method for obtaining such information is flourescent labeling of the bone tissue of experimental animals.However, patterns of tissue structure and growth remodeling in smaller short lived mammals are not strictly comparable to those of large, bipedal primates (Enlow,1976). Garn (1970) has provided extensive data on periosteal and endosteal bone gain and loss in the human second metacarpal and Frost(1963) on Haversian remodeling of the rib,but there is very little tissue-level microscopic cortical growth data on the child and adolescent skeleton.

Fresh samples of subadult human bone are generally unavailable from cadaver and forensic collections.But human skeletal samples from archaeological sites often contain large numbers of subadult bones which,until recently,have been underused in skeletal biological research.Several workers (Huss-Ashmore,1981;Keith,1981;Hummert,1983) have investigated cortical area changes and Haversian remodeling in the femur and tibia of human subadults from archaeological sites but these studies are presently restricted to midshaft thin sections,not the whole bone.

The present study is an attempt to map periosteal and endosteal patterns of whole bone remodeling on a sample of subadult human femora from an archaeological site using undecalcified microscopic thin sections and scanning electron microscope (SEM) surface scans. The SEM technique is based on studies of fresh bone which demonstrate that one can identify actively forming,resorbing and resting bone surfaces when the overlying periosteum or endosteum is removed to reveal the characteristic surface appearance of the mineralized osteoid (Boyde and Hobdell, 1969; Jones,1973). Such surface growth activities have also been identified on exhumed bones (Bromage,1982) but with the proviso that actively mineralizing osteoid is quickly lost both on fresh bone during sample preparation (Boyde and Sela, 1978 ; Bromage, 1984) and on buried bone (Saunders, 1985). Descriptions of growth activity must therefore be restricted to the more generalized terms, deposition and resorption (Saunders, 1985).

In the absence of identifiable osteoclasts and osteoblasts in unfixed or dry specimens, depository and resorptive surfaces can be identified in thin sections on the basis of subsurface cortical tissue types and the degree of surface regularity or irregularity as seen in cross section (Enlow,1968).In addition,thin sections can facilitate accurate reconstructions of the succession of growth changes where surface studies cannot, by demonstrating the cortical stratification within the substance of the bone.

The research described herein is designed to determine how well surface growth patterns are preserved on archaeological specimens, to ascertain whether the patterns correspond to those expected for normally growing long bones and to document any evidence for inter-individual variability.

MATERIALS AND METHODS

A sample of eight subadult human femora were selected from the Shaver Hill ossuary, a historic Iroquoian site dated to approximately 1600 to 1620 A.D. (Stothers,1972). The general unavailability of recent subadult human skeletons and the necessity,in the present study, of the destruction of the bones by multiple thin sectioning is the reason for choosing this less adequate sample source. Because they lack associated dentitions, age at death for the individuals represented by these femora was estimated from maximum diaphyseal length. The age estimates range from 6 months to 5.5 years. The bones were chosen from the total sample of subadults in the ossuary on the basis of their surface preservation. The overall length of the bones was also a consideration in sample selection since the entire periosteal surface was to be replicated and mapped.

All bones were washed in an ultrasonicator for 30 minutes in a solution of distilled water and laboratory detergent at neutral pH,then air dried.

Total anterior and posterior periosteal surface replicas were obtained using high precision silicone impression material (GC Exaflex) . These replicas were cut to 1-2 cm lengths with their orientation carefully maintained. Positive replicas were prepared from these negatives with precision epoxy resin (Ciba-Geigy) following the method described by Rose (1983) for observation in the scanning electron microscope. The surface replicas were cut to a small size, allowing for their fit into the microscope vacuum chamber. The positive surface replicas were then graphed to 5x magnification using the stereomicroscope, noting any useful landmarks to aid in the mapping procedure. The replicas were then examined in a Philips 501 SEM at 15 kilovolts at a variety of tilt angles and magnifications. The presence of resorptive surfaces (as indicated by the presence of resorption lacunae), smooth surfaces (indicating depository or resting bone) and damaged areas were mapped onto the graphed drawings. Whole bone periosteal surface reconstructions of surface growth remodeling were then produced from these drawings.

After surface replication, the original bones were cut at specified levels along the shaft and embedded in Wards' Bioplastic. A minimum of five ground undecalcified thin sections were prepared for each bone in order to compare subsurface cortical structure to surface identifications of growth activity. The sections were prepared according to standard petrographic techniques. That is,the embedded blocks were ground and polished on one side and then glued to glass slides. The excess blocks were cut off with a diamond saw and the final surface ground and polished to an approximate thickness of 75 μm using a diamond grinding wheel. They were then examined at various magnifications up to 100x using polarized light.

Before examining the growth remodeling results an attempt was made to determine if these bones are representative of normal femoral endochondral growth.One would wish to exclude bones affected by diseases that alter growth remodeling or samples of populations experiencing abnormal growth. Huss-Ashmore (1981) has suggested that under conditions of nutritional stress, long bone length and width will be maintained at the expense of cortical thickness. While cortical thickness decreases with adult aging, bone formation exceeds resorption during the first two decades of life so that substantial deficiencies in cortical thickness or cortical area during the growth period would indicate pathology. Consequently, percent cortical areas of midshaft cross sections were calculated using the grid point counting technique.

RESULTS

Table 1 compares percent cortical area recorded from the thin sections of the present sample to percent cortical area averages obtained for various age categories in studies by Keith (1981) and Huss-Ashmore (1981). There are no major differences in cortical area between the figures for the bones in the present study and the averages obtained by the other two researchers. The present sample and the data obtained by Keith suggest that there is a decrease in percent cortical area after the first year of life. In fact,this is a normal documented phenomenon (Steendjik,1969). It occurs because the midshafts of fetal long bones are physiologically osteosclerotic (being composed mainly of woven bone with little marrow cavity) that are later replaced by other kinds of cortical tissues and an expanding marrow cavity.

Given that the specimens appear to represent normally growing children, the SEM maps and thin sections were examined for evidence of normal, expected patterns of growth remodeling.

In the present study, the proximal and distal cortices of every bone in the sample are predominantly composed of compacted cancellous bone or convoluted bone (Enlow, 1968) as shown in Figure 1. This would be expected if the metaphyseal ends are undergoing reduction of their flare according to the V principle of growth. However, as the SEM maps indicate (Figures 2 and 3) the periosteal surfaces of the metaphyseal ends of these bones are never completely covered by resorption lacunae. Generally, areas of smooth bone (depository or resting) are centrally located on the anterior or posterior surface of the shaft. These smooth areas can be identified in cross section and consist of a thin layer of periosteally produced lamellar bone (Figure 4) or, in the case of tendon attachments such as the linea aspera, of a thin layer of woven bone.

Areas of periosteal resorption caused by metaphyseal narrowing are found predominantly on the medial and lateral surfaces of the shaft. However, these resorptive areas are greater in extent at the distal end and extend further up the shaft than do those at the proximal end. Thin sections cut closer to the middle of the shaft contain secondary osteons which have

TABLE 1

Shaver Hill Subadult Femora-Percent Cortical Area

Specimen	Age Estimate	%Cortical Area	Keith	Huss-Ashmore
1	0.5-1.5	68.1		
2	0.5-1.5	69.8	62-68	68
3	0.5-1.5	72.2		
4	1.5-2.5	56.6		
5	1.5-2.5	56.4	58	72
6	2.5-3.5	59.0		
7	2.5-3.5	62.3	60-61	58
8	4.5-3.5	61.1	50-60	70

Figure 1: Proximal metaphyseal section from bone #6. Shows convoluted bone by the compaction of cancellous bone which proceeds endosteally. The periosteal surface (p) is resorptive.

replaced convoluted and periosteal lamellar bone at this level at an earlier stage of growth when the shaft was shorter. Resorptive periosteal surfaces are identified by the cut-off appearance of the osteons at the periosteal surface edge when viewed in cross section (Figure 5). The endosteal surfaces of the proximal and distal cortices of these bones can be identified as depository by the smooth layers of lamellar bone that have been laid down at these sites (Figure 6).

Next, the sections and maps were examined for evidence of cortical drift. Drift occurs when a bone surface facing toward the direction of progressive growth receives new bone deposits by osteoblastic activity and the surface facing away undergoes osteoclastic resorption. This produces a direct growth movement of any given area of bone.

It is best to search for drift at the center of the long bone shaft so as to distinguish it from metaphyseal remodeling. Consequently, all midshaft thin sections as well as the SEM maps were examined. Drift is absent from the shafts of the three youngest femora. Although there are some damaged areas at midshaft on these bones as indicated by the SEM maps, all preserved areas are smooth, indicating depository or resting bone. In thin section, the midshaft cortices of these bones are comprised of periosteally produced lamellar bone containing many primary osteons which are produced by the enclosure of vascular canals on the periosteal surface as the shaft grows in width.

Femora 4 and 6 do show evidence for cortical drift both in thin section and on the SEM maps. The shafts of both of these bones were drifting in a posteromedial direction at the time of death. This is indicated in the SEM maps by the resorptive bone on the anterior periosteal surface and smooth bone found posteromedially. In thin section one can clearly identify anterolateral periosteal resorption by the cut off apppearance of the secondary osteons while the endosteal surface is depository (Figure 7). On the opposite posteromedial cortex periosteal lamellar bone was being deposited externally and endosteal bone comprised of secondary osteons which replaced earlier convoluted bone was being resorbed.This drift can be traced up and down the shaft towards the metaphyses in other thin sections (Figures 2 and 3). Femora 5 and 7 were not experiencing drift at the time of death. Their midshaft cross sections display the textbook appearance of bone cortex consisting of periosteal and endosteal lamellar bone with secondary osteons in the center of the cortex. Femur 8 is unique in that periosteal resorption appears to be concentrated around the lateral side of the shaft. In this case the shaft

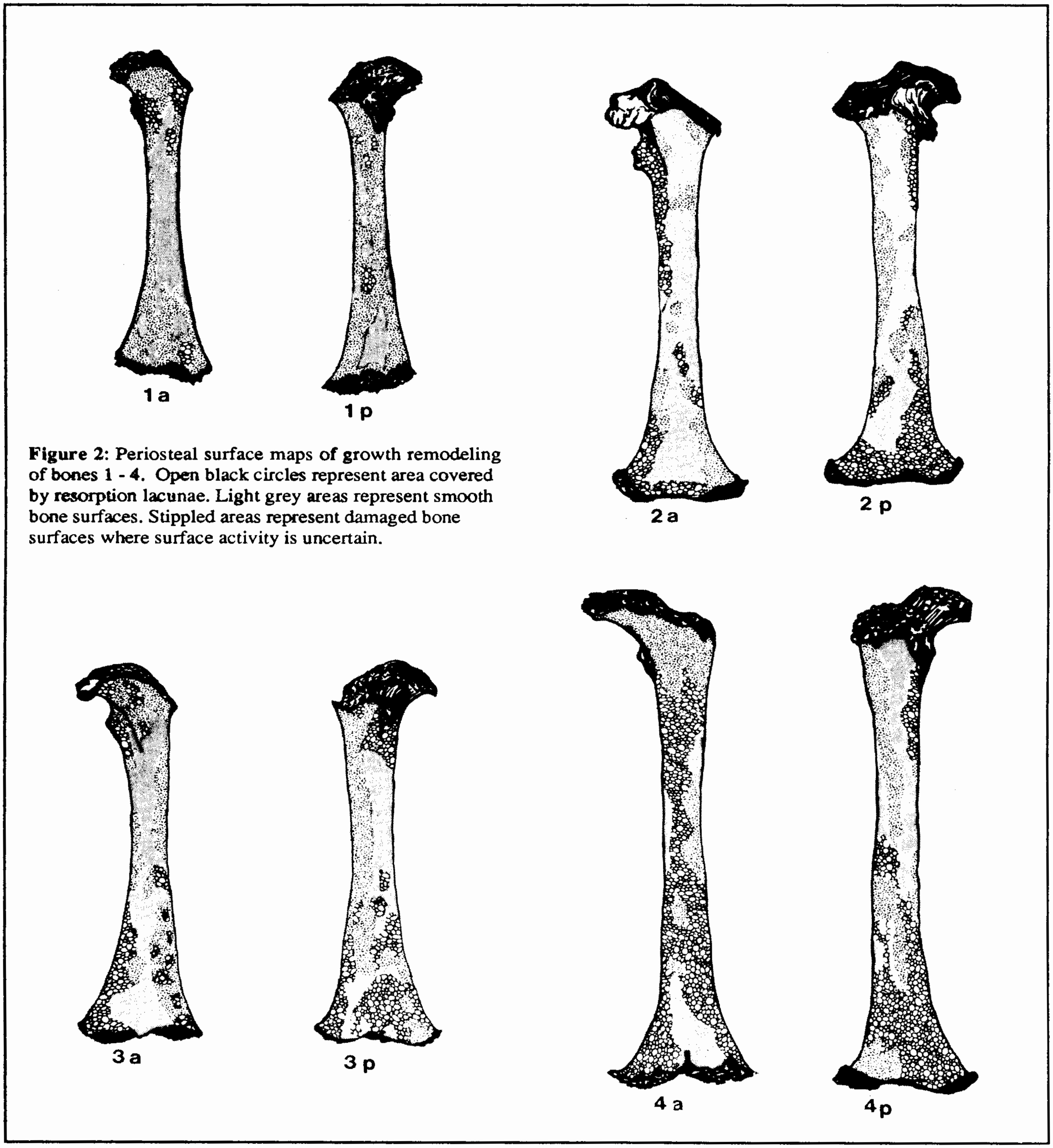


Figure 2: Periosteal surface maps of growth remodeling of bones 1 - 4. Open black circles represent area covered by resorption lacunae. Light grey areas represent smooth bone surfaces. Stippled areas represent damaged bone surfaces where surface activity is uncertain.

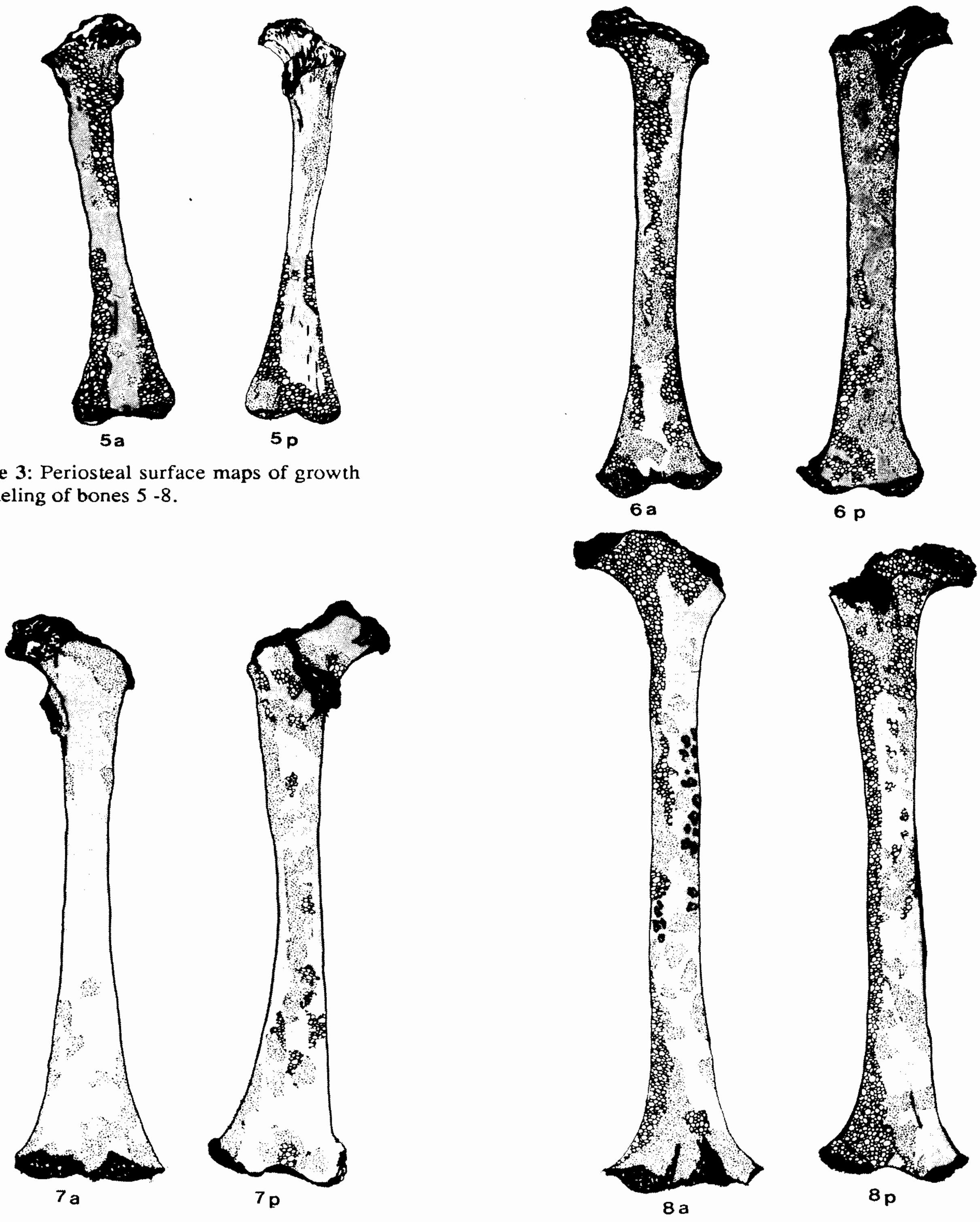


Figure 3: Periosteal surface maps of growth remodeling of bones 5 -8.

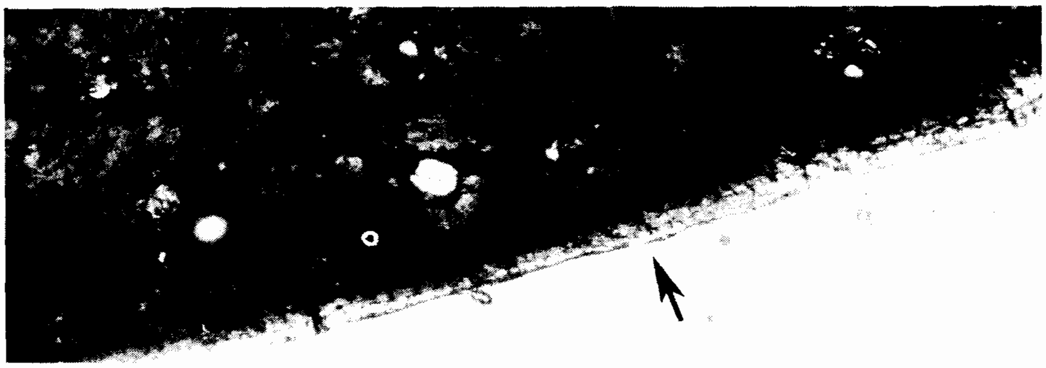
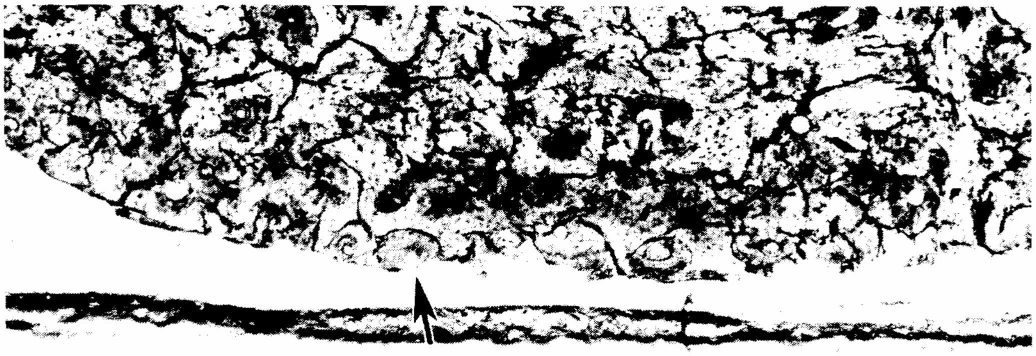


Figure 4: Proximal metaphyseal thin section showing convoluted bone covered by an area of periosteal lamellar bone (arrow) indicating bone depostion at this site rather than expected periosteal resorption according to the V principle of growth.

Figure 5: Mid-distal section from bone 4. An area of periosteal resorption is identified in the thin section by the cut-off appearance of periosteal secondary osteons (arrow).



appears to be drifting medially.

Both the SEM maps and thin sections demonstrate the existence of variation in growth remodeling of these femora. The surface patterns of resorption and deposition are never identical. Metaphyseal resorption appears to decrease in extent in the older femora. Only three bones show evidence of cortical drift. Finally, intracortical structure varies between femora at the same level.

