Tracy Rogers,[1] M.A. and Shelley Saunders,[2] Ph.D.

Accuracy of Sex Determination Using Morphological Traits of the Human Pelvis

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ABSTRACT: This study assesses the accuracy and reliability of 17 individual morphological traits of the pelvis frequently used to determine the sex of human skeletal remains. A sample of 49 right and left adult hip bones and sacra of documented individuals were available from an historic church cemetery dating from the 19th century. A hypothetical ranking of the accuracy of traits was drawn from the literature. Next, individual traits were evaluated for precision and accuracy of observations, and combinations of two and three traits were evaluated for their collective effectiveness as sex indicators. The effect of age on the accuracy of traits for sex determination was also examined. Precision of traits was generally good. Several combinations of three criteria produced higher levels of accuracy than the trait list as a whole. A total of six traits was judged to be most effective as sex discriminators because of low intraobserver error levels and better than 83% accuracy rates. There was no indication of an age effect on the precision or accuracy of these traits although sample sizes are small.

KEYWORDS: physical anthropology, human identification, pelvis

Methods of determining the sex of an individual based upon skeletal remains can be broadly divided into two groups: morphological or "subjective" observations; and metric or "objective" techniques. Researchers prefering the former approach argue that metric analyses usually require better preservation of the skeleton, they may use ill-defined landmarks or vague definitions of procedures and measurements that have an inherently limited descriptive ability [*1–3*]. Furthermore, the discriminatory power of existing mathematical functions of sex determination, such as those developed by Giles and Elliot [*4*], may be limited in series where the pattern of sexual dimorphism does not mimic that of the original sample [*5,6*].

Researchers favoring metric techniques believe that they produce fewer indeterminate cases, broaden the range of bones that may be used to determine sex, are easier to teach, and are more reliable than morphological assessments [*4,7–12*]. Metric methods of sex determination more readily lend themselves to statistical testing and data manipulation and have more frequently been the subject of systematic analyses of accuracy and precision [*6,13*]. Until recently the choice of specific pelvic morphological features for use as sex discriminators has been largely a matter of experience and preference [*14,15*]. With the exception of the Phenice [*16*] method [*17,18*], the preauricular sulcus [*19,20*] and dorsal

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[1] Department of Archaeology, Simon Fraser University, Burnaby, B. C., Canada.
[2] Professor, Department of Anthropology, McMaster University Hamilton, Ontario, Canada.

pubic pitting [21–23], few tests of accuracy and reliability have been conducted on individual morphological features of the pelvis commonly attributed to sexual differentiation.

The purpose of this report is to assess the accuracy and reliability of 17 individual morphological traits of the pelvis frequently used to determine the sex of human skeletal remains. Both accuracy of the traits in determining sex and intraobserver error or precision of recording are evaluated.

Consideration is also given to the possibility that the morphological approach produces a bias in favor of one sex, and the direction of this bias is examined. It has been suggested that the female pelvis shows limited variability due to the combined functional requirements of childbirth and locomotion [1]. Thus, we would expect greater misclassification of male skeletons and female bias. However, Tague [24] observes that the measured size and shape of the male true pelvis is not more variable than the female pelvis and suggests that it may be the visual clues employed by researchers that exhibit greater variation in male skeletons [24]. Despite these arguments, most skeletal pelvic traits depend upon the differential growth of the female pelvis for their expression suggesting that borderline cases will be classified as male due to lack of evidence for alteration. Consequently, in this study it was hypothesized that bias would be in favor of males.

Materials and Methods

The sample consists of both right and left hip bones and sacra, when available, of 49 adult skeletons from a 19th century cemetery located on the grounds of the St. Thomas Anglican Church in Belleville, Canada. A total of 577 intact skeletons excavated from the cemetery in 1989 represents 37% of all individuals (1564) interred there over a 53 year period from 1821 to 1874 [25,26]. A subsample of 49 adults with intact pelves were personally identified on the basis of legible coffin plates recovered from the graves. The names on these coffin plates were also checked against the parish registers or lists of interments recorded by the church's ministers during the cemetery's use.

A battery of 17 morphological traits (Table 1) reported in the literature was examined and treated individually. In addition, a hypothetical ranking of the accuracy of pelvic traits was produced (Table 2) by recourse to the literature [13,24,27,28,29]. Pairs of hip bones were studied individually and observations were taken in succession as listed on the data recording sheet. Features were assessed as either male, female or indeterminate. The close spacial proximity of traits prevented their complete visual separation by shielding, but every effort was made to consider each trait separately so as not to bias remaining observations.

Evaluation of precision consisted of calculating the percentage of cases for each trait that underwent a reversal in sex assignment between trial one and trial two of an intraobserver error sample. The accuracy of sex determination of the individual traits was evaluated by comparing trait sex assignments to the known sex of the documented individuals. The usefulness of traits was ranked according to a combination of least amount of intraobserver error and greatest accuracy.