DISCUSSION

The femora used in this study appear to have been undergoing normal growth at the time of the individuals' deaths based on comparisons with previous studies. Huss-Ashmore (1981) and Keith (1981) found what they believe to be a pathological decrease in cortical bone area in their samples from prehistoric Nubia and Late Woodland/Middle Mississippian Illinois. But their observed values show no measureable decreases in percent cortical area until the 5 year age category is past. Recently Martin (1985) observed signs of osteoporosis, including poorly mineralized bone and rapid resorption,in histological thin sections of the 2-6 year old children from Sudanese Nubia. Histologically, none of the bones in the present study shows evidence of extensive resorption that would indicate poor bone quality. Neverthe-less,although the present sample appears normal we must concede that the individuals used in this study died before reaching adulthood and are more likely to be a biased sample representing less fit members of the population.

Evidence for the existence of metaphyseal remodeling was first demonstrated in labeling studies of rats' long bones by Leblond et.al.(1950). Gardner and Gray (1970) have examined growth remodeling of the prenatal human femur. They found that periosteal surface resorption indicative of metaphyseal remodeling begins in the fetal femur at 92 mm crown-rump length on the proximal anterolateral aspect of the shaft at the level of the lesser trochanter and spreads around the shaft though never forming a complete ring of resorptive bone. At the distal end, periosteal resorption

Figure 6: The arrow indicates an area of endosteal deposition as shown by the layers of lamellar bone.

Figure 7: Bone #8, which as undergoing medial drift at the time of death, shows an area of periosteal resorption (**p**) and endosteal deposition (**e**) on the lateral side of the diaphysis at midshaft.

begins along the medial supracondylar line and spreads longitudinally but in their prenatal sample resorption was absent from the anterior and posterior aspects of the distal shaft.

The present study extends observations of femoral growth activity into early childhood. Significantly, there is never a complete ring of periosteal resorption at either the proximal or distal ends of the femora in this sample. Metaphyseal remodeling is generally restricted to the medial and lateral margins although the posterior distal shafts of femora 2 and 4 are exceptions.

Periosteal resorption associated with metaphyseal remodeling is more extensive at the distal ends of these bones. Two factors help to explain this observation. First, the distal end of the femur possesses greater flare which must decrease in curvature and diameter towards the central shaft as growth in length proceeds. Second, the distal endochondral plate of the femur contributes to more than two thirds of the total growth in length of the bone. The proximal epiphysis of the head of the femur serves mainly to increase the length of the neck (Weinmann and Sicher,1955).

Ogden (1980) has argued that the prevailing notion that the trailing edge of the metaphysis progressively decreases in diameter is a misconception. He notes that the overall size of the metaphysis reflects the size that the diaphysis will eventually attain by subperiosteal deposition laterally. He claims that the early schematics of long bone growth over-accentuate the flare to the metaphysis and ignore lateral growth.

The results of the present study support Ogden's view to the extent that periosteal metaphyseal resorption in the femur does not cover the entire surface of the shaft at the ends of the bone. Consequently, a variety of architectural patterns are produced in the cortex by the laying down of periosteal lamellar bone in some areas or of woven bone, particularly in areas of tendon attachment. Nevertheless, the majority of the proximal and distal cortices are comprised of convoluted bone produced by metaphyseal remodeling.

The shapes of bones develop as a result of intrinsic, genetically determined factors and by mechanical adaptation to loads placed on them. Cortical drift in the shafts of long bones is seen as a response to flexural strains and stresses. Drift is described as occurring in precise patterns on the periosteal and cortical-endosteal surfaces of bones, stereotyped and reproducible from one individual to another of the same species (Frost,1980).

Only three bones in this sample show clear evidence of cortical drift. In two cases, the shaft was drifting posteromedially. Femur 8 appears to have been drifting medially during life. The lack of drift in the youngest bones in this study might be expected if this process does not start until after walking and the initiation of biomechanical forces related to weight bearing and bipedalism. The lack of drift in femur 7 is unexplained.

Frost (1980) argues that bones remodel themselves according to a mechanically based flexure drift law that states that bones attempt to neutralize bending stresses by remodeling and will drift towards the direction of increasing concavity as flexural strain develops. He uses the fractured femoral shaft as an example of how the flexure-drift law works. It is noted that vertical compression loads of body weight and vertical muscle pull act to produce a medial-lateral angulation in the femoral shaft. The medial surface of the shaft is under compression and the lateral surface under tension. Thus, the expected direction of cortical drift would be medial. The observations of cortical drift in femur 8 would fit with this model. However, the model is strongly criticized on the grounds that it does not account for the signalling mechanisms that would promote remodeling and that it does not explain the situation when bones are subjected to a combination of different loads (Currey,1984).

Ruff and Hayes (1983) studied the cross-sectional geometrical properties of a large sample of adult femora and tibiae from the Pecos Pueblo skeletal collection. They observed that the orientation of greatest bending rigidity (greatest stress within the section under bending load) rotates counterclockwise down the femoral shaft from a proximal medio-lateral position to mid-distal where it is antero-posteriorly oriented. At midshaft,the greatest bending rigidity is oriented antero-laterally to posteromedially. This results from combined medio-lateral and antero-posterior bending loads of almost equal magnitude at this level of the shaft.

It is interesting to note that the orientation of greatest bending rigidity at the adult femoral midshaft corresponds to the region where cortical drift is identified in femora 4 and 6 in the present study. Ruff and Hayes (1983) note that a relatively circular cross-section such as is found at femoral midshaft would be expected when combined bending loads are applied in two perpendicular planes, e.g.A/P and L/M bending so that one would expect that cortical drift at the femoral midshaft would be postero-medial if medial <u>and</u> posterior flexures are produced by these bending loads. However, theirs is a study of adult bones in which the actual loadings during life are not known.

Experimental studies of the relationship between mechanical bone deformation and remodeling have produced equivocal results. Hert et.al. (1972) subjected the tibiae of rabbits to intermittent bending loading for up to one month. Examinations of the cross sections of these bones showed that considerable extra bone was deposited on both loaded sides. That is, the effect of remodeling was to deposit bone on both the side under tension and the side under compression rather than producing a drifting response.

From the present study we can say that there is no consistent pattern of cortical drift at least in subadult femora but rather drift is variable. This variability applies between individuals,but with a cross sectional study such as this we cannot say whether the variability is the result of within individual changes throughout the growth period due to the dynamic nature of biomechanical stresses on bones as well as changing metabolic conditions. The relatively short age span represented by these bones argues against such a conclusion but definitive answers will require more detailed work and much larger samples.

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ASSESSING MOLAR CROWN AREAS BY MACROPHOTOGRAMMETRY

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Abstract: Molar crowns constitute both a largely genetically controlled, species specific plenotype, and are numerically the most abundant fossil mammalian material available for comparative study. Traditional methods of analysis leave much to be desired in terms of diagnosis of complex shapes. This paper will briefly address the problem of molar shape qualification and discuss a simplified macrophotogrammetrical procedure. This method of analysis is then applied to 734 lower molars of *Pan, Pongo and Gorilla.* The "Cope-Osborn moieties" (trigonid/talonid) were separately measured and analysed using several statistical tools. The findings indicate marked sexual dimorphism in *Pongo* and *Gorilla* as well as surprising conservativeness in the distribution of crown components between all three populations.

Resumé: Aussi qu'elles soient les plus abondantes pour les études comparées d'evolution des mammifères, les couronnes molaires constituent une phenotype spécifique de l'espèce dans la plupart sûr le contrôle génétique. Les méthodes d'analyses traditionelles de ces couronnes sont insufficiantes pour analyser leurs contours complexes. Cet oeuvre s'adresse au problème d'analyse de la forme molaire et discute une méthode macrophotogrammétrique. Cette méthode était appliquée à 734 dents molaires inférieures des genres *Pan,Pongo,* et *Gorilla* étaient mésurées à part et analysées par divers outils statistiques. Les résultats nous indiquent un dimorphisme sexuel parmi *Gorilla* et *Pongo,* et un conservatisme des charactères coronales étonnant en toutes les trois populations.

Keywords: **Palaeontology, Molar Crown Area, Photogrametry, Cope-Osborn Theory.**

INTRODUCTION

Researchers investigating inter- and intra-specific variation always face a difficult task in quantifying complex configurations which do not readily lend themselves to linear assessment. The evaluation of dental crowns, especially molars, represents one of the most obvious examples of this problem.

Probably, the most significant advance in the evolution of hominoid molars, once the initial heterodont mammalian dentitions evolved in the late Triassic (Hopson and Crompton, 1969), was the appearance of a "heel" or talonid on the distal surface of the lower molars of certain Jurassic mammals. Edward Drinker Cope referred to this complex molar as a tuberculo-sectorial tooth (Gregory, 1916, 1922, 1934; Osborn, 1907). The relationships (both functional and phyletic) of the lower molar trigonids (the original mammalian three-cusped structure) and talonids have long intrigued odontologists. The condition first appears in the Pantotheria of the middle Jurassic through lower Cretaceous (Romer, 1966). George Gaylord Simpson (1928, 1929) regards this group as the basal stock which gave rise to later therian mammals.

The significance of this type of molar morphology, as compared to the reptilian single-cusped, or haplodont, tooth derives from the fact that the upper and lower molars no longer simply slipped past each other in occulsion, but the protocone of the upper molar was able to smash into the basin formed by the lower molar talonid in mortar and pestle fashion. For the first time in the development of life, mastication could take place, making mammals the only animals capable of commencing digestion in the oral cavity, thus greatly increasing the efficiency of the digestive system. Presumably, this was a response to the need to improve and expedite the processing of the relatively large volumes of food required by homoeothermic mammals. Teeth were no longer simply grasping and holding structures, but had become part of the digestive system.

Gregory (1934), in detailing the evolution of hominoid molar patterns, has documented that, by the time the Eocene Adapid Primates such as *Pelycodus* (Simons, 1972) had appeared, the talonid had widened transversely so as to exceed the width of the trigonid and had become a part of the grinding surface of the molar, no longer functioning as a part of a shearing mechanism. By the time true anthropoids appear in the fossil record, the lower molar consists of a mesial moiety bearing only the protoconid and metaconid, the paraconid having been lost and a talonid consisting of a hypoconid, entoconid and hypoconulid (see figure 1). Many researchers, recognizing the different phyletic origins of these components, attempt in their analyses to deal with them as separate elements.

The most typical approach is to measure two separate buccolingual molar diameters and treat them accordingly (Swindler, 1976). This follows what is, probably, the most commonly employed dental analytic technique used to generate continuous metric data for quantification of crown morphology. This approach consists of simply measuring the maximum length (mesiodistal diameter) and width (buccolingual diameter) at the height of contour, or the most bulbous portion of the crown. These data are then subjected to a variety of statistical and methematical manipulations (Goose,1963; Moorrees, 1957). This approach has become, undoubtedly, the most popular, and the anthropological literature, in particular, abounds with this kind of material (Ashton and Zuckerman, 1950; Hooiher, 1948a, 1948b; Moss and Chase, 1968; Selmer-Olson, 1949; Suarez and Bernor, 1972; Swindler and Sirianni, 1975; Townsend and Brown, 1979; Wolpoff, 1971a, 1971b, 1973). Probably, the major advantage to this type of study is repeatability and comparability. Since so much has been and continues to be published utilizing these measuring procedures, it is a simple matter to make inter- and intra-population comparisons.

The use of overall tooth crown measuration suffers from the overlapping size ranges of quite unrelated forms while telling us nothing about the shape of the tooth. Analyses of this kind can result in confusion; specimens belonging to different lineages come to be regarded as members of the same taxa because of similarity in gross size as, for example: Ashton and Zuckerman (1950) and Eckhardt (1973). Yet, this inherent limitation fails to diminish the obvious enthusiasm manifested in this type of research. Recently large and exhaustive compilations of such measurements have been published (Eckhardt, 1973; Swindler, 1976; Wolpoff, 1971a) which provide an available reservoir of data for neophyte dental analysts, making it unnecessary for them to venture into the field to collect raw data. All that is required today is to decide what forms one wishes to compare, look up the published data, and perform an analysis.*[1]

The post-canine teeth and in particular the molars, are the focus of most of the dental analyses being performed. Molar crowns represent a complex, variable and species specific phenotype, virtually unique to mammals. It is obvious that considerable information regarding genetic relationships and phyletic distances are to be gleaned through the application, in the analysis of molar crown morphology, of techniques designed to describe complex shapes. Indeed, "one of the great needs in dental anthropology today is a method of measuring and expressing shape" (Moss and Chase, 1968:225).

METHODS OF ASSESSING COMPLEX SHAPE

A number of ingenious methods have been developed to aid in the description of complex configurations. In 1927, Scammon and Scott suggested the use of planimeters for the accurate assessment of areas in quantitative biology. Various methods were tested and the stability of photographic film was found to provide an ideally dependable medium. The area-by-weight method was thought by the investigators (Scammon and Scott, 1927) to be somewhat more accurate, but this advantage was outweighed by the relative accuracy and convenience of planimeters.

In many applications, the dental pantograph is one of the best tools available for the assessment of larger dental shapes (Stanton, Fish and Ashley-Montagu, 1931; as cited in Hayashi, 1956 and Biggerstaff, 1969b). An instrument of this type is useful for transcription of three dimensional shape and reduction or enlargement without distortion. The obvious limitation of such apparatus is that it leaves the problem of quantifying shape unresolved. Hayashi (1956), in describing dental arch variation, worked out a simpler approach using an instrument called the cubic craniophor, which reduced the translation of a complex reality (in this case a full dental cast) to a simple series of points on paper, which could then be connected by a smooth curve to describe a dental arch. Both methods, while of value in assessing larger structures such as crania and dental arches, have been found unsuitable for use in tooth mensuration (Singh and Savara, 1964; Biggerstaff, 1969b).

A method of producing Xerox prints of dental casts is described by Singh and Savara (1964). The advantages stressed by the authors are the simplicity of the technique, as well as its economy. When one considers that what is in fact being produced is a life-sized, very poor quality photograph of a cast, one wonders if these advantages, in fact, offset the effectiveness of direct mensuration of the original tooth, or the superior quality and control obtainable from use of standard photogrammetrical techniques.

Savara (1965) has presented a method of reproducing three dimensional aspects of tooth crowns, as well as other complex shapes. This is accomplished with elaborate, expensive and subsequently restricting, photogrammetic apparatus. This technique produces a series of topographic maps, again leaving the quantification of shape unresolved. The major drawbacks of such approaches are the need for highly trained personnel to accomplish the measuring, and the very restrictive time factor involved, which greatly limits the size of the population that can be realistically studied (Biggerstaff, 1969b; Ramaekers, personal communication).

Sneath (1967) has suggested the use of transformation grids to assess relative differences in two dimensional shape. This involves plotting specific morphological points on a photograph, or other representation of a specimen, laid out on a grid pattern. When a photograph or tracing in the form of a transparency of a second specimen, adjusted to the same absolute size is placed on top and the same anatomical points recorded, the deformation of the lines of the second grid may be used to measure the degree of morphological change. Szalay (1968) has utilized this technique to assess early, tertiary, primate tooth crown morphology.

Erdbrink (1965, 1967) has measured groups of human (European, 1965 and deutero-Malayan, 1967) and ape lower permanent molars in an attempt to better understand the derivation of the hominoid lower molar pattern. The molars were photographed with the occlusal plane parallel to the film plane and photographic prints made of each tooth enlarged ten times linear (five times in the case of the ape teeth). Each tooth was diagnosed as having the "Y" or "X" pattern and the contact groove between the appropriate cusps was measured with venier calipers. Each cusp as well as the total "of what I considered to be the occlusional surface of the molar" (Erdbrink, 1965) was measured with a planimeter. The cuspal areas were expressed as percentages of the total "occlusional surface" and the lines of significant cuspal contact were "expressed as the percentage of the root of the absolute value found for the sum of the individual projected surfaces of the cusps" (Erdbrink, 1965). It is never clearly stated exactly what use these caliper measurements were put to.

Biggerstaff (1968), like Erdbrink, is interested in hominoid lower molar occlusal surface morphology. He proposed a scheme which he feels is simpler, and introduces the concept of quantifying post-canine tooth crown morphology by computerized means. Biggerstaff establishes a series of standardized, post-canine, dental crown landmarks (1969a) and, subsequently, attempts to utilize these points in a systematic, computerized method of areal assessment (1969b). He has photographed a series of complete dental casts after first marking them with his standardized reference points. The negatives, which are produced with a 4 x 5 camera in a 1:1 ratio, are used, since the black ink reference points on the casts show up as white dots on the negative. An orientation line is marked on a plexiglass overlay with fiducial lines relating to the anterior-most point on the mandibular incisors and to the anterior-most point of lingual contact between the mandibular and maxillary incisors. Using these orientation lines and fiducial marks as reference, the 1:1 negatives are digitized on an optical chart reader, which records each of the anatomical landmarks as a pair of X and Y co-ordinates. It is possible with such a system to approximate the areas of tooth crown components by utilizing the plotted reference points to generate vectors such that any three points will describe a triangle whose area can be computed.

In 1970 Hanihara, Tamada and Tanaka published a report outlining a simple, effective technique for assessing relative sizes of independent tooth crown occupied by the hypocone. To effect this analysis, they photographed a series of maxillary molars using a Nikon camera with bellows attachment and a 135 mm Nikkor lens in order to obtain 1:1 negatives. Prints were enlarged five times linear or twenty-five times areal. The tooth crown images were then cut out of the prints, and weighed on a direct reading, analytical balance, accurate to 1/1000 gram. The hypocones were cut from the total crown image, and the components weighed separately. The hypocone weights were expressed as a percentage of the total tooth crown weight, thus permitting a direct comparison of the relative proportions of crown components, which are free of any absolute influence caused by measuring technique.

Kay (1975), in a thorough analysis of functional adaptations in primate molars, found it necessary to assess the maximum area of potential tooth contact between the upper and lower molar crowns. In order to accomplish this the teeth were adjusted under a binocular microscope with the crushing surface oriented parallel to the plane of force. The outline of the potential area of contact was drawn by means of a camera lucida and measured with a polar planimeter. The surface areas were summed according to the author (Kay, 1975), and it may be assumed that Kay was assessing multiple surface areas per tooth. These figures were corrected for magnification, which apparently, implies that the magnification in the camera lucida setup was not consistent.

In an attempt to provide a means of quantifying continuous variation in molar crowns for phyletic assessment, Ramaekers (1975) developed techniques using polar co-ordinates. A major portion of Ramaeker's work deals with establishing a consistent orientation of the tooth that is subsequently photographed or traced with a camera lucida. The orientation technique, as used, would probably not be applicable to hominoid molars. Once the photo or tracing is finished, a central point is established, and in the case of the *Phenacolemur* molar studies, this was accomplished by projecting tangent lines between the protoconid and entoconid, and the metaconid and hypoconid. The intersection of these two lines becomes the arbitrary, centralized reference point. The angle formed between the metaconid, the reference point, and the protoconid is bisected to provide a fiducial line that coincides with the 90-degree axis, on a polar co-ordinate grid with the reference point at the origin. The distance from the origin to the edge of the crown tracing was recorded in 5-degree increments. Additional morphological landmarks were similarly plotted including the major cusps. The resulting data were run through a principal component analysis program.

PHOTOGRAMMETRIC TECHNIQUE

In order to evaluate the relative proportions of lower molar moieties (trigonid vs. talonid) in hominoids, a method was sought that would yield areal measurements of these structural components. Several conclusions may be drawn from the above discussion of efforts to define dental crown morphology. First, lengths and breadths are inadequate in providing any worthwhile reflection of variations in shape within the crown of any tooth type, particularly molars. Second, assessment techniques which rely on easily abraded landmarks, particularly cusp tips, are inherently strictly limited in terms of the number of specimens available for study (Biggerstaff, 1969b, Corruccini, 1977). Finally, as they avoid these drawbacks, analyses, like those of Hanihari et al (1970), which derive their points of reference from fissure patterns and height of contour, have the greatest potential for yielding accurate and pertinent data.

It follows, then, that the approach which appears potentially most fruitful would be a derivation of photogrammetry. In one form or another, this general methodology was employed by Singh and Savara (1964), Savara (1965); Erdbrink (1965, 1967), Biggerstaff (1968,1969a, b), Hanihara, et al (1970) and Kay (1975). However, a less complex, more readily repeatable technique, was needed, and a variation of photogrammetry as developed by aerial cartographers seemed most feasible.

Photogrammetry is the obtaining of accurate measurements from photographs. The general concept is almost as old as flight, since the original and typical application of photogrammetrical techniques are in aerial photography and, particularly, in cartography. The technique has been applied to the study of complex three-dimensional phenomena such as facial morphology (Beard and Burke, 1967). Macrophotogrammetry, in which the photographs are larger than the subject, provides a more accurate method of mensuration than the use of mechanical tools such as calipers (Hallert, 1953).

The method used to obtain information for subsequent analysis is analogous to that used by aerial cartographers. A precisely oriented photograph of the occlusal surface of each tooth is made on film of high dimensional stability, with an orienting scale introduced into the original photograph at the occlusal plane. Prints of high dimensional stability are subsequently made. Such photographs may be regarded as topographic maps with an integral orientation scale. Various measuring instruments can then be employed.

This technique provides a permanent record, allowing repeated retrieval of more highly detailed information than would, otherwise, be possible. It should, also, be noted that such an approach utilizes original material. Clarke and Howell (1972) have admonished researchers against making analyses of measurements derived from photographs. They do not, however, refer to photogrammetry, but simply to the practice of measuring published photographs that are provided only to give a visual indication of approximate size and shape, but are not intended to be diagnostic.

Macrophotogrammetry simplifies a minuscule, complex, three- dimensional reality, reducing it to a two-dimensional abstract, and allowing expansion of a controlled nature that yields reliable, precise and reprintable photographs to be taken with a minimum of time and effort. This permits a grasp of complex structures, the measuration of which would otherwise be an extremely formidable task.

METHODS

In order to approach the problem of quantification of molar crown variation, I decided that the most effective method, given reasonable limitations of time, mobility, and finances, would be use of a variation of photogrammetry. A technique was needed with sufficient inherent flexibility to provide for the investigation of a variety of primate materials, ranging in size from an adult male *Gorilla* skull, or a *Gigantopithecus* mandible, down to a single tooth, measuring as little as 2 or 3mm in length or breadth. A further limitation was the need for portability, since in many studies it would be desirable or even necessary to visit several collections in order to encompass an adequate sample for meaningful analysis. These requirements for high-quality photographic equipment and portability are adequately met by the 35mm format cameras. The Nikon F-series cameras with the 55mm micro-nikkor copy lens provides ideal, high-quality and readily available photographic equipment, the effectiveness of which could only be surpassed by costly custom-made apparatus (as employed by Savara, 1965). It is unlikely that any special design could improve upon the convenience of the Nikon portable copy stand that is small enough to require minimal space, but flexible enough, when used with the 55mm focal length micro-nikkor lens, to allow skulls from even the largest primates to be easily accommodated. In order to simplify a tedious data collecting chore, I decided to use a standard 1:1 photographic ratio. This allows focusing to be accomplished by raising and lowering the entire camera on a copy stand carriage, since the micro-nikkor lens *sans* the "M" ring may be employed, permitting focusing down to 1:1. A machinist's metric steel rule was introduced into each photograph at what was judged to be the level of the occlusal plane, in order to provide a check for enlargement of prints. Care was exercised on each exposure to ensure that the axis of the tooth was perpendicular to the film plane. In many cases, one photograph sufficed to record both first and second molars, but the emplacement angle of third molars almost always required a separate exposure for them. All molars from the populations studied were photographed which allowed for selection of the best images during analysis of the prints. Contact prints of each roll of film were produced, and the photographs of the best tooth in terms of wear and enamel breakage were chosen. In the event that no discernable difference between sides of a dentition could be found, the right side was utilized. Standard practice is to analyze one side of a dentition, since statistical problems can result if material from both sides is introduced, and since left-right correspondence has been reasonably demonstrated (Schulman and Brace, 1954). After the pictures were chosen, prints were made by enlarging each photograph five times on the linear scale.

The total basal area of each molar, and of each of the cuspal components, was measured using a Geotec optical planimeter. Following standard procedure, each measurement was taken at least twice, first with the instrument to the left and then to the right of the photograph. The mean of these measures is regarded as the "truest" estimate. These data were then punched onto IBM cards for computer analysis.

The total basal area of each molar was defined by the maximum perimeter at the height of contour. The components were delineated by the height of contour at the outer surfaces, and by the major grooves separating the components, in accordance with the original Cope-

Table 1

Basal areas of *Pongo* trigonids (mm^2).

		n	X ±s.e	Range	v	t-value
	M	12	48.493 ± 2.106	39.2 - 60.4	15.04	
dM_2	F	11	42.055 ± 2.421	27.6 - 57.0	19.09	2.01*
	T	32	43.999 ± 1.328	27.6 - 60.4	17.08	
	M	48	67.447 ± 1.289	44.9 - 95.8	13.24	
M_1	F	42	54.643 ± 1.152	41.6 - 86.0	13.66	4.29**
	T	98	61.331 ± 1.871	41.6 - 95.8	16.78	
	M	37	79.024 ± 1.757	54.9 - 100.8	13.52	
M_2	F	39	64.475 ± 1.128	46.0 - 80.4	10.93	6.97**
	T	76	71.558 ± 1.326	46.0 - 100.8	16.15	
	M	16	75.650 ± 3.566	54.0 - 113.2	18.85	
M_3	F	29	63.362 ± 1.690	45.8 - 91.2	14.37	3.11**
	T	45	67.731 ± 1.871	45.6 - 113.2	18.53	

* significant at .05 level
** significant at .01 level

Table 2

Basal areas of *Pan troglodytes* trigonids (mm^2):

		n	X ± s.e.	Range	v	t-value
	M	5	30.840 ± 3.095	23.4 - 39.0	22.44	
dM_2	F	11	31.200 ± 1.632	25.2 - 39.2	17.35	-0.11
	T	30	31.047 ± 1.117	21.0 - 45.4	19.71	
	M	32	45.344 ± 01981	36.4 - 58.2	12.24	
M_1	F	25	45.604 ± 1.397	31.8 - 56.4	15.31	-0.31
	T	76	44.730 ± 0.715	31.6 - 58.2	13.93	
	M	24	49.217 ± 1.093	39.0 - 59.2	10.88	
M_2	F	18	46.744 ± 1.951	35.4 - 61.0	17.71	1.46
	T	52	48.027 ± 0.939	35.4 - 61.2	14.09	
	M	14	47.357 ± 1.760	32.2 - 56.4	13.90	
M_3	F	11	43.473 ± 2.317	32.4 - 57.2	17.68	1.40
	T	31	46.542 ± 1.311	32.2 - 58.6	15.68	

Table 3

Basal areas of *Gorilla* trigonids (mm^2):

	n	X ± s.e.	Range	v	t-value
dM$_2$	M 6	60.567 ± 4.888	43.2 - 71.8	19.77	
	F 5	57.280 ± 2.651	51.0 - 63.8	10.35	0.94
	T 18	59.278 ± 2.186	43.2 - 73.8	15.64	
M$_1$	M 76	89.529 ± 1.343	69.8 - 113.6	13.08	
	F 19	78.100 ± 1.996	65.2 - 99.6	11.14	3.98**
	T 98	87.241 ± 1.198	65.2 - 113.6	13.60	
M$_2$	M 74	109.95 ± 1.772	76.4 - 148.8	13.99	
	F 19	89.758 ± 3.061	62.2 - 117.0	14.87	5.01**
	T 94	104.85 ± 1.724	62.2 - 148.8	15.94	
M$_3$	M 64	103.45 ± 1.942	54.4 - 134.0	15.02	
	F 18	87.700 ± 3.213	67.4 - 113.0	15.54	3.90**
	T 84	100.29 ± 1.784	54.4 - 134.0	16.30	

** significant at .01 level

Table 4

Basal areas of *Pongo* talonids (mm^2):

	n	X ± s.e.	Range	v	t-value
dM$_2$	M 12	46.027 ± 2.946	29.4 - 64.6	22.17	
	F 11	39.455 ± 3.510	27.8 - 69.0	29.51	1.43
	T 32	41.551 ± 1.784	27.8 - 69.0	24.29	
M$_1$	M 48	77.494 ± 1.613	50.0 - 107.2	14.42	
	F 42	61.850 ± 1.475	44.0 - 90.2	15.45	3.28**
	T 98	70.404 ± 1.291	44.0 - 107.2	18.15	
M$_2$	M 37	87.007 ± 2.051	49.1 - 121.0	14.34	
	F 39	68.830 ± 1.699	39.8 - 87.8	15.42	6.85**
	T 76	77.679 ± 1.684	39.8 - 121.0	18.89	
M$_3$	M 16	80.375 ± 3.587	60.8 - 112.6	17.85	
	F 29	62.042 ± 1.992	35.2 - 85.8	17.29	4.86**
	T 45	68.560 ± 2.222	35.2 - 112.6	21.74	

** significant at .01 level

Table 5

Basal areas of *Pan troglodytes* talonids (mm^2):

	n	X ± s.e.	Range	v	t-value
dM_2	M 5	36.280 ± 5.112	25.0 - 53.6	31.51	
	F 11	31.873 ± 1.468	23.4 - 41.2	15.28	1.11
	T 30	31.667 ± 1.416	20.6 - 54.0	24.50	
M_1	M 32	48.962 ± 1.134	39.0 - 66.2	13.10	
	F 25	53.836 ± 1.644	36.0 - 69.2	15.27	-2.60*
	T 76	50.093 ± 0.834	36.0 - 69.2	14.24	
M_2	M 24	53.875 ± 2.298	36.4 - 77.4	20.90	
	F 18	53.255 ± 1.868	43.8 - 78.6	14.88	0.32
	T 52	53.797 ± 1.329	36.4 - 78.6	17.81	
M_3	M 14	47.286 ± 3.425	28.6 - 74.6	27.10	
	F 11	39.891 ± 2.145	31.6 - 51.6	17.83	1.74
	T 31	45.187 ± 1.875	28.6 - 74.6	23.11	

* significant at .05 level

Table 6

Basal areas of *Gorilla* talonids (mm^2):

	n	X - s.e.	Range	v	t-value
dM_2	M 6	52.700 ± 5.365	40.0 - 74.6	24.94	
	F 5	53.400 ± 4.833	37.6 - 64.6	20.24	0.25
	T 18	52.022 ± 2.718	28.0 - 74.6	22.16	
M_1	M 76	90.235 ± 1.543	53.2 - 122.9	14.91	
	F 19	81.447 ± 3.253	62.0 - 115.8	17.41	2.52*
	T 98	88.534 ± 1.392	53.2 - 122.9	15.56	
M_2	M 74	113.72 ± 2.415	54.4 - 170.6	18.27	
	F 19	97.501 ± 4.247	63.6 - 141.6	18.99	3.10**
	T 94	110.31 ± 2.185	54.4 - 170.6	19.21	
M_3	M 64	106.26 ± 2.527	67.4 - 164.4	19.03	
	F 18	86.544 ± 3.335	58.2 - 105.6	16.35	3.87**
	T 84	102.14 ± 2.233	58.2 - 164.4	20.04	

* significant at .05 level
** significant at .01 level

Osborn concept of molar evolution (see figure 1). One of the major advantages to this technique is that a reasonable degree of crown wear is acceptable. As long as the major fissues are discernable, and wear has not passed the height of contour, the tooth is measurable.

MATERIALS

The material studied consisted of 734 lower molars from the three genera of extant pongids (great apes): *Pongo* (the orangutan),*Pan* (the chimpanzee) and *Gorilla.* The *Pan* sample consists only of*Pan troglodytes* (the common chimpanzee), as an attempt to collect data on *P. paniscus* (the pygmy chimpanzee) did not result in a sufficient sample for analysis. The pongids were chosen since they, probably, represent the best available examples of generalized hominoid molar configuration. Modern human molars may not be morphologically typical as a result of the rapid late Pleistocene reduction in hominid dental crown size that, particularly, affected the distal molars.

The teeth examined consist of the lower deciduous second molar (dM_2),*[2] as well as the three permanent lower molars (M_1, M_2,and M_3). The deciduous first lower molar was not analysed, as in most catarrhines this tooth tends towards sectorialism and, thus, a unicuspid configuration. The molar crowns were partitioned into their respective"Cope-Osborn moieties" and treated accordingly. The basic statistics (measures of central tendency) are tabulated in Tables 1 through 6.*[3.] On occasion, especially in juvenile skulls, the sex could not be positively determined. As a result, the total (T) usually exceeds the sum of identified males (M) and females (F). Those molar components that could be identified as to sex were subjected to t-tests in order to evaluate the observable degree of sexual dimorphism. As can be seen from these tables, there is a trend in both *Pongo* and *Gorilla* for these components to exhibit marked sexual dimorphism in absolute size.

A more meaningful insight into intraspecific molar morphology may be gained by assessing the relative amount of sexual dimorphism within crown components. Thus, the components were tested using the arcsin transformation test as explained by Sokal and Rohlf (1969:608):

$$t_s = \frac{\arcsin \sqrt{P_1} - \arcsin \sqrt{P_2}}{\sqrt{820.8(1/n_1 + 1/n_2)}}$$

The results of the tests on the talonids for sexual dimorphism are tabulated in Table 7a, b and c. No significant differences in the proportions of any molars, attributable to sexual dimorphism, were found in any of the three species. Given the complimentary nature of the components, testing the trigonids would be pointless as they represent the reciprocals of the talonids.

Interspecific differences in the relative distribution of these crown moieties were sought through arcsin transformation tests, and the data grouped in species pairs (Table 8a, b and c). As can be seen from this table, the arcsin transformations were then subjected to t-tests. The results demonstrate an obvious conservativeness of these structures among pongids with no significant difference observed.

DISCUSSION

Several findings emerge from this photogrammetric study. First, sexual dimorphism is readily apparent in the absolute sizes of all components in *Pongo* and *Gorilla.*. *Pan* shows no significant sexual dimorphism at this level of analysis. Simply stated: male orangutans and gorillas possess larger molars and the components that constitute these molar crowns are significantly larger than those found in females of these populations. Chimpanzee molars are not distinguishable as to sex on the basis of size. These findings are consistent with the observable high level of sexual dimorphism in the body mass of gorillas and orangutans. Chimpanzees exhibit very little sexual dimorphism in body mass (Napier and Napier, '67).

The second point to emerge from this study is that while absolute size differences between sexes occur in two of the populations studied, relative differences attributable to sex are not apparent. In other words, while gorilla and orangutan males possess larger molar crowns than do the females, those components which make up the crowns are of relatively the same proportions and, hence, they do not vary in shape.

Perhaps the most interesting revelation derived from this research concerns interpopula-

Table 7

Arcsin Transformation Test for Sexual Dimorphism Talonid/ Total Basal Area

a) *Pongo*

		n	Talonid/TBA	Arcsin	t
	M	12	.5033	45.19	
dM_2	F	11	.4820	43.97	.1020
	T	32	.4979	44.88	
	M	48	.5275	46.58	
M_1	F	42	.5336	46.93	.0578
	T	97	.5339	46.94	
	M	37	.5236	46.35	
M_2	F	39	.5134	45.77	.0882
	T	76	.5189	46.08	
	M	16	.5132	45.76	
M_3	F	29	.4964	44.79	.0639
	T	45	.5033	45.19	

b) *Pan*

		n	Talonid/TBA	Arcsin	t
	M	5	.5420	47.41	
dM_2	F	11	.5031	45.18	.1443
	T	30	.5028	45.16	
	M	32	.5166	45.95	
M_1	F	25	.5400	47.29	.1752
	T	76	.5210	46.20	
	M	24	.5126	45.72	
M_2	F	18	.5294	46.69	.1086
	T	52	.5231	46.32	
	M	14	.4982	44.90	
M_3	F	11	.4762	43.64	.1092
	T	31	.4910	44.49	

c) *Gorilla*

		n	Talonid/TBA	Arcsin	t
	M	6	.4619	42.81	
dM_2	F	5	.4768	43.67	.0496
	T	18	.4630	42.88	
	M	76	.4976	44.87	
M_1	F	19	.5102	45.59	.0980
	T	98	.5003	45.02	
	M	74	.5048	45.28	
M_2	F	19	.5212	46.21	.1262
	T	94	.5079	45.45	
	M	64	.5054	45.31	
M_3	F	18	.4917	44.53	.1020
	T	84	.5028	45.16	

Table 8

Arcsin Transformation Test for Conservativeness Between species Talonid/Total Basal Area

a) *Pongo / Pan*

		n	Talonid/TBA	Arcsin	t
dM_2	Pongo	32	.4935	44.63	.0728
	Pan	30	.5028	45.16	
M_1	Pongo	32	.5319	46.83	.1439
	Pan	76	.5210	46.20	
M_2	Pongo	76	.5189	46.08	.0466
	Pan	52	.5231	46.32	
M_3	Pongo	45	.5033	45.19	.1047
	Pan	31	.4910	44.49	

b) *Pongo / Gorilla*

		n	Talonid/TBA	Arcsin	t
dM_2	Pongo	32	.4935	44.63	.2073
	Gorilla	18	.4630	42.88	
M_1	Pongo	98	.5319	46.83	.4422
	Gorilla	98	.5003	45.02	
M_2	Pongo	76	.5189	46.08	.1425
	Gorilla	94	.5079	45.45	
M_3	Pongo	45	.5033	45.19	.0057
	Gorilla	84	.5028	45.16	

c) *Pan / Gorilla*

		n	Talonid/TBA	Arcsin	t
dM_2	Pan	30	.5028	45.16	.2669
	Gorilla	18	.4630	42.88	
M_1	Pan	76	.5210	46.20	.2695
	Gorilla	98	.5003	45.02	
M_2	Pan	52	.4231	46.32	.1757
	Gorilla	94	.5079	45.45	
M_3	Pan	31	.4910	44.49	.1113
	Gorilla	84	.5028	45.16	

tional variation. While the three populations studied sort out quite clearly in terms of absolute size, none of them shows any significant difference in the relative distribution of crown components. There is no observable difference in shape between any of the three populations studied in so far as the distribution of these crown components is concerned.

The implications of this last point are potentially far reaching. Serious attempts have been made (Pilbeam, 1969; Simons, 1972) to locate the ancestors of today's ape populations among the diverse hominoid fossils of the Oligocene and Miocene epochs. If the morphology of molar crowns is under strong genetic control, as appears to be the case (Alvesalo and Tigerstedt, 1974) then those genes which exercise this control in the great apes have either not been affected by evolutionary forces for a considerable time, or the living pongids have had a recent common ancestry. Much more research of a comparative nature, especially involving other related primate groups is required to shed light on this issue.

Finally, it appears that macrophotogrammetry holds considerable promise for future dental crown analysis. The ability exists to go to various collections, or even into the field, accumulate the vast amount of potential information inherent in a single photograph, return this data to the laboratory and apply any of a number of analytic procedures. This methodology far surpasses the information generating ability of a pair of calipers. Such an approach achieves a truer picture of the kind of variation that exists in a complex dental phenotype. Additionally, this method of analysis opens up new areas of investigation by providing a means of quantifying individual cusps as well as aggregations of cusps such as the "Cope-Osborn moieties" and such non-cuspal elements as the cingula. These structures are not quantifiable in a manner and with a precision previously possible to attain. With greater access to computers and digital indexing instrumentation, photogrammetry should become an increasingly valuable approach to dental analysis.

NOTES

*1 Some examples of such secondary use of original data are Conroy, 1972, (using data from Pilbeam, 1969 and Wolpoff, 1971a); Gingerich, 1974, (using data from a number of original sources including Hooijer, 1948a; Leutenegger, 1971; Pilbeam, 1969; Russell, Louis and Savage, 1967; Swindler, Gavan and Turner, 1963); Gingerich and Schoeninger, 1979 (using data primarily from Swindler, 1976); Greenfield, 1975 (using some of Pilbeam's 1969 and Wolpoff's 1971a data); Henderson and Greene, 1975 (using Hooijer's 1948a data); Lavelle, 1974 (using Wolpoff's 1971a data); Marcus, 1969 (using Hooijer's 1948a data); Suarez and Bernor, 1972 (Pilbeam's 1969 data).

*2 It is becoming increasingly obvious that a real problem exists in the terminology used to refer to the deciduous and permanent post-canine teeth. First, it is becoming common to refer to the deciduous teeth as "deciduous premolars". The term 'premolar' denotes a tooth which precedes a molar in the dental arch and is not itself a molar. The succedaneous teeth which replace the first and second deciduous molars are true premolars, however, during at least half of their functional existence the two deciduous molars do not precede any other molars, and are, themselves, throughout their existence, functionally and morphologically, molar teeth.

The deciduous and permanent molars are all produced by the same continuous dental lamina (Scott and Symons, 1964), and share a continuous morphological gradient. The only real difference between them seems to be a function of whether or not the secondary, lingual tooth bud is suppressed or not. In the three permanent molars the secondary bud is suppressed and as a result these teeth are both primary and permanent. In the two anterior primary (and deciduous) molars the secondary bud is not suppressed and develops into a morphologically and functionally different tooth: the succedaneous premolars.

Schwartz (1978a, b) has suggested that in the primitive eutherian dentition there were eight (8) post-canine loci. He further suggests (1978a) that in catarrhines the first, third and eighth of these are phylogenetically lost. Schwartz (1978a) refers to the remaining teeth as: dP2; dP4; dP5; M1 and M2. The latter three of these are functionally part of the permanent dentition. Assuming Schwartz is correct, the absurdity of this terminology is apparent; how is it possible to have a "deciduous premolar" as part of the permanent dentition? The denotative definition of 'deciduous' is something which is shed or lost, fleeting or transitory. A permanent tooth, by definition, can not be a "deciduous" tooth. It makes much more sense to refer to all the primary post-canine teeth as molars, whether they are deciduous or permanent is obviously and simply a function of whether or not they are lost and replaced. Hence, it might make more sense, assuming Schwartz is correct, to refer to the primary catarrhine post-canine dentition as: dM2; dM4; M5; M6 and M7. The permanent dentition could be referred to as: P2; P4; M5; M6; and M7. This would make for a more phylogenetically correct terminology.

*3 It will be noted that the co-efficients of variability generated in this study (Tables 1 through 6) tend to be considerably higher than typically reported V's

(Schuman and Brace, 1954; Moss and Chase, 1968; Pilbeam, 1969). The only published V's found to be as large are those in Eckhardt's (1973) appendices 21 through 34, but these particular tables seem to represent gross aggregations of dental data compiled without regard for species indetification. When V's are calculated for "rectangular areas" based on the product of published mesiodistal by buccolingual diameters such as Pilbeam's (1969) data, the results are comparably high. It appears that the total surface of a structure, i.e.; areal measurement, however obtained, reveals considerably more inherent variability than is to be expected with measurements of a linear nature. This is consistent with Simpson's (1953) pronouncement that V's of about three to about ten are to be expected for linear dimensions of functional mammalian hard parts. Obviously, areal assessments, not constituting linear dimensions, would not be so limited. The reason for Eckhard's high coefficients of variability seems to be a function of the pooling of various species of fossil pongids together into a single geographically oriented group of data and treating them statistically as homogeneous population

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Editorial Note: One of the referees for this paper made a specific criticism of the statistics utilized in Tables 7a to 8c, and this was to be the major item that Dr Williams was to correct before publication. However, since we have lost contact with the author, I thought it appropriate to provide the readership with the text of the referee's criticism.

"The arsin transformation is not appropriate for the analysis of the Talonid/TBA ratios. This transformation was developed by R.A.Fisher to stabilize the variance in tests of binomial population parametres ("probability of success") based on sample preparations. He showed that if **x** is the number of "successes" in a random sample of size n froma binomial population with parametre **u** and if $\mathbf{p = X/n}$, then for large **n** the quantity $\sqrt{\mathbf{n}}(\mathbf{arcsin}\ \sqrt{\mathbf{p}} - \mathbf{arcsin}\ \sqrt{\mu}\mathbf{28.6})$ is approximately standardized normal. The arcsin transformation arises naturally in the case of the binomial distribution because the standard deviation (σ) is a function of the mean (μ), i.e. $= [\mathbf{n}\mu(\mathbf{1}-\mu)]^{\mathbf{1/2}}$. (See H. Scheffé, (1959), The Analysis of Variance, Wiley , p.365).

The ratios considered by the author do not arise from a "binomial type" experiment. Rather, they are continuous random variables on the range (0, 1). I believe that it would be more appropriate for the author to preform simple t-tests of differences in means of Talonid/TBA ratios in males and females."

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ULTRASOUND MEASUREMENT OF FACIAL SOFT TISSUE THICKNESS IN LIVING CHIMPANZEES

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Abstract: Although facial soft tissue thicknesses at standard points have been published, beginning in the 19th century (Welcker, 1883; His, 1895; Kollmann & Böchly, 1898) for several human populations, no comparable data exist for any other species. We report here the results of measuring soft tissue thicknesses in 14 male and 15 female chimpanzess (*Pan troglodytes*) at the Primate Research Institute, Holloman Air Force Base, New Mexico. These data were obtained through the use of ultra-sound equipment, which we believe to offer distinct advantages in comparison to traditional techniques.

Résumé: Depuis le 19iéme siécle, on mesure l'èpaisseur du tissu doux facial à certains points de référence fixes (Welcker, 1883; His, 1895; Kollmann & Böchly, 1898) dans plusieurs populations humaines, mais cette sorte de donnée n'existe pas pour d'autres espéces. Nous avons mesuré l'èpaisseur du tissu doux dans un ensemble de 14 chimpanzés mâles et 15 femelles *Pan troglodytes* a l'Institute pour Recherche primatologique (Holloman AirForce Base, New Mexico), et présentons nos résultats ici. Par contraste avec les techniques traditionelles, qui sont invasives,nous avons utilisé un appareil ultrasonique, ce qui offre certains avantages importants.

Key Words: **Tissue Thickness, Forensic Identification, Ultra-sound, *Pan troglodytes*.**

INTRODUCTION

The research reported here was conducted in July-August, 1984, in support of the thesis project of a graduate student at the University of Manitoba (Pinch, 1985). The thesis project in question involved the reconstruction of facial soft tissue features of selected robust australopiths. Any rigorous attempt to restore facial features to a skull must unavoidably be based upon standardized measurements.

Thus we argue. Historically, facial reconstructions in two and three dimensions of various fossil hominines have been produced in abundance. The authors of these (e.g., Augusta & Burian, 1960; Shapiro, 1974) were evidently guided by personal and culturally derived biases, fashion, artistic license, and sometimes by indicators of cranial muscularity, but not by data-oriented patterns of soft tissue distribution (not just muscles). It is our position, that even the recent and generally highly regarded work of Gerasimov (e.g., 1971) and of Mattemes (e.g., Rensberger 1981) are deficient in this respect, from the most appropriate sample, of facial soft tissue thickness. The project requiring restoration of australopith facial features was made difficult at the outset by the absence of published facial soft tissue standards for any primate species other than contemporary humans. The decision was made to initiate a project to obtain the necessary data from the most appropriate species, confined to the most phylogenetically proximate genus, *Pan*. An arguably more appropriate choice might have been *Pan gorilla*, in consideration of the sagittal-nuchal cresting and facial proportions of robust australopiths. The choice of *Pan troglodytes* was dictated by the insurmountable difficulties of obtaining data from a gorilla sample of adequate size.

MATERIALS AND METHODS

The ultra-sound unit we used was a Smith-Kline Mark II with a low-intensity (3.5 MHz) transducer. The pulse of sound emitted by the transducer is readily transmitted through soft tissues such as skin, fat, and muscle, but is reflected by material of significantly greater density, such as bone, or of very low density, such as air. This machine was equipped with a cathode ray tube (CRT) to register ultrasound echoes as vertical deflections of a horizontal trace divided into 2 mm. intervals (Fig.1). The Smith-Kline unit was also fitted with a Polaroid camera housed over the CRT to provide a permanent, and measurable, record of the echo pattern on the CRT. The CRT trace operated in both an up and a down mode, making it possible to record two readings by double-exposing the same film, halving the cost of the quite expensive Polaroid film (Video Image Recording Film, Type 611).

The thickness of the combined soft tissues was recorded with the transducer gently and perpendicularly positioned against the surface of a water-filled cushion centered over the measurement point on the subject's face.

For each subject, tissue thickness was recorded at the same 21 standardized points (Fig. 2) specified by Rhine and Campbell (1980), ten in the mid-line and eleven on the left side. It took approximately twenty-five minutes, on the average, to obtain a complete set of measurements for one subject. The Polaroid prints were measured later, under magnification, at the University of Manitoba.

The chimpanzees in our sample were those under-going anaesthesia as part of the quarterly medical checkup conducted by the staff of the Primate Research Institute at Holloman Air Force Base, New Mexico. Following their checkups and while still anaesthetized, we collected our ultra-sound data. We have no reason to believe that the chimpanzees experienced any additional stress or discomfort, beyond what was required for their medical evaluation, as a

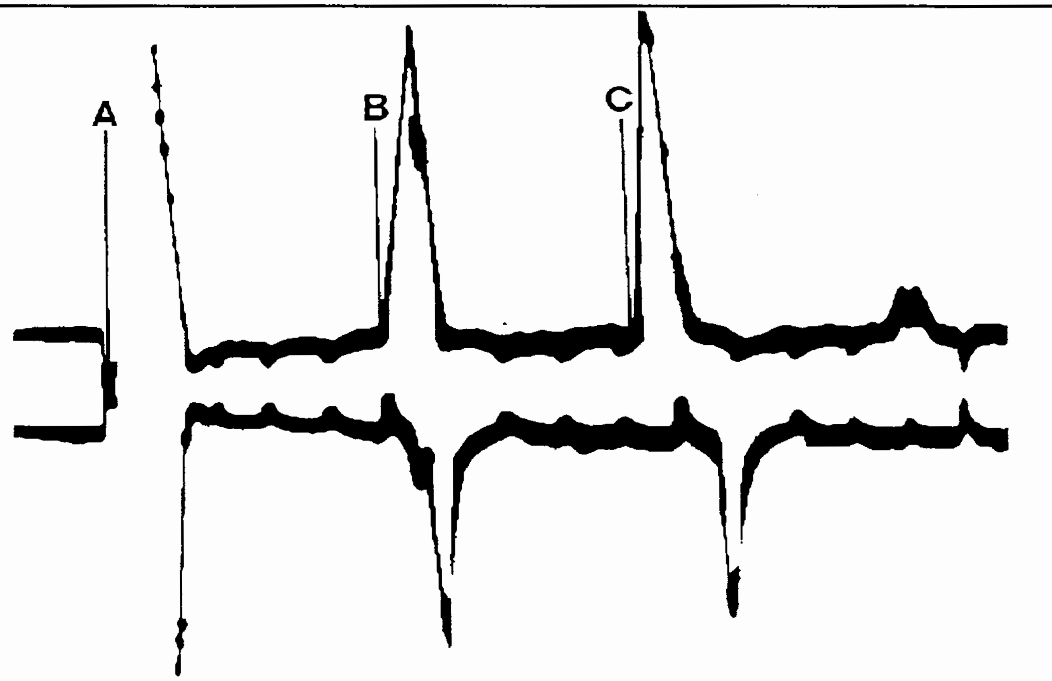

Figure 1: Sample Polaroid exposure of two CRT traces, one in the up mode, one in the down mode (double exposed).
A = transducer head,
B = skin surface,
C= bone surface:
A-B = fluid filled cushion, B-C = soft tissue thickness.

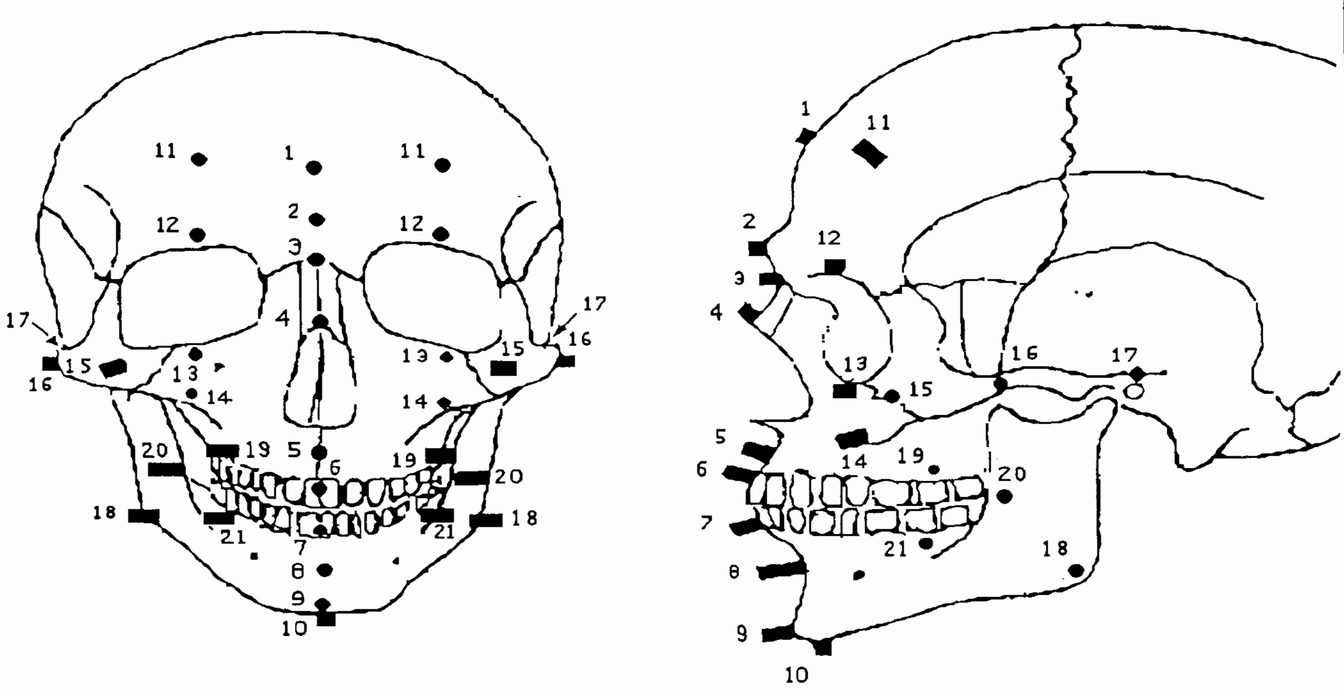

Figure 2: Measurement points (from Rhine and Campbell, 1980)

result of our work with them.

RESULTS AND DISCUSSION

The chimpanzees at the Primate Research Institute, although all evidently *Pan troglodytes*, are clearly a heterogeneous group whose sub-specific identities are not well, if at all,established. Thus, it is difficult to compare them in any meaningful way with other chimpanzee groups. For example, the PRI chimps (Table 1) are close in weight (- 8.5% for males, +0.6% for females) to the wild sample of *Pan troglodytes troglodytes* reported by Jungers (1985:349). On the other hand, the PRI chimps are larger (+12.9% for males, + 43.7% for females) than the *Pan troglodytes schweinfurthii* sample reported by Jungers.

In comparison to humans, there are, not surprisingly, very clear differences in the values at most measurement points and in the general pattern of distribution of facial soft tissues, in both males (Table 2) and females (Table 3). Disappointingly, any statistical comparison of the chimpanzee and human samples would be suspect, if not meaningless, because of the very considerable differences in size of the variances in the two samples.

One of us (WDW) regards the extremely small variances reported by Moore with some skepticism, although noting that Moore's overall sample is stratified and ours is not.

Soft tissue thickness is generally much more uniform in chimpanzees than in humans, although some of the disparity is clearly due to technical differences in measurement of the respective human and chimpanzee samples. The human sample reported by Moore (1981) consists of 'normal' (segregated from 'slender' and 'stout' sub-samples) American White cadavers, from which data were obtained by needle probe. In this technique, labial and buccal measurements represent the distance from the skin surface to the bone surface and often includes a combination of soft tissue mass and empty space between the lip/cheek and the underlying bone. These measurements have a much greater error margin than those obtained elsewhere, where the soft tissues are in direct contact with the underlying bone. These same measurement points are further affected, in an adverse way, by their position above irregular bony surfaces, where the tip of the needle may strike a local convexity or slip into a depression. In our experience, the measurements most seriously af-

TABLE 1

Ages and weights by sex

Males (N=14)

P.R.I. Number[1]	Name	Weight (kg)	Age (mos.)
32	Paleface	96.4	321
713	Chino	65.2	173
714	Taco	60.8	173
806	Ted	59.6	138
674	Cliff	58.4	230
748	J.D.	57.6	159
752	Dave	57.2	262
673	Emory	57.2	225
478	Lou	56.0	230
234	Gromek	55.4	250
853	Leonard	54.6	142
756	Patrick	53.8	153
923	Leo	50.2	82
1063	Dalton	49.0	84
	Male Mean	55.3	187

Females (N=15)

P.R.I. Number[1]	Name	Weight (kg)	Age (mos.)
549	Arlene	57.2	211
621	Connie	53.0	229
978	Tracy	52.0	213
258	Violet	51.6	256
649	Kate	49.6	259
774	Kitty	49.2	256
973	Jamie	49.0	142
640	Clair	47.6	229
679	Susie	46.2	220
985	Denise	45.8	191
631	Lolita	44.8	327
932	Lupe	43.2	101
819	Monica	42.6	166
1137	Crystal	41.8	133
778	Sherril	41.6	130
	Female Mean	47.7	204

[1] Number assigned by the Primate Research Institute

fected are Numbers 5-7, 14, and 18-21. At these same measurement points, different, though comparable, difficulties are encountered in ultra-sound measurement. Although the ultra-sound measurements of actual soft tissue are almost certainly more accurate than needle probe measurements, they exclude empty spaces altogether. The result is a serious underrepresentation of the distance from the skin surface to the bone surface, or, in other words, a false lowering of facial contours surrounding the oral cavity. Pinch (1985) discusses at some length the difficulties this represents for facial restoration, and how these problems may be overcome. Researchers should be aware that soft tissue measurements surrounding the oral cavity are a problem, particularly in regard to the representation of facial contours, with both needle probe and ultrasound techniques. It is our shared conviction that the labial-buccal area is, more than any other area of the face,subject to inaccurate restoration and that this is an extremely important concern in forensic work.

Males

We were surprised to note the general negative relationship (Table 4) between facial soft tissue thicknesses and weight at all 21 measurement points, and between tissue thicknesses and age at 20 of the 21 points. This is all the more surprising in light of the significantly strong positive relationship between age and-weight. Although male chimps continue to gain weight as they grow older, the face clearly does not participate in the general accumulation of soft tissue mass. This pattern is so striking as to suggest that the depth of facial soft tissues may be a reliable inverse indicator of age.

Females

The pattern of relationship between soft tissue thickness is somewhat different in females (Table 5), although there is about the same strength of positive association between age and weight. There is also, as in the males, a generally negative,though slightly weaker, relationship between facial soft tissue thicknesses and age. However, there is a distinctly different pattern of association in females between soft tissue deposition and weight. At 10 of 21 measurements sites, there was a positive correlation which was statistically significant at three sites.

Sexual Dimorphism

Clearly, these captive, well-fed, animals are heavier than their wild-grown counterparts (Table 1), and probably less sexually dimorphic in general. As an indication of diminished sexual dimorphism, the mean weight of 15 females was 86.3% of the mean weight of 14 males. Much of the male excess can be attributed to the aberrantly large male, Paleface (PRI No. 32). With this male removed, female mean weight increases to 91.6% of mean male weight. This

TABLE 2

Comparison of facial soft tissue thicknesses in human (white) and chimpanzee males

	Moore (1981) [1]	Present Study [2]	
Mid-line Measurements	Mean (mm.)	Mean (mm.)	Range
1. Supraglabella	4.36 ± .13	10.10 ± 1.89	7.44 - 12.89
2. Glabella	5.26 ±.14	9.77 ± 2.35	5.87 - 13.30
3. Nasion	6.45 ± .16	9.28 ± 1.67	6.17 - 11.07
4. End of nasal	3.01 ± .10	9.19 ± 2.12	5.50 - 11.64
5. Mid-philtrum	10.01 ± .27	9.08 ± 1.89	6.35 - 11.36
6. Upper lip margin	9.72 ± .34	9.90 ± 1.61	7.07 - 11.94
7. Lower lip margin	10.91 ± .37	9.75 ± 2.10	6.30 - 13.03
8. Chin-lip fold	10.85 ± .25	9.09 ± 2.56	5.20 - 12.03
9. Mental eminence	11.26 ± .29	9.55 ± 2.02	6.33 - 12.40
10. Beneath chin	7.25 ± .22	9.57 ± 2.05	6.06 - 11.65
Left Side Measurements			
11. Frontal eminence	4.35 ± .12	9.95 ± 2.25	6.09 - 12.78
12. Supraorbital	8.26 ± .18	9.83 ± 2.18	6.00 - 12.03
13. Suborbital	5.79 ± .22	9.07 ± 2.56	4.59 - 13.24
14. Inferior malar	13.34 ± .38	9.59 ± 1.98	6.22 - 12.21
15. Lateral orbit	9.75 ± .36	10.16 ± 2.16	6.62 - 13.13
16. Mid-zygomatic arch	7.04 ± .26	9.12 ± 2.18	4.62 - 11.65
17. Supraglenoid	7.94 ± .40	9.67 ± 1.74	6.21 - 11.42
18. Gonion	10.69 ± .47	9.55 ± 1.84	6.20 - 11.71
19. Supra M^2	18.78 ± .71	9.62 ± 1.66	6.59 - 13.23
20. Occlusal line	17.54 ± .56	9.90 ± 1.76	6.12 - 11.87
21. Sub M_2	15.03 ± .56	10.10 ± 1.79	6.85 - 12.72

[1] N = 67
[2] N = 14, execept in measurements 4, 10, and 21, where N = 13

is considerably less sexually dimorphic than the comparative weights of wild chimpanzees reported by Jungers (Ibid.), in which female mean weight (N = 15) was only 77.2% ofthe male mean (N = 11) in *Pan troglodytes schweinfurthii* and79.0% in *Pan troglodytes troglodytes* (N = 20 in both the male and female samples).

We speculate that the relatively slight sexual dimorphism in weight in these animals is an indication of equal access by both sexes to all available nutrients, especially during gestation and lactation. As the females in our sample are part of a breeding colony, births are presumably scheduled at greater frequencies than in the wild, with shorter intervals of infant/juvenile care by mothers.

At all 21 points, mean soft tissue thickness was greater in females than in males (Fig. 3), although the difference was statistically significant at only one point. The excess of soft tissue in the female faces was fairly uniform except at the Upper Lip Margin and at Sub-M_2 (Points 6 & 21), where the differences were negligible due to convergence, at the Chin-Lip Fold (Point 8), where the greatest difference was recorded, and at the Mid-Zygomatic Arch (Point 16), where the difference was large but not statistically significant. These differences are interesting but, to us at least, opaque.

CONCLUSION

Our research has achieved two principal objectives.

First, as far as we can determine, we have provided the first facial soft tissue thickness data available for any non-human species. These results are both intrinsically interesting and extremely useful in application to comparative analyses of the sort undertaken by Pinch

TABLE 3

Comparison of facial soft tissue thickness in human (white) and chimpanzee females

	Moore (1981) [1]	Present Study [2]	
Mid-line Measurements	Mean (mm.)	Mean (mm.)	Range
1. Supraglabella	3.47 ± .26	10.97 ± 1.94	5.84 - 13.42
2. Glabella	4.82 ± .27	11.05 ± 1.75	6.07 - 12.81
3. Nasion	5.44 ± .31	10.58 ± 1.41	7.62 - 12.39
4. End of nasal	2.68 ± .19	9.92 ± 1.56	5.24 - 12.24
5. Mid-philtrum	8.42 ± .51	10.47 ± 1.92	4.48 - 13.19
6. Upper lip margin	8.92 ± .64	10.08 ± 1.76	5.98 - 14.02
7. Lower lip margin	10.09 ± .70	10.40 ± 1.17	8.19 - 12.67
8. Chin-lip fold	9.55 ± .48	11.24 ± 1.78	5.93 - 13.85
9. Mental eminence	9.89 ± .54	10.40 ± 1.48	6.84 - 12.09
10. Beneath chin	5.69 ± .49	10.92 ± 1.62	7.14 - 13.45
Left Side Measurements			
11. Frontal eminence	3.61 ± .23	10.56 ± 1.59	5.50 - 12.88
12. Supraorbital	7.07 ± .34	10.44 ± 2.55	4.21 - 13.43
13. Suborbital	5.93 ± .41	9.69 ± 2.05	5.35 - 12.82
14. Inferior malar	12.28 ± .72	9.89 ± 1.30	7.07 - 11.93
15. Lateral orbit	10.53 ± .67	10.46 ± 1.66	6.65 - 12.78
16. Mid-zygomatic arch	7.13 ± .49	10.51 ± 1.57	7.13 - 12.48
17. Supraglenoid	7.93 ± .76	10.79 ± 1.49	7.24 - 13.66
18. Gonion	9.41 ± .88	10.52 ± 2.14	5.55 - 13.69
19. Supra M^2	17.82 ± 1.34	10.47 ± 1.14	8.28 - 11.94
20. Occlusal line	16.97 ± 1.05	10.58 ± 1.59	6.46 - 13.09
21. Sub M^2	15.18 ± 1.05	10.21 ± 1.63	6.89 - 12.37

[1] N = 19
[2] N = 15, execept in measurements 6, 7, 19, and 20, where N = 14, and in measurement 21, where N = 13.

(1985), keeping always in mind our caveat in regard to our (or anyone's) measurement of tissue thickness external to the oral cavity.

Second, we believe that there are manifest advantages in the use of ultra-sound, as opposed to traditional, measurement of soft tissue thickness. Our work with chimpanzees would have been practically impossible had we been limited to an invasive technique applicable only to cadaver samples. Living chimpanzees, although rare, are still more common than chimpanzee cadavers. For this we are as grateful as the chimps would be if they knew. There is, of course, the added benefit of measuring living tissue that is free of distortion from *post mortem* edema and/or desiccation, the unnatural swelling induced by the infusion of chemical preservatives, and the unnatural contours produced by the position of the cadaver in storage.

We make no pretense that our ultra-sound work represents a 'state of the art' approach to the measurement of soft tissue thickness. The most accurate measurement of human samples will probably come, in time, from Computed Axial Tomography scanning, or similar, technology, with the additional benefit of solving the problems of accurate extra-oral measurement. However, the use of a small portable ultra-sound unit makes possible certain kinds of research that would otherwise be impracticable, a good example being provided in the present case by a chimpanzee research sample that could not be brought together with large, definitely non-portable, CAT-scan equipment.

ACKNOWLEDGEMENTS

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TABLE 4

Spearman's rank-order correlation coefficients, males

	x Weight	x Age	N
Age	+ .501 *	---	14
Mid-line Measurements			
1. Supraglabella	- .433	- .215	14
2. Glabella	- .007	- .171	14
3. Nasion	- .042	- .125	14
4. End of nasals	- .225	- .304	13
5. Mid-philtrum	- .284	- .314	14
6. Upper lip margin	- .301	- .022	14
7. Lower lip margin	- .490 *	- .237	14
8. Chin-lip fold	- .305	- .242	14
9. Mental eminence	- .314	- .391	14
10. Beneath chin	- .132	- .284	13
Left Side Measurements			
11. Frontal eminence	- .345	- .378	14
12. Supraorbital	- .446	- .026	14
13. Suborbital	- .333	- .510 *	14
14. Inferior malar	- .530 *	- .422	14
15. Lateral orbit	- .451	- .347	14
16. Mid-zygomatic arch	- .481 *	- .396	14
17. Supraglenoid	- .319	- .385	14
18. Gonion	- .007	+ .099	14
19. Supra-M^2	- .138	- .376	14
20. Occlusal line	- .452	- .460 *	14
21. Sub-M_2	- .319	- .459	13

* P < .05

TABLE 5

Spearman's rank-order correlation coefficients, females

	x Weight	x Age	N
Age	+ .523 **	---	15
Mid-line Measurements			
1. Supraglabella	- .146	+ .123	15
2. Glabella	- .011	+ .155	15
3. Nasion	+ .011	- .430	15
4. End of nasals	+ .225	- .084	15
5. Mid-philtrum	.000	+ .132	15
6. Upper lip margin	- .459	- .743 ***	14
7. Lower lip margin	+ .196	+ .009	14
8. Chin-lip fold	+ .711 ***	- .077	15
9. Mental eminence	+ .011	- .268	15
10. Beneath chin	+ .125	- .248	15
Left Side Measurements			
11. Frontal eminence	+ .725 ***	- .095	15
12. Supraorbital	- .229	- .388	15
13. Suborbital	+ .461 *	+ .054	15
14. Inferior malar	+ .025	- .359	15
15. Lateral orbit	- .154	- .238	15
16. Mid-zygomatic arch	- .075	- .205	15
17. Supraglenoid	+ .102	- .089	15
18. Gonion	- .154	- .423	15
19. Supra-M<2	- .152	- .552 **	14
20. Occlusal line	- .125	- .363	14
21. Sub-M=2	- .170	- .298	13

* P < .05
** P < .025
*** P < .0025

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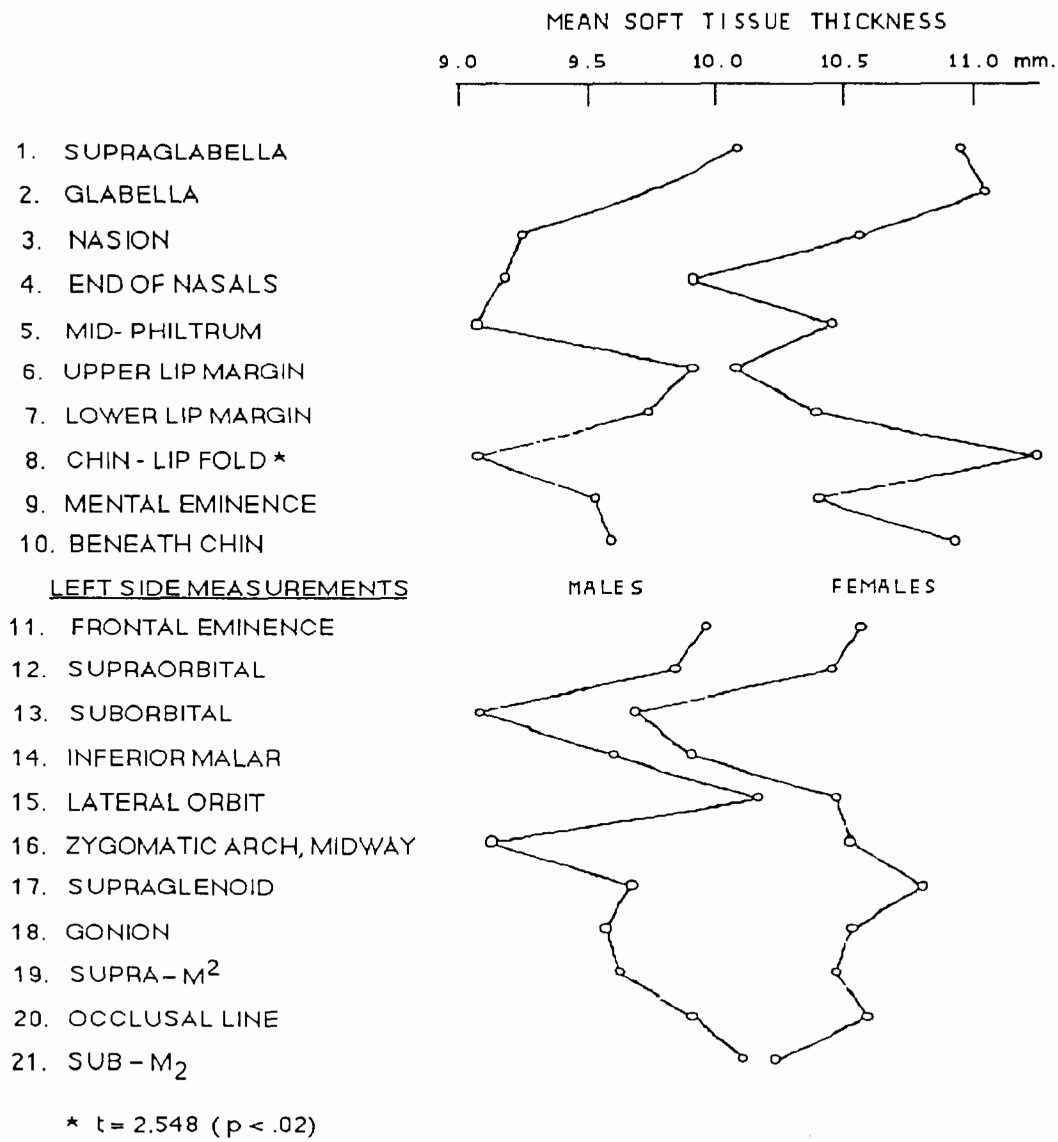

Figure 3: Sexual dimorphism in soft tissue thicknesses.

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A NEW METHODOLOGICAL APPROACH TO DERMATOGLYPHIC VARIABILITY

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Abstract: The study of dermatoglyphic variability in physical anthropology has been carried out for more than a century with the help of some systems of classification which use basically nominal scales. The methodology which employed qualitative criteria or discontinuous variables was not effective in biological studies examining environmental and genetic interactions within human populations. Some relevant information about the morphogenesis of dermatoglyphics leads us to consider as legitimate the measurement of the curvature of a planar curve on the topography produced by the cylindrical projection of a finger print. This methodology seems to be promising.

Résume: L'étude de la variabilité des dermatoglyphes digitaux en anthropologie physique a été effectuée pendant plus d'un siècle à l'aide de systèmes de classification dont les échelles étaient surtout nominales. Ces méthodologies qui font usage de critères qualitatifs ou de variables discontinues sont inefficaces pour des études biologiques ayant pour object l'examen des interactions environnementales et génétiques qu sein de populations humaines. Des informations pertinentes sur la morphogénèse des dermatoglyphes nous amène à considérer comme léfitime la mesure de la courbure d'une courbe planaire sur la topographie porduite par la projection cylindrique d'un dermatoglyphe digital. Cette méthodologie semble très prometteuse.

KEY WORDS Dermatoglyphics, Ridges, Curvature, Methodology, Technique, Digitizer

INTRODUCTION

In 1980, Dr André Leguebe from the Institut Royal des Sciences Naturelles de Belgique published a feature article on the analysis of dermatoglyphic data. His topic was basically related to methodological considerations. He demonstrated that dermatoglyphics are suited to a study of intra-population variability, regional variability and world variability under some unquestionable requirements. The first condition implied the most elementary and fundamental of scientific procedures: to be effective, information had to be communicated to the other researchers who belong to the community of anthropologists. However, he pointed out that since the 70's, the huge development of this field, the complexity of the description and the superabundance of details seem to have contributed to the isolation of the people who are specialized in dermatoglyphics.

A second condition is the nature of the scales used to evaluate the physical characters. They have to be studied in connection with the adequate and proper biometrical methods to analyze them. An example may illustrate a part of the problem: Cummins and Midlo (1981, p. 71) include an unfortunate sentence: "*arches, loops and whorls form a sequence of increasing pattern complexity*". Not only do they not formally define what they mean by complexity but also they mislead by giving the impression that these descriptors are based on the determination that one descriptor has a greater value than another. In fact, we are dealing with a nominal scale which has been considered as an ordinal scale.

A third condition is partially associated with the problem of choosing the right variable. Since qualitative variables are arbitrarily determined, data analysis may conduct some particular faults at the level of interpretation. It is always a possibility that different genetic action may produce by the convergence effect, a look a like phenotype. Loesch summarized perfectly the problem. We quote:

> "The main difficulty is in what way patterns should be classified in order to obtain character equivalent to biological entitles..."(Loesch, 1982:46)

Figure 1

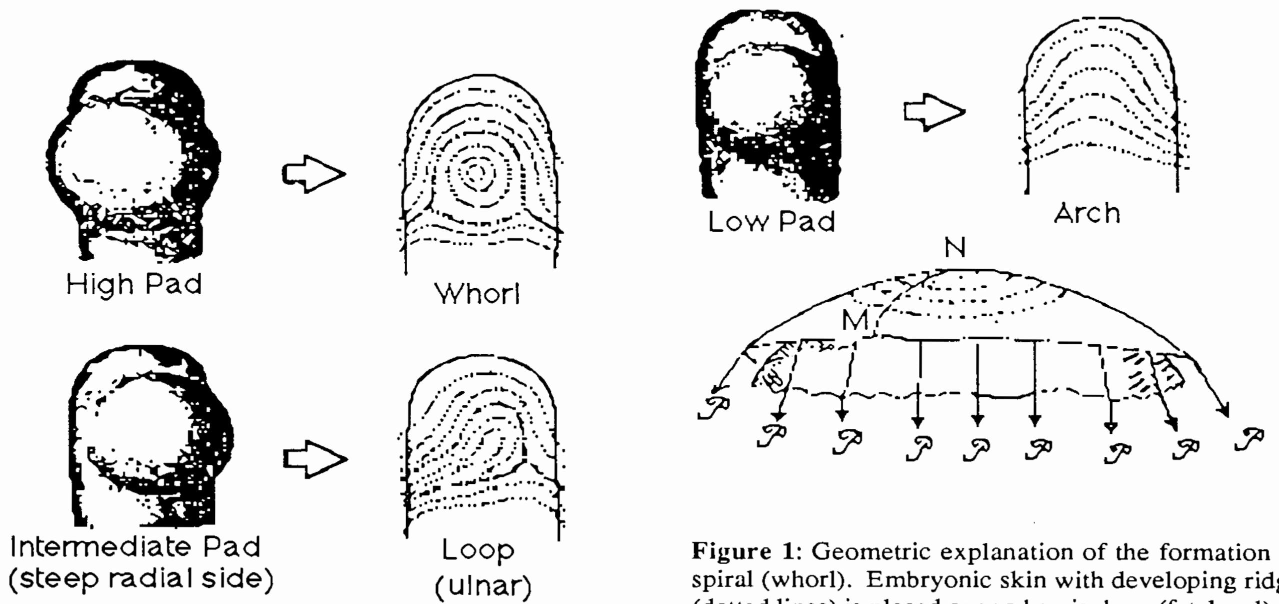


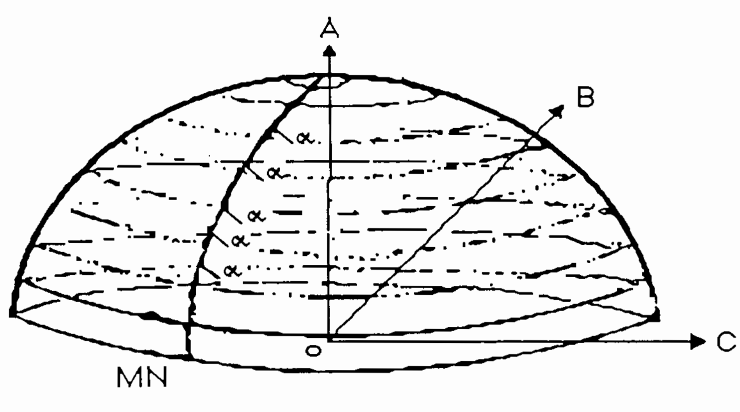
Figure 1: Geometric explanation of the formation of a spiral (whorl). Embryonic skin with developing ridges (dotted lines) is placed over a hemisphere (fetal pad) producing a stretch force ℘ which casuses the ridges to form angle a with any meridian MN. The ridges then are under mimimum tension. In calculus, this curved line is the graphic display of the equation: $\sqrt{x^2 + y^2} = ce^{\text{arc tan}\, y/x}$ (after Mulvihill and Smith,1969).

The use of quantitative characters did not solve the methodological dead-end. One such quantitative measurement is the ten finger ridge count (TRC). Meier (1980) gave this definition:

> "The summed ridge count for a person's ten digits, based upon the larger ridge count in the case of whorls. Mean TRCs for populations generally run between 100 and 150."

It may help to evaluate the size of dermatoglyphic structures. But, the use of TRC is not without methodological danger and a note of warning is necessary. Weninger (1965, 1976) criticized the additivity model for TRC.

Figure 2: OA = OB = OC = radius



1) Ridge counts won't provide accurate assessments of pattern and petal pad size.
2) The distribution of TRC is consistently shown to be negatively skewed and flattened.
3) The TRC is the sum of a mixed set of values from the individual digits and therefore can not be biologically meaningful as a homogeneous character.

Jantz (1977) also explained that the presence of variable proportions of arches, which correspond (by convention) to a null and void number of

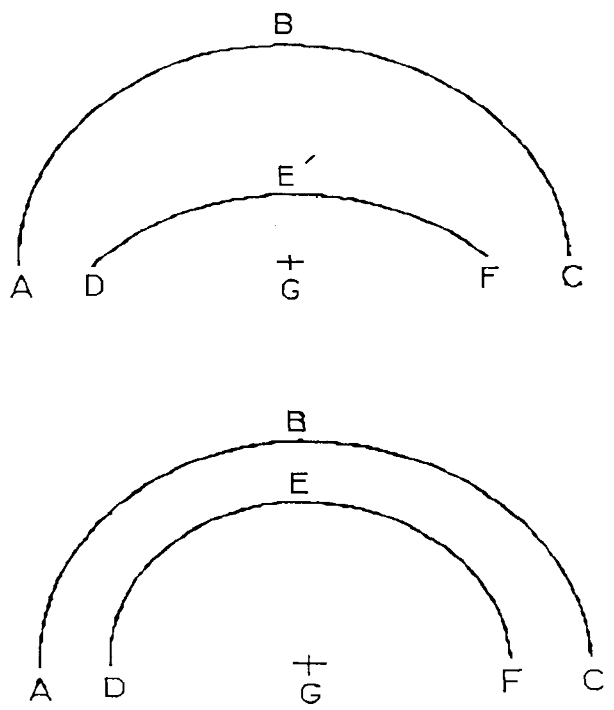


Figure 3
After Silk, 1984 pp. 482.

ridges, can deviate the distribution from normality. The reader can find more information about this subject in Mavalawala (1978) and in Wertelecki and Plato (1979). Also, the actual impass based upon differing concepts of polygenic inheritance of TRC, seems to be related to over reliance upon strict genetic mechanisms without considering the developmental processes as altered by environmental effect (Meier, 1980).

The use of TRC in this article is more for pragmatic reasons (such as a comparison of two systems) and should not be considered as an unconditional endorsement by the author for this kind of index (TRC) in the future. Even with the use of multivariate analysis, it is always excruciating to know that because of arches, which are traditionally considered as patternless, we lose a part of the biological information. Our position regarding this matter may be summarized as follows: for contemporary researchers the classical manner of examining dermatoglyphic structures through some qualitative criterion is not appropriately objective, especially where one has to deal with challenging questions, most of them related to genetic and environmental effects on human populations.

THE PHILOSOPHY

The problem we addressed at the Université de Montréal was the quantification of the intensity of a dermatoglyphic structure. We were looking for a geometrical, a topological or metric criterion, enabling us to gauge, objectively in this restrictive sense, the strength of a given set. We have tried to merge this criterion with the classical methodology, looking for an improvement of previous approaches rather than for a revolutionary new rule of classification. The main problem we wanted to address is the recognition of a non-trivial structure in a nonrectilinear field: we believed that an arch is not the same thing as an open field, and it is this difference we have tried to assess.

THE THEORY

The concept of measuring the curvature of a particular dermatoglyphic ridge came from two divergent pathways. One is related to the theoretical model suggested by Mulvihill and Smith about the mechanism responsible for the formation of dermatoglyphic patterns such as whorls, loops and arches. After examining some comparable works in different research fields such as primatology, embryology, human population studies and pathology they concluded that the best geometric explanation of the formation of pattern is related to the heighth of a volar pad during morphogenesis. At that point in time, the embryonic skin develops ridges which are stretched over a hemisphere (the volar pads) producing a stretch force " $\wp$ " which causes the ridges to form angle α with any meridian - *MN*. The ridges are under minimum tension. Normally volar pads are ellipsoid in shape. The specific case where three semi-axes are identical in length, will give us a symmetrical hemisphere. See figure 1.

Theoretically if all the volar pads were homogeneous hemispheres, that is to say, if the length of the semi-axes a,b,c were the same, we would consistantly obtain a pattern which is similar to a whorl (if full cell proliferation is acheived). The length of the radius determines both the volume and the surface area. Consequently the relation between the planar curvature and the surface area, will be an inverse ratio. In other words, if the radius has a large value, the curvature value will be low and the surface area will be large. Naturally the number of ridges which are covering such a hemisphere is not exactly related to the size of the surface area. This relationship has been expressed, specifically between sex chromosomes and the total finger ridge count (TRC), in an equation for the numerical value of an expected mean TRC: **E = 187-30x-12y**, by Penrose in 1967, (Schaumann , and Alter , 1976). See figure 2.

Thus the correlation between the curvature and the number of ridges is close to an inverse ratio. In theory we should not have a perfect negative correlation because volar pad morphogenesis is under genetic control and is environmentally altered (or may be altered) during early gestation, and as a result such correlation will probably be lower. In addition, the curvature of a ridge is directly related to the size of the fetal pad which is not as accurate in the case of TRC!

THE METHOD

The second approach is derived from descriptive geometry. Dermatoglyphics will be considered to be a set of lines in the plane. The mere action of taking a printed record of a dermatoglyph "*finger printing*" assumes, by its "unrolling" of a finger, that the structure is on the surface of a cylinder. Any analysis of this record must therefore assume that it is two-dimentional. Sophisticated morpho-genetical studies, in which the third dimension of the dermatoglyph plays a crucial role, are therefore inaccessible by this means (Miller, 1981); we will, however, not be concerned with such studies. In contrast to previous work of a topological, or theoretical nature, most notably that of Penrose, we consider dermatoglyphics as discrete sets of lines. This seems to us to be closer to the anatomy, and points toward the line we pick to do our measurement, the main line of a structure or the great circle of the hemispheric form of a volar pad. So, how do we measure the ridge curvature? Dr Jacques Belair (1984) from the department of Mathematics at the Université de Montréal elaborated the following approach. We have reduced the hard technical version to a softer one, however it may still appear to some as extremely complex.

Curvature of a plane curve

Let us consider a plane curve; we want to measure by how much this curve deviates from a straight line. By analogy, one may recall that the tangent to a curve is the best measure of its direction. Let thus **Y** be a curve in parametric form $\psi(t) - (x(t),y(t))$ on an interval $[a,b]$: as the variable **t** takes values between **a** and **b**, the coordinates $(x(t),y(t))$ are those of the points on the curve **Y**. The direction of this curve is given by the tangent vector $(x'(t), y'(t))$, where ' denotes $\frac{d}{dt}$.

Given two different points, there is exactly one straight line through them. Take two points of **Y** close to a fixed point **P**, also on **Y**; as these points tend to **P**, the limiting direction of the line through them, if this direction exists, is that of the tangent to the curve at **Y**, the best linear approximation to the curve at this point. If one considers three points instead of two, there is exactly one circle going through these points; in the limit when all three points tend to **P**, this circle tends (most often!) to a limiting position, and provides the best quadratic approximation to **Y** at **P**. This circle is called the osculating circle; its centre is located on a line perpendicular to the tangent of **Y** at **P**, the so-called "normal line", and the reciprocical of its radius is called the curvature of the curve at the point **P**.

There are other ways, albeit less geometrically appealing, to define the curvature, for example, as the derivative of the tangent when the curve is parametrized by arc length.

When the curve is given in a parametrised form $(x(t), y(t))$, an algebraic sign can be given to the curvature, according to the orientation of the normal tangent frame. In canonical orientation,

$$k(t) = \frac{x''y' - y''x'}{((x')^2 + (y')^2)^{3/2}}$$

In particular, when a function is used in the parametrisiation, i.e. $x = t$ and $y = f(t)$, then

$$(1) \quad k(x) = \frac{-f''}{(1+(f')^2)^{3/2}}$$

It is this latter expression which will be used. It is not difficult to establish that the units of the curvature are $(\text{length})^{-1}$, whatever the parametrization may be. This agrees with intuition, since the reciprocical of the curvature is the radius of the osculating circle. Equation

(1) can be readily used to compute the curvatures of a circle of radius **R** and a straight line, giving respectively $^1/_R$ and O.

Silk (1984) has addressed the problems encountered in implementing the use of the curvature in studies of plant growth. (Our studies were accomplished independently). In particular, she emphasizes the difficulties involved in "eye-balling" the value of the curvature, camber being apparently more natural than curvature to the eye. Figure 3 illustrates this difference between two arcs of the same camber and two arcs with the same curvature. Kavanagh and Richards (1942), and Ninio (1979) as well, have discussed this problem of perception.

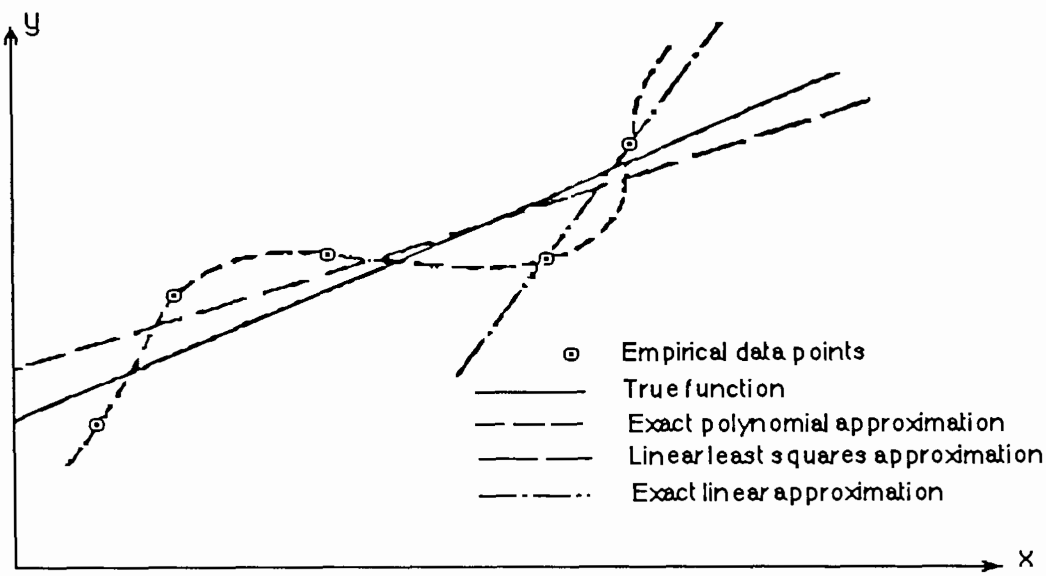


Figure 4
Least Squares and exact approximations.

Numerical representation of a curve.

Curvature is only defined for a continuous curve, in parametric form or otherwise. The line of interest in a dermatoglyphic pattern must therefore be put in this form in order for the analysis to be performed.

The problem can be divided in three steps: numerical representation of the continuous line, by discretization, analytical reconstitution of these numerical values, and, finally, computation of the curvature according to equation (1). Each of these problems has a documented history, and we now give the solution obtained for each one.

The last two steps have been considered together, by a careful representation of the numerical values. We first considered low-degree polynomials, rather unsuccessfully, and moved to the next step of complexity, namely linear combination of B-splines. This class of functions is advantageous in many respects: speed and stability for its evaluation, and wide range of applicability. As in the case of polynomials, all its derivatives can be analytically computed; this permitting the avoidance of dangerous numerical differentiation, which is unanimously and strongly NOT recommended.

For example, consider Hildebrand (1956):

> "...numerical differentiation should be avoided wheneverpossible, particularly when the data are empirical and subject to appreciable errors of observation." (p.65)

On the other hand, there is really no "objective" criterion available in the choice of the class of functions to be used in the approximation:

> "The key to obtaining satisfactory approximation is the choice of the approximation function. This choice is discussed...but...in discussion both form and norm...one must rely on experience and intuitive feeling in any particular situation," (Cox, in Jacobs (p.63),

and

> "...the solution we offer depends largely on judgement, trial and error, and very limited experience." (Hayes, p.83).

As far as the first of the three aforementioned steps is concerned, the need to smooth, in contrast to interpolate, the data is emphasized. This smoothing is specially important when working in the presence of experimental errors; this is illustrated in Fig. 6.1, p.249 of Ralston, reproduced in Figure 4.

Let us briefly recall the nature of spline functions, and their role in smooth approximation. Consider a set (X_r,Y_r), $1 \le r \le m$ of data points such that $x_1 \le x_2 \le ... \le x_m$, and a set of knots k_i, $1 \le i \le N-1$, satisfying $x_1 < K_1 \le K_2 ... \le K_{N-1} < x_m$, and a set of knots $k_{i-4}, k_{i-3}, ..., k_i$, the normalised cubic B-spline $N_i(x)$ is the function which is a polynomial of degree three on the interval (k_{i-4},k_i), is positive on this interval, is zero outside of it, and whose values, as well as those of its first two derivatives, is zero at the knots k_{i-4} and k.

A function $s(x) = \sum_{j=1}^{N+3} c_i N_i(x)$,

linear combination of these B-splines, is computed next, with the coeficients c_i, $1 \le i \le N+3$, chosen in such a way as to minimize the error

$$\sum_{j=1}^{m} (s(x_j)-y_j)^2 \quad .$$

All derivatives of $s(x)$ needed to evaluate the curvature are then computed using numerically stable recurrence relations.

Procedure and error analysis

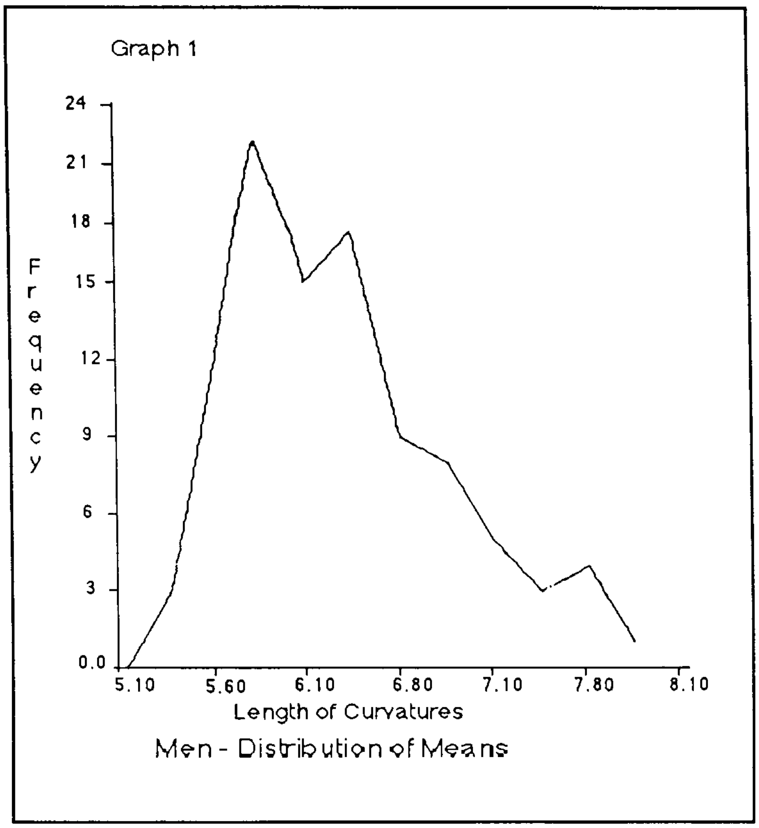
The number of points used to discretize was taken to be eleven, after trial-and-error experiments on a random sample and a graph of the function $\cos(x)$. Dermatoglyphic patterns were used in actual size, to avoid measurement errors introduced in enlarging them, and thus "thickening" main lines (ridges). The main source of errors is the digitizing of the main line. That is why an error criterion is used in assessing the smoothing function, namely the "root-mean-square error", a measure, over all data points, of the goodness-of-fit of the spline. More precisely,

$$\text{r.m.s.} = \sqrt{\frac{\sum_{j=1}^{m} (s(x_j)-y_j)^2}{m-N-1}}$$

Low values for this quantity will provide a control on the level of the errors introduced in the first stages of data processing.

THE TECHNIQUE

Once the finger prints had been taken, we placed these topographic records on a digitizing tablet. This electronic device translates the Cartesian co-ordinates of a point that we marked with a light or a magnetic pen. On a chosen line we registered eleven points as reference marks. See diagrams A,B,C,D. These coordinates served as a base for the determination of the form of the curve. To evaluate the curvature of a planar curve we have to realize that curvature is only defined for a continuous curve, in parametric form or otherwise. Indeed



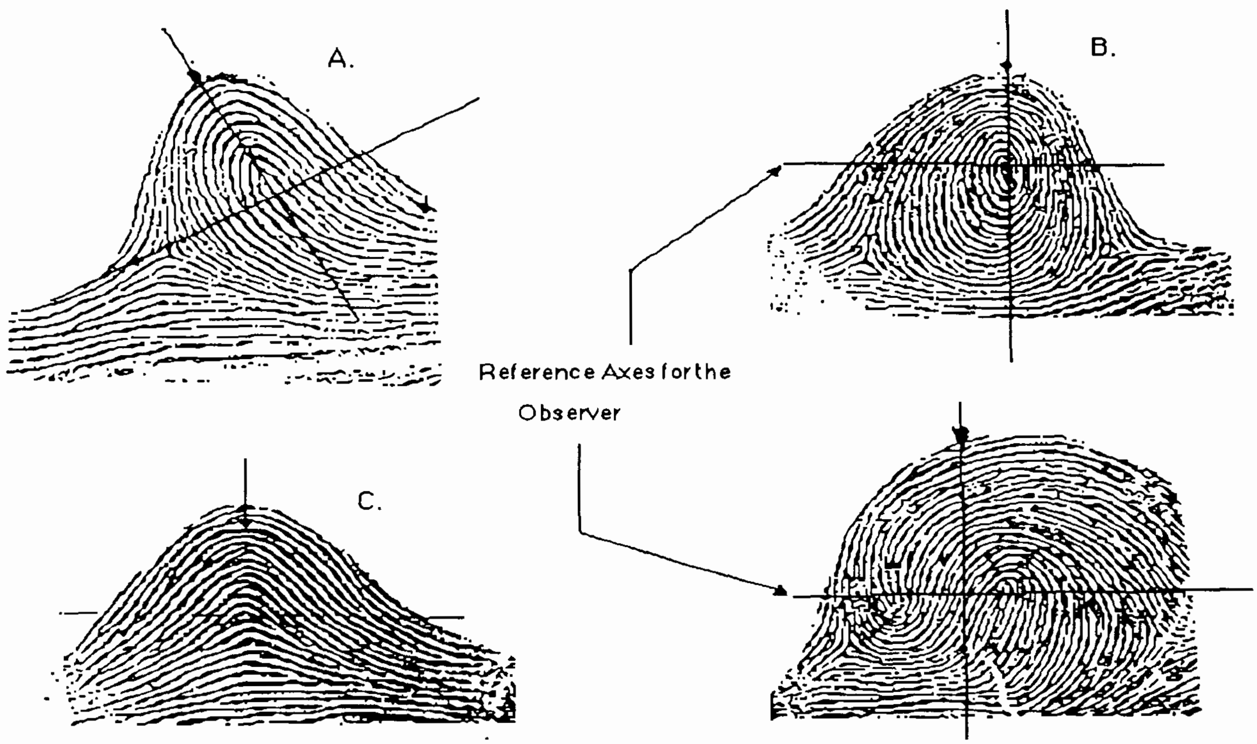


Diagram 1
Arrows indicate the chosen lines in each case.

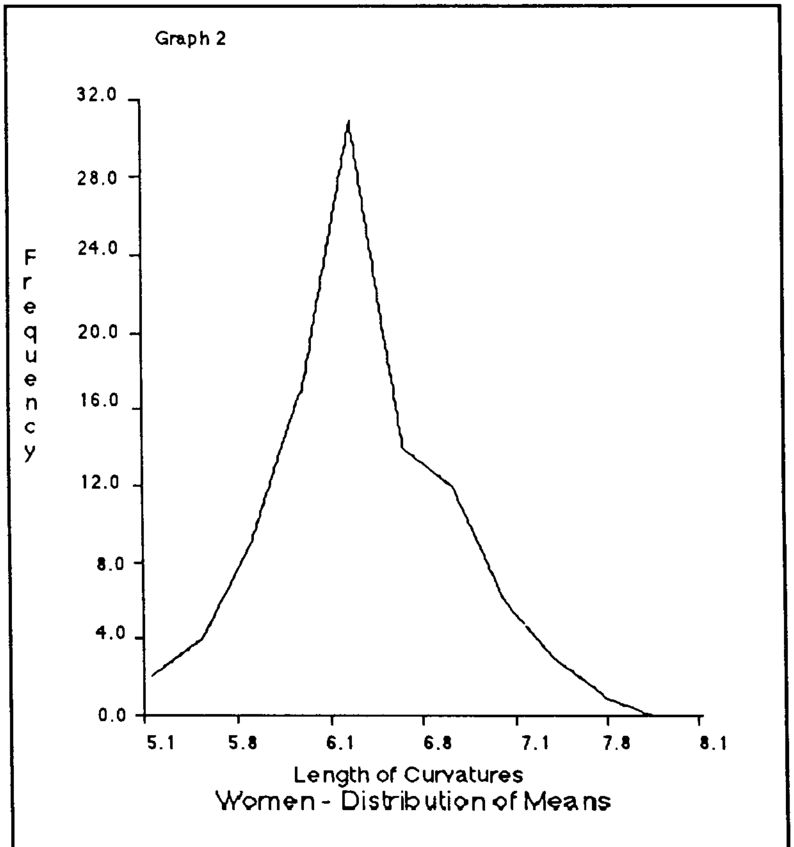
the curve is presented graphically not in analytical fashion. The dermatoglyphic ridge of interest must, therefore, be put in this form in order for the analysis to be performed. To do so, we have to work out a discretization. This operation consisted only in the transformation of a continuous quantity into a discontinuous one. When this operation is completed, we used linear combinations of B-splines. This class of functions ensures numerical stability and precision computation.

RESULTS

During the winters of 1982, 1983 and 1984 we took the dermatoglyphics of 198 students of both sexes. The sampling was not random because of the selection process related to the enrolment policy of our department. The graphs 1 and 2 are characterized by two normal distributions, after a $\log_n$ data transformation. The graphs 3 and 4 demonstrate the results of a scattergram between the TRC and the mean of the $\log_n$ of curvature. This new methodology was tested with a HP9825B calculator for computation and numerical implementation. The data gathering was done using an HP9864A Digitizing Tablet with effective precision of $\pm .254$ *mm*. This methodology was compared with the **Total finger ridge counts** during a multivariate analysis. The total $\mathbf{R^2}$ for each variable tended to demonstrate that the new methodology gathered 7% more information then the TRC.

DISCUSSION

The results confirmed the theoretical predictions of an inverse ratio correlation between the number of ridges and the curvature of dermatoglyphic configurations. Actually the measurement of the dermatoglyph ridge curvature corresponded to the three basic requirements speci-



fied by Dr André Leguebe.

1) No special description with a superabundance of details is needed by the scientific researcher to study dermatoglyphics.

2) This methodology is based on the metric scale.

3) The character is related to a morphogenetic process by means of geometry.

In addition:

4) The curvature of a ridge is related to the size of the fetal pad. This methodology also does not discriminate against patterns such as tented arches and simple arches. However, new tests will be needed to verify the reliability of this methodology.

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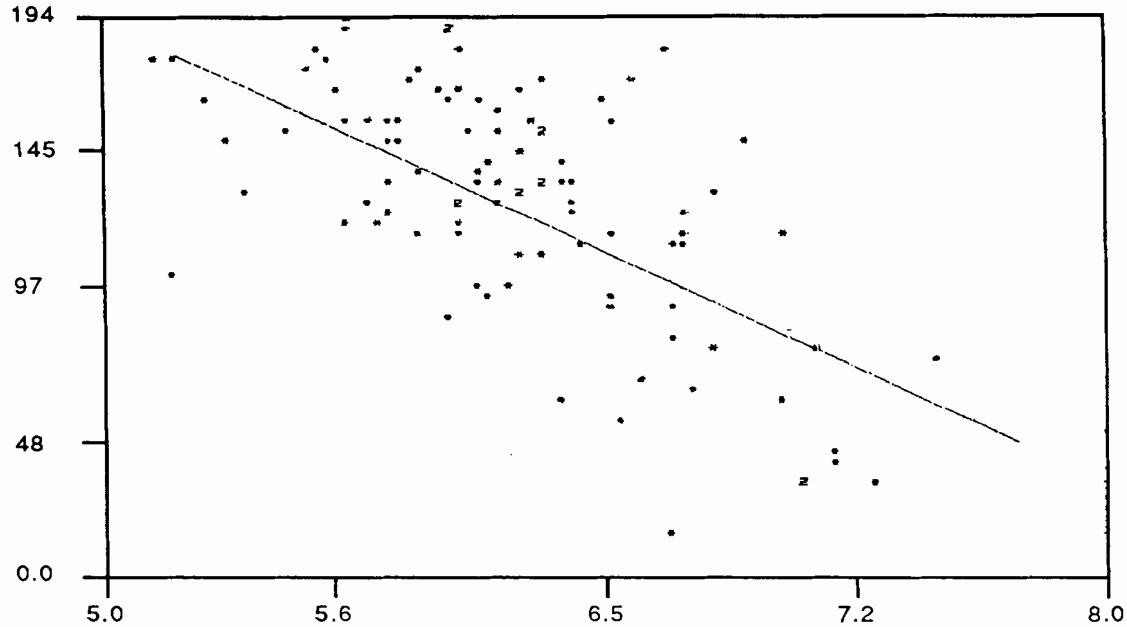
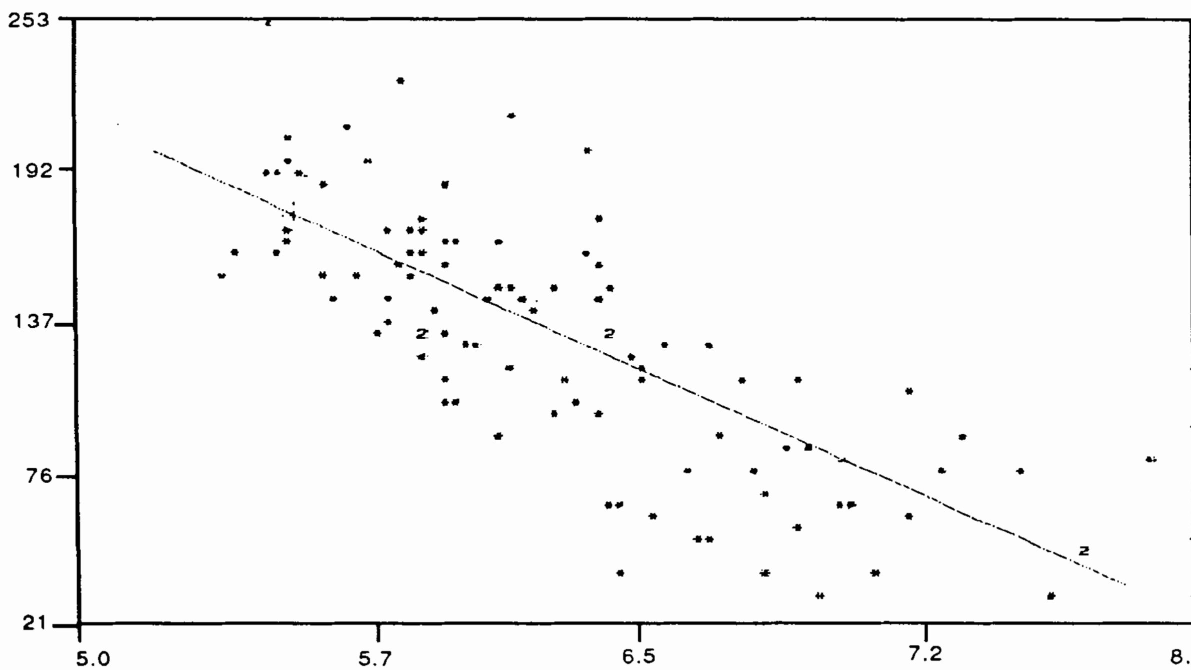
Graph 3



Simple Regression : Scattergram of the TFRC and the (log) Curvature Means for Women

Graph 4



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A Report on Pedigrees of two females Affected with Red Green Colour Vision Deficiency

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Abstract: The present paper deals with the dedigrees of two affected females. The study is based on 829 Bengali Muslim individuals (616 males and 213 females) from four villages around a Muslim pilgrimage centre at Ghutiari Sariff (24, Parganas district, West Bengal). The pedigrees of the affected females are discussed.

Resumé: Cet étude examine 829 individus musulmans de Bengale (616 mâles et 213 femelles de quartre villages autour d'une centre des pélérins musulmans à Ghutari Sarci (24, Dist. Parganas). Les pedigrées de deux femelles affectées sont discutées.

Key Words: **Red green colour blindness, Deutan, Protan, Linkage, Coefficient of inbreeding for 'X' linked traits.**

This study is based on 829 Bengali Muslim individuals (616 males and 213 females) from four villages (Makhaltala, Bonmalipur, Dhogatha and Bansra) around a Muslim pilgrimage centre at Ghutiari Sariff (24 Parganas district, West Bengal). The villages are situated approximately 27 km. south east of Greater Calcutta. The individuals were tested with Ishihara's (1964) 38 colour plate edition in indirect sunlight strictly following the guide literature accompanying the colour plates. Individuals with impaired vision and/or night blindness and/or mental retardations were not included in this study.

It is reported that 6.49 per cent males and 0.94 per cent females were found to be affected with red green colour vision deficiency. Extensive pedigrees of the affected females have been collected from the Muslim sample.

Pedigrees of the females affected with red green colour blindness (or red green colour vision deficiency) are presented in figures 1 and 2. In a sibship of four (ref nos. BL 45.2, M90.4, M90.5 and M90.6 of generation V), one daughter (M90.4) was found to be affected with protan type, and one son affected with duetan type of colour blindness. The sibship also included one normal son (M90.6) and one normal daughter, recognized as a carrier for the protan type of colour-blindness, since the grandson (ref no. BL 45.3 of generation VI) was found to be of the protan type. The father (M90.1) is a protan colour blind, this indicates that the mother (ref. no. M90.3) of the propositii was a double heterozygous (in replusion phase) at the deutan and protan loci. Vander Donck & Verriest (1960) and Siniscalco et al (1964) suggested that the genes for protan and deutal colour blind pertain to different loci. Vander Donck and Verriest's (1960) suggestion is based on the observation of a pedigree with two normal, two dueteranopic and one protanomalous sons of a normal mother. Siniscalco et al's (1964) suggestion is based on observation of a more or less similar pedigree and also on the relative positions of deutan and protan loci in respect of the G6PD locus.

The second pedigree suggests that the affected female M125.3, generation V (of duetan type) is due to the effect of matrilateral second cousin marriage of her parents. The coefficient of inbreeding for an X-linked trait estimated (after Li (1955) and Reid (1973) for the affected female was found to be 1/32 or 0.03125.

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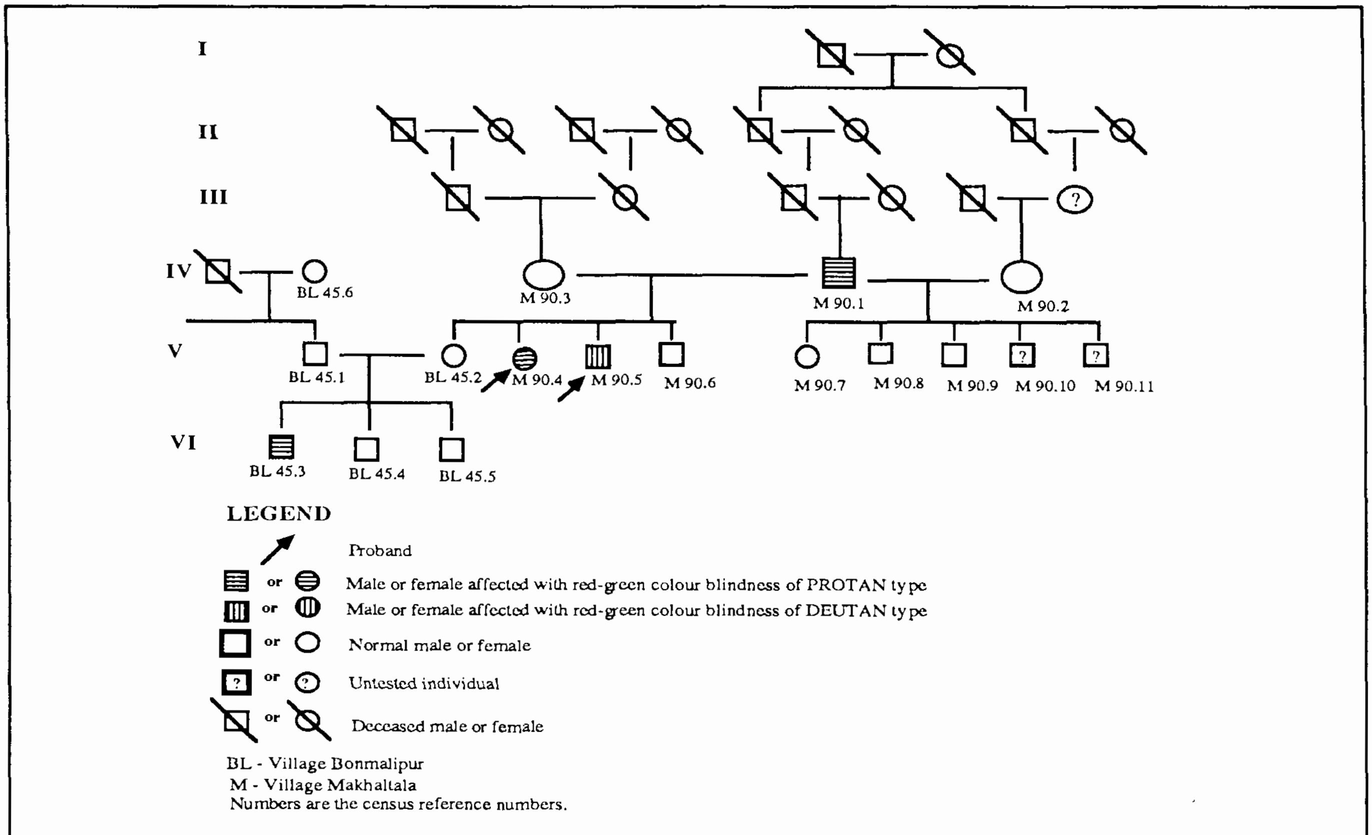
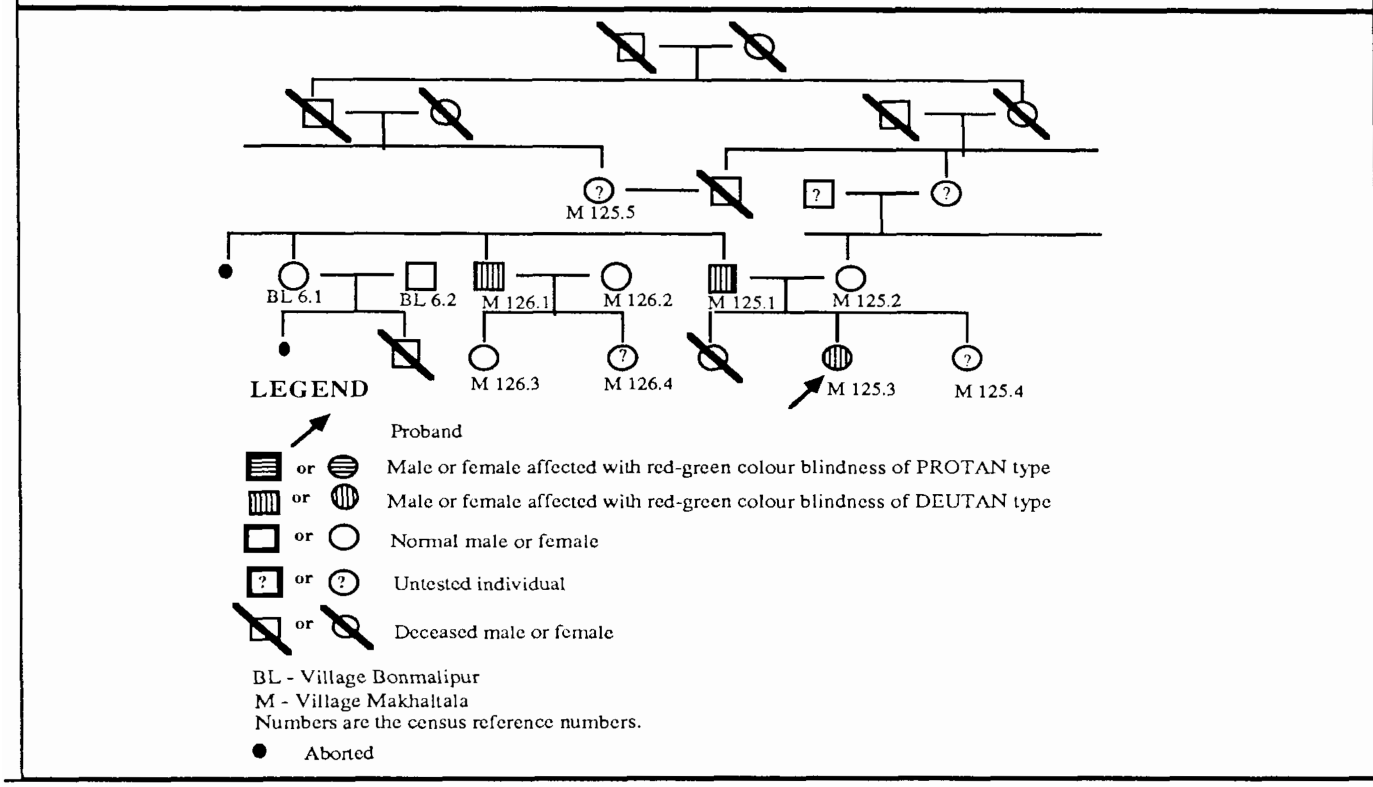

I
II
III
IV
V
VI
BL 45.6
M 90.3
M 90.1
M 90.2
BL 45.1
BL 45.2
M 90.4
M 90.5
M 90.6
M 90.7
M 90.8
M 90.9
M 90.10
M 90.11
BL 45.3
BL 45.4
BL 45.5
LEGEND
Proband
Male or female affected with red-green colour blindness of PROTAN type
Male or female affected with red-green colour blindness of DEUTAN type
Normal male or female
Untested individual
Deceased male or female
BL - Village Bonmalipur
M - Village Makhaltala
Numbers are the census reference numbers.


M 125.5
BL 6.1
BL 6.2
M 126.1
M 126.2
M 125.1
M 125.2
M 126.3
M 126.4
M 125.3
M 125.4
LEGEND
Proband
Male or female affected with red-green colour blindness of PROTAN type
Male or female affected with red-green colour blindness of DEUTAN type
Normal male or female
Untested individual
Deceased male or female
BL - Village Bonmalipur
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Numbers are the census reference numbers.
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An Extreme Example of Syndactyly

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Abstract : The present study is a case report of absent 'b' and 'c' interdigital triradii on the left palm of a 12 year old girl. Absence of these two interdigital triradii is very rare on the human palms.

Resumé: Cet étude raconte un cas de l'absence des triradii interdigitaux "b" et "c" de paume gauche d'une fille de 12 ans. L'absence de ces deux tri-radii de la paume humaine est très rare.

Key Words: **Dermatoglyphics, absent, triradius, syndactyly**

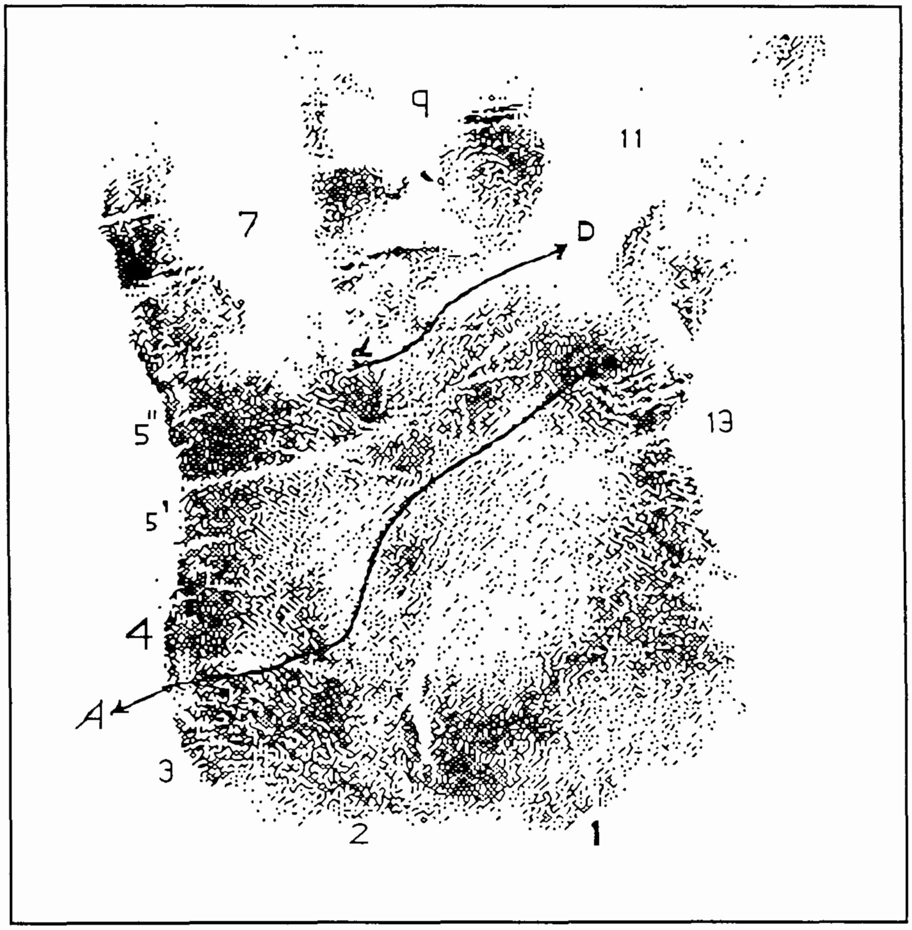
The present case was dound during a dermatoglyphics survey among a particular caste group (Kamboh), mostly living around Patiala district in the Punjab state (India). In a total sample of 174 (104 males, and 70 females) only one case is reported of a rare dermatoglyphic variant (absence of palmar 'b' and 'c' triradii on left hand) in a girl about 12 years of age (Fig. 1).

The data analysis has been prepared according to Cummins and Midlo (1961).

There are normally four interdigital triradii 'a', 'b', 'c' and 'd' situated at the base of each finger. Sometimes, in addition to interdigital triradii, accessory triradii are also present and usually associated with patterns.

In some palms, a digital triradius is absent, a condition almost confined to interdigital triradius 'c' (Cummins and Midlo, 1943). Absence of the interdigital triradius 'd' is also extremely rare and is reported in some abnormal males with the sex chromosome complement XXXXY (Miller et al., 1961).

As far as we are aware, only one or two cases of absence of 'b' and 'c' interdigital triradii together on a single palm in normal population have been reported in the dermatoglyphics literature (Cummins and Midlo, 1961). We think this example of such a rare case is worth recording.



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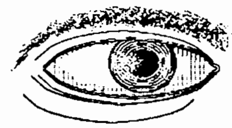
The Reviewing Stand



In this issue, we have a book review by A.J.Petto, some perspectives on digitizers for the Macintosh Computer, and brief reviews of some software of interest, by the editor.

FERTILITY IN CANADA: FROM BABY-BOOM TO BABY-BUST

by A Romaniuc. Statistics Canada, Ottawa, 1984. 156 pp., illus. $8.85 ($10.60 outside Canada).

Reviewed by A.J.Petto, Tufts University , Harvard University, New England Regional Primate Research Center

Ever since Malthus, social theorists have been trying to understand the strong association between declining fertility and economic development in Western society. Yet, few have been able to unravel the complex intervening associations among biological, behavioural, and social variables. Indeed it is rare that the data necessary for such an undertaking are available. Fertility in Canada: From Baby-boom to Baby-bust is a beginning. The main problem is identified in a preface by Martin Wilk, Canada's chief statistician. Fertility in Canada is below replacement. A general decline in fertility began late in the 19th Century and was only temporarily reversed by the post-war baby-boom. Canada's population growth is sustained by immigration and by the sheer size of the cohort bearing children.

The first chapters of Fertility in Canada: From Baby-boom to Baby-bust present data from studies of Canadian fertility. Chapter 1 focuses on large-scale measures -- crude fertility rates, total and cohort total fertility rates, and total children ever born per 1,000 women. This chapter contrasts Canada's experience with that of other industrialised countries and reviews pronatalist policies in Eastern Europe. A more complete review of the results of these policies is found in the book's final chapter. Romaniuc concludes that these policies have little impact.

Chapter 2 shifts the level of analysis, examining age-specific fertility rates, interbirth intervals, parity distribution, and completed family size. Romaniuc points out the steady decline in the number of children expected by women at the beginning of their childbearing years. In addition the rate of out-of-wedlock births has trebled between 1951 and 1981 due in part to the large size of the population at risk of pregnancy and to a delay in the age at marriage.

The steady increase in contraceptive use during the study period is examined in Chapter 3. For all segments of the population Romaniuc points to a significant rise in the frequency of sterilisation in particular. Although sterilisation may occur for reasons not related to contraception, the data show that sterilisation is occurring at smaller family sizes. Evaluation of statistics on abortion are also difficult. Because abortions in Canada remain restricted to "therapeutic" abortions, their role in fertility regulation is not clear.

These first chapters present copious amounts of data in a wide variety of tables and charts. Although many are not directly comparable because they are scaled differently, the presentations are generally clear and are supplemented with data from the appendices.

In the chapters that follow Romaniuc attempts to establish associations among variables that affect fertility. One chapter focuses on the changing role of women in Canadian society over the past forty years. Women are increasingly engaged in activities associated with decline in family size.

Subsequent chapters focus on the social and economic environments in which the declining fetility has occurred. Women have increased their level of education and their participation in the work force. Their contribution to family income has increased, and more are heads of households. There are also more divorces, some without remarriage, thus reducing the number of years "at risk" of reproduction. This review is comprehensive, but forms little more than a familiar litany of well-known associations.

One of the real strengths of Fertility in Canada: From Baby-boom to Baby-bust is the review of three models of the way that fertility responds to social and economic factors. Romaniuc seems to favour the sociological model that current low fertility rates are an extension of a continuing secular trend, but devotes considerable discussion to cyclical and countercyclical economic arguments. In cyclical models, members of large cohorts have smaller families than members of small cohorts, because the former are faced with more competition and more economic constraints to family formation. The countercyclical model holds that workers, especially working women, that are successful in the work place will limit family size due to the relatively large opportunity cost of having children. Romaniuc points out that the cyclical argument is male-based and the countercyclical female-based. These models are not, however, mutually exclusive.

Romaniuc identifies five variables most strongly associated with the changing pattern of Canadian fertility:

1. female labour force participation;
2. changes in marriage patterns;
3. relative size of cohorts and the relationship between cohort size, economic opportunity, and family formation;
4. those who have put off fertility for economic reasons who increase or begin fertility in anticipation of economic improvement;

and

5. those who have put off fertility for any reason who have decided that they should not delay any longer.

The most interesting of the chapters in this book examines the future of Canada's population. The population size, age-sex distribution, and proportion of immigrants necessary to sustain growth through the year 2050 are illustrated by a routine that models birthrate, mean and modal fertility, and life expectancy at birth. Population growth rates are allowed to vary, as are the lengths of fertility cycles. These are not predictions of Canada's future, Romaniuc warns, but examinations of how the variables in the model interact. As such, these simulations are among the most valuable parts of this book.

Overall, Fertility in Canada: From Baby-boom to Baby-bust overcomes its weak points. The review of the interactions between social and economic conditions and individual behaviour does not go beyond generalisations. Many of the analyses are at too crude a level for understanding how individual decisions about fertility are made and how these decisions relate to the observed secular trend toward smaller families.

The strengths of Fertility in Canada: From Baby-boom to Baby-bust lie in the population projection models in Chapter 6, in the discussion of sociological and economic models of fertility change, and in the data presentation in the tables, graphs, and appendices. Fertility in Canada: From Baby-boom to Baby-bust also provides incidental insight into the way in which policy makers approach and analyse social problems. This volume would be a worthwhile addition for anyone interested specifically in trends in fertility in 20th Century Canada, the process of development of population policies, or good descriptive statistics on the relationship between fertility and a variety of social, historical, and economic factors.

Acknowledgement:: I would like to thank Kelly Dunn who assisted in the preparation of the manuscript.

Thunder and Magic:
Digitizing for the Macintosh

Hardware Review by James D.Paterson
Anthropology, University of Calgary

The Macintosh and Macintosh Plus computers are generally seen as graphically orientated machines, in that graphic imagery plays a large part in the operating system and in many of their applications. In some ways, the Macintosh may be seen as a poor man's Apollo or Sun 3 workstation, but it is a compromised resemblance, limited in speed and capability. The Mac does use the same processor family as these workstations, however it uses the 68000, rather than the 68020 processor. The Mac has smaller amounts of RAM and ROM, and runs at a much lower clock speed, but then it only costs a fraction of the price of either workstation.

Like the Apollo and Sun Workstations, there are a number of ways to get graphic images into the Macintosh, but other than drawing with the mouse, or transfering graphics from clip-art collections, all have costs associated with them.

This review will deal with two devices

which serve to convert images into electronic representations for the Macintosh user. ThunderScan™, by Thunderware is an optical scanning system while Magic™ by New Image Technology is a camera-based system. Both of these devices work well, but the results of each system are unique in form and quality of image produced.

One factor which is of considerable importance for all digitizing systems is the format of the Macintosh screen. The Mac does not possess the capacity to present gray scales at the pixel level. Pixels (the screen "dots") are either 'on' or 'off'. Furthermore the pixels are square on the screen (and round on dot matrix printer output), with 512 by 342 of them representing the full screen. In this system, the shading of images must be done with patterns of pixels to give the impression of shadowing. The designers relied upon the foibles of the human visual system to provide the final gloss to acceptable imaging quality.

Both of the digitizing systems to be discussed here are designed to work either with MacPaint directly, or to provide MacPaint documents indirectly.

ThunderScan™

The ThunderScan system is both the cheapest and easiest to use of all digitizing systems, but it requires an Apple dot matrix printer (either Imagewriter I or II) to operate. The hardware components consist of: a scanner head which replaces the ribbon cartridge of either printer; a cover plate to replace the front cover of the Imagewriter I, and instructions for the removal of the transparent portion of the Imagewriter II cover, a package of timing tapes for installation on the printer platen; and cabling with a switch box which links the scanner and the printer cable to the Macintosh. For Mac Plus machines an accessory kit with an external +5 volt transformer is required due to the removal of that voltage supply from the printer interface. Installation of the system is quick and very simple. Anyone who can change the ribbon in their printer can set up ThunderScan for operation in less than a minute.

The software continues with this simple approach, and as might be expected of something written by Andy Herzfield (one of the authors of the Macintosh ROMs, and famous for his "Switcher" program), it follows the "Macintosh interface" rigorously.

The scanner is operated through menu control with a focusing operation and a secondary "dialog" box which sets up the operational configuration of the process. The area of the scan can be up to a full 8.5" by 11" page, but as would be expected the larger the area the longer it takes to scan the image. A full page takes between 14 and 18 minutes for input, and if the "Gray Map" option is turned on, the amount of memory required for the image is tremendous - 266K in the case of an 8 by 10 inch original. It is adviseable to run ThunderScan with ample room on your disk, or a good supply of blank disks if a lot of scanning is to be done. The image can be saved either as a MacPaint document (small size) or as a ThunderScan document (large!).

There are a number of control variations during input which are useful; the image can be input at any magnification from 25% to 400%. The contrast and brightness, as well as the limit stops for the gray map, can be adjusted during scanning, or afterwards through the menu option 'ReHalftone' (as long as the Gray Map was 'on'). A specific defect of the software, in my opinion is any provision for pattern changing; the gray scale bit map is the only mode of manipulation in which Thunderscan operates. There is also a high contrast menu option geared towards line drawings, however if the drawing has a large number of straight lines it is adviseable to feed the image into the scanner with those lines oriented horizontally.

Magic™

Magic stands for **MA**cintosh **G**raphics **I**nput **C**ontroller. It is at once the most complex and difficult digitizer to learn, and the most flexible. The Magic system consists of a graphics input controller box and a video camera, plus a power supply unit.

The controller box has no controls, only two RCA jacks and two standard DIN plugs. One of these plugs is for the power supply, the other connects to the Macintosh. Of the two RCA jacks, one is for the camera, while the other carries a "terminator plug". The latter outlet may be connected to a video monitor, which can serve as a very useful adjunct for focus and composition.

Magic can utilize any video source for input - videotape or even broadcast material. However, black and white mode is the only one quick enough to capture a moving image since it is capable of focusing 2 frames per second . Installation of the hardware merely involves connecting all of the cables and switching on the system.

The software for Magic is one of the few that I have encountered which does NOT make use of the standard Mac interface. This lack of the standard interface may have been part of a series of compromises made by the programmers to allow Magic to work with a complete 512 by 342 pixel screen, but it only makes the complexity of operating the system that much more involved. The one advantage of this situation is that there is normally only one control screen to deal with, no pull down menus to hunt through, and dialog boxes exist only for opening and closing pattern files and saved documents. Still, the Magic screen is cluttered and the controls are not immediately obvious as to their function, purpose, and operating manner.

Magic can make three distinctly different kinds of images - plain black and white without any shading, "edges only" and patterned pictures with the pattern set installed in the palette on. The time it takes to produce an image depends upon the number of patterns in the palette,ranging from 7 minutes 13 seconds for a 38 gray scale pattern to 8 seconds for a 3 pattern set. Patterns are loaded in from MacPaint pattern files. As mentioned earlier, the Magic interface is extremely complicated and difficult to learn, but it can combine an enormous number of effects.

The programmers of both ThunderScan and Magic recognized the need for a direct interface to MacPaint and have provided a transfer function to load MacPaint without going back to the desktop. This function is less useful now that Switcher is available to provide almost instantaneous movement to and from MacPaint, Fullpaint, or Superpaint. However, if you use ThunderScan under Switcher note that it requires about 300K plus of RAM if full page scans are to be attempted. It is also worth noting that the newest versions of the ThunderScan software are capable of running in a background mode under Switcher, but at a greatly reduced speed.

Comparison of ThunderScan™ and Magic™

As for the most frequently asked question -- Which digitizer is better? -- the answer is not simple. The two approaches have little in common, their hardware and software mechanisms being distinctive. The first question a potential user must ask is how important is the resolution of images. If resolution is of paramount consideration, then ThunderScan is currently the best choice, as long as the source material can be run through the printer rollers. If flexibility of image manipulation, the ability to reproduce "real world" objects, or take images from video recordings are of primary concern, then Magic is the appropriate choice. If resolution is critical **and** real world images must be worked with, the only option is to use film photography to convert the image to a printed form, then run the photographic print through the ThunderScan. Another marked difference between the two systems lies in the output. ThunderScan inputs, at its maximum, a full page-sized document, while Magic can only generate a screen-sized item, about a half page in final form. Access to a LaserWriter can change this situation by printing the documents at various enlargements. In any lab or office in which both resolution and flexibility is required, the solution may be the purchase of both systems.

Both applications offer the capability of printer output independent of MacPaint. This allows for the introduction of "smoothing" routines lacking in MacPaint, as well as correction for some of the minor distortions which the Paint print driver creates. The latest versions of both applications have modifications to make use of the LaserWriter.

Conclusions

The world of image input for the Macintosh has developed in distinct directions in the past three years. The digitizers discussed above represent the lower end of the price range. A recent development is the emergence of independent optical type scanners which cost approximately $2500 U.S. as opposed to the $229 U.S. list price of ThunderScan. The image quality of these scanners (a large number of the graphics in this issue of the Review were scanned in with an Abaton scanning machine, others were done with ThunderScan) may not be appreciably greater, but the setup and speed of operation is significantly faster. There are also more sophisticated, expensive camera digitizers available on the market , but the incremental quality of these models may not be visible on the Mac screen or in its output. As in so many other things, one has to weigh the advantages and disadvantages of each system.

While I find both systems usable and valuable, I perceive the software associated with both ThunderScan and Magic to have shortcomings. I would like to see the addition of the capacity to manipulate patterns, and few more 'Tools' from the MacPaint/Fullpaint set added to ThunderScan. I would also like to see the Magic software totally revised into a standard Mac interface pattern. In addition, it would also be of significant value to add the 'Gray Map' capability to Magic. Perhaps in the next year we will see more sophisticated programs for both digitizers.

One area which gives me some concern is the lack of any attempt by the manufacturers of these systems to make the user community aware of the copyright situation. Their own warranty statements cover the company, but seem to encourage the users to go out and digitize anything handy, copyrighted or not. It would probably be advisable that anyone contemplating the publication of a digitized image of which they are not the original author, take the precaution of obtaining reprint/reproduction rights just as they would to use the original image. This whole area is an untested ethical and legal ground littered with traps for the unwary. But, it is exciting.

Useful Macintosh Software - Mini Reviews

Thinktank 512 version 1.3np from Living Videotext
Statview 512+ version 1.0 from Brainpower
Fullpaint version 1.0 from Ann Arbor Softworks
Ready Set Go!3.0 from Manhattan Graphics
CricketGraph from Cricket Software

James D.Paterson, editor

The Macintosh computer, since its introduction in January of 1984 has matured significantly as a highly useful and easy to learn but very powerful word and graphics machine.

During its first year, it was criticized for a lack of software, its slowness, its lack of a programing language, and many other perceived deficiencies. This situation has changed enormously and for the better in all areas. The current version, the Mac Plus, is far faster, has a full 1,024K of memory available, has numerous high level languages available, and certainly is now adequately endowed with software. In this portion of the reviews column, I will provide my perceptions of some of the software that I have found to be useful in my own work as an academic, researcher, and editor.

Thinktank 512 originated in life as an outlining program for users of the Apple II line of computers, was ported over to the Macintosh 128 and later expanded to the 512K version. It is also available in a crippled form for IBM compatible computers. Thinktank is largely a program which enables the user to type in random thoughts and ideas, and later to shift them around into a meaningful arrangement, and add extended notes and text, and graphic images to the document. As such it has a great deal of simple utility as a "pre-writing tool" which can layout and organize any document. The utility of this approach is such that a very large number of imitations have been generated for various machines, and almost all new wordprocessing packages now include an outliner. In the Macintosh version there are a number of extra goodies which can be valuable - the ability to store graphic images and then to play them back in sequence as a "slide show" can be useful for presentations (especially if a "video-Mac" is utilized with a video projector), and it may occasionally be useful to be able to sort idea topics, but the single most useful application of the program is in the preparation and maintainence of course notes. I have been using Thinktank 512 for this purpose for the past year, and have found it to be the single most important teaching innovation that I have encountered in the past 16 years. I have been able to construct daily note outlines, prepare extended blocks of text, reshuffle them as necessary, and ultimately the material in them might serve as the basis of a textbook. Thinktank in any of its incarnations would be a very useful investment for any academic.

Statview 512+ may be, as of this point in time, the very best statistics program available for any computer, mainframe, mini, or micro. This program developed out of the earlier Statview 128 through a straightforward process of enhancement and addition of statistical procedures. Currently, the program lacks a few of the procedures found in SPSS-X, but makes up for it by including a number which SPSS lacks. The program makes full use of the Macintosh interface, and is extremely fast - significantly outperforming SPSS on the Honeywell Multics system. It is able to handle data sets of enormous size, 100,000 data points, each of 6 digit numbers is well within its capabilites. The value of this program is demonstrated in the variations which are available for the presentation of the results. The outcome of analysis can be presented in tables and in a bewildering variety of graphs, it even does a number of non standard forms and can provide curve matching. Statview 512+ comes with an extremely well written manual which can functionally serve as a comprehensive and comprehensible introduction to statistics. A highly recommended program.

Fullpaint is what MacPaint promised to be. It is faithful to the initial model, but includes virtually every enhancement that a graphics user could want. The palettes of patterns and tools can be hidden, the full screen can be used, and the addition of the free rotate, skew, perspective and distortion tools has increased the value of this program for the generation of graphic images. Most of the images used in this issue of the Review, after being scanned, have been through the Fullpaint process for cleaning up and final form modifications. The only program which is likely to prove better than Fullpaint will be SuperPaint from Silicon Beach - a program that I have not yet had the opportunity of testing. In the meantime, Fullpaint is an outstanding graphics program.

ReadySetGo 3.0 is, like its competitor Pagemaker, a page layout program. I have over the past few weeks gotten to know ReadySetGo very thoroughly, since the journal that you hold was set up using it. RSG is a unique program that allows one to replicate the process of manual layout of pages, and while the first effort does take a substantial amount of time, succeeding sessions become progressively faster. The program works with "blocks" which may be either text or graphics, and provides a direct view of "what you see is what you get", and in a fashion that must make Pagemaker users envious, you may edit in any sized view, from the miniature full page view, to the double sized image where pixel by pixel placement is possible. In addition to text and graphics imported from any wordprocessor, MacPaint, Fullpaint, SuperPaint, or MacDraw files, the program has its own set of graphic drawing tools to place lines, scotch rules, hairlines, and outlines wherever they are wanted. The text manipulation capabilities are absolutely fantastic. Lines, words, or individual letters can be moved up or down within the line, kerned, letterspace adjusted, and the interline spaces adjusted up or down. The program also has a very good wordprocessor incorporated, as well as an 80,000 word spelling checker, and an extremely advanced hypenation engine. This last has been allowed to operate throughout the course of laying out this issue, those readers who find hyphenation errors are asked to advise me, and a hyphenation exception table will be created for the next issue. As you can tell, I am thoroughly happy with ReadySetGo 3.0.

Finally for this edition, **Cricketgraph** is perhaps the finest graphing package currently available. It can be fed with data from other programs, or the data may be directly typed into the datafile, and then the user is faced with the task of choosing which type of graph to generate out of over 100 different forms. The program runs very fast, and while it is not a statistics package, it does have the capacity to provide simple statistics, as well as something which I have not seen anywhere else, the capability of fitting curves to the data at up to sixth order levels AND to provide the formula for the curve. The program also has the capacity to produce plots and graphs in colour on either Hewlett-Packard compatible plotters or on the Imagewriter II using a four colour ribbon.

The Macintosh, in spite of its advanced operating system user interface with Windows, Icons, Mouse, and Pointers, is no longer a WIMP with all of these software packages to choose from!

ERRATA:

The editor wishes to make his most sincere apologies to those individuals who have been subjected to the indignities of errata in their publications printed in the last two volumes of the CRPA/RCAP. The editor apologizes to **Dr Michael W. Spence** for the error in his name on the back cover and in the table of contents of Volume 5. Unfortunately, he was not in a position to make the final corrections necessary to erase these, and indeed was himself the victim of one gremlin which added a second 't' to his name in Volume 4.

The only other item of errata reported to the editor occured in the Abstract Volume which was sent as supplement to Volume 4. On page 4, twenty words were inadvertently dropped from the abstract of Dr Gary Heathcote. The corrected version follows with the missing section in boldface.

A cross-sectional study of age-dependent dimensional variation among 187 adult male crania from Alaska, the Mackenzie delta, and southern Ontario found that 13 variates, out of 80, displayed significant age-regression. All but three of these are measurements of or to the facial skeleton. The fact that significant age-related decreases, as well as increases, were found, challenges the conventional wisdom that continued growth of the craniofacial skeleton is simply the outcome of **ectocranial apposition and endocranial resorption. My findings suggest that continued growth in the facial region may be the outcome of** more complex remodeling processes, involving regionally differential deposition and resorption on the cortical surfaces. While this suggestion may be pushing interpretations too far, the fact that so many statistically significant age changes were found makes a strong case for human osteologists testing for age "noise" in comparative craniometric studies.

STYLE MANUAL
FOR
THE CANADIAN REVIEW OF PHYSICAL ANTHROPOLOGY
REVUE CANADIENNE D'ANTHROPOLOGIE PHYSIQUE

Manuscripts should be prepared according to the stylistic rules of the AJPA with the following additions:

1) Charts, figures, and illustrations should be presented **as photographic plates and be of final finished size** in dimensions of either 7.5 or 16 cm wide by 8, 12, 18 or 24 cm high.

2) Tables should not be provided in final form **unless** being submitted as a Macintosh file (see below).

3) Typed texts should be submitted in IBM Selectric **Courier 10** typeface. ***This is especially relevant to items not available on a compatible computer textfile, in order that they comply with the needs of our optical scanner.*** **It is also requested that underlining NOT be used, but that square brackets [ ] be placed around words to be underlined or italicized.**

4) **If** possible, submission of final copy is requested to be on 5.25" **IBM** diskettes in either formatted MS Word files or **unformatted, plain ASCII textfiles**, or on 3.5" **Macintosh** disks in MS Word or MacWrite files. (We have the capability to transfer files from IBM and Zenith CP/M-86 single and double sided formats as well.)

5) **Abstracts in both French and English** must be supplied by the author(s), and should be **no more than 400 words in length**.

6) The authors are expected to supply **up to six appropriate keywords** in both languages.

7) The format for the reference list is as follows:

Author's last name, initials, [second and succeeding author name, initials] and [final author name, initials]
Year of publication [tab] Title of paper, book or monograph. Journal name or publisher and location. Volume number [colon] [inclusive page numbers]

In the case of edited volumes, the title is followed by - [*In*] Editor's name, initials (ed.): volume title, publisher and location, [inclusive page numbers].

If in doubt consult the format used in this issue of the Review.

Rest assured that we will do everything we can to help you prepare your submissions, and will make available to anyone interested as much expertise as we can supply.

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