In an effort to assess the effects of age on accuracy, the documented sample was divided into three adult age categories, and Fisher's exact probability tests were run for each trait by age. Blocks of traits were also analyzed for their collective effectiveness as sex indicators by calculating two by two tables, controling for documented sex, of all possible combinations of criteria. The probability of achieving a correct sex assignment was calculated by dividing the number of correct sex estimates (when compared to documented sex) by the total number of estimates. For example, when the ventral arc and the true pelvis are used in combination, the probability of estimating "male" when the individual was in fact male was 23/23 or 1 (P[m/male] = 23/23 = 1.0). The number 23 represents the sample size of male pelves for which both traits could be observed. The probability of estimating "female" when the actual sex was female was 9/10 or .9 (P[f/female] = 9/10 = 0.90). In this case,

TABLE 1—*List of morphological pelvic traits chosen for examination.*

Pubic bone	Male Expression	Female Expression
1. Subpubic concavity angle	V-shaped	U-shaped
2. Ischiopubic ramus ridge	Ridge absent	ridge present
3. Ventral arc presence	Arc absent	arc present
4. Shape of pubic bone	Narrow	broad & rectangular
5. Dorsal pubic pitting	Absent	present
Ilium		
6. Sciatic notch shape and size	Small, close, deep	wide, shallow
7. Auricular surface height	Not raised	raised
8. Preauricular sulcus presence and shape	Absent or thin grooves	large, circular depressions
9. Ilium shape	High, vertical	laterally divergent
Overall Pelvis		
10. Pelvic inlet shape	Heart-shaped	elliptical
11. True pelvis size and shape	Small	shallow and spacious
12. Obturator foramen shape	Large, ovoid	small, triangular
13. Acetablum size and orientation	Large, directed laterally	small, directed antero-laterally
14. Development of muscle markings	Marked, rugged	gracile, smooth
Sacrum		
15. Sacrum shape	Long, narrow	short, broad
16. Number of segments	5+	5
17. Posterior view of sacrum, visibility of sacroiliac joints	Visible	not visible

of 10 observable cases, 9 were correctly assessed female and one was assessed indeterminate. The probability of making no decision (perhaps one criterion suggested "male," the other "female" or both were "indeterminate") when the individual was actually female was 0.10 or .1 (P[?/female} = 1/10 = .1). The total number of estimates available for male or female cases varied with the preservation of those traits on observed hip bones.

TABLE 2—*Hypothetical ranking of morphological pelvic traits based on published literature.*

		References
Most effective	True pelvis shape Length of pubis Subpubic concavity Ventral arc	Coleman, 1969 St. Hoyme, 1984
Second	Auricular surface height Sciatic notch Sacrum shape	St. Hoyme, 1984 St. Hoyme & İşcan, 1989
Third	Preauricular sulcus Dorsal pitting	St. Hoyme, 1984 Tague, 1988
Fourth	Ischiopubic ramus Ilium shape	Coleman, 1969
Fifth	Pelvic inlet Sciatic notch	Coleman, 1969
Least effective	Acetabulum Obturator foramen Muscle markings Sacrum shape Posterior view of the sacrum	Coleman, 1969 St. Hoyme, 1984

Therefore, the probability of a correct answer was the probability of estimating male when the case was male plus the probability of estimating female when the case was female, divided by two ({P{m/male] + P[f/female]}/2). In the example, the probability of making a correct estimate was 0.95 ([1.0 + 0.90]/2), and the probability of indeterminate cases was 0.05 ([0.10 + 0]/2). If errors occurred, the probability of error was calculated in the same manner, P[error/male] = no. of errors/no. of cases, P[error/female] = no. of errors/ no. of cases, P[error for the trait overall] = (P[error/male] + P[error/female])/2). Since the original method of analysis (each criterion having equal weight with the majority decision defining the sex) produced an accuracy level of 95.9%, combinations of traits which generated probabilities under 0.95 would be less effective than using all traits and are not, therefore, presented in this study. Table 3 lists the expected probabilities equal to or greater than 0.95 for combinations of two traits.

In order to assess any evidence for the presence and direction of bias, the total number of sex assignments for individuals, including both assessments for those examined in the intraobserver error study, was compared to documented sex based on coffin plates and parish records. The number of errors made and the direction of error were recorded.

Results

The overall degree of intraobserver error for all pelvic traits in combination was 11.3%, a value slightly higher than the acceptable level of 10% [*30*], suggesting that some features are difficult to observe. Intraobserver error by trait identified four problematic criteria: acetabulum size and shape (11.2%); auricular surface height (11.3%); preauricular sulcus (11.3%) and ischiopubic ramus shape (11.3%). The remaining traits ranged from no error to 9.7% (Table 4).

The results of the accuracy tests for individual traits (their ability to correctly identify sex) are shown in Table 5. The overall rankings of each trait, taking into consideration both degree of intraobserver error and level of accuracy, are shown in Table 6.

Results of the tests for differences in accuracy of each trait by age category are presented in Table 7. Only the accuracy of the observations made on the posterior view of the sacrum increased significantly with age.

The accuracy tests of all possible combinations of two criteria and combinations of three criteria revealed that the highest degree of accuracy could be obtained by examining the obturator foramen and the ventral arc in combination (98%) or the obturator foramen and the true pelvis shape (requires both hip bones) in combination (98%). The combinations

TABLE 3—*Probability of estimating sex correctly for combinations of two traits.*

Combination	Probability Correct	Probability No decision	Probability Error
Obturator foramen/Ventral arc	$P = .98$	$P = .02$	$P = 0.0$
Obturator foramen/True pelvis	$P = .98$	$P = .02$	$P = 0.0$
Pubis shape/Acetabulum	$P = .96$	$P = 0.0$	$P = .04$
Ventral arc/True pelvis	$P = .95$	$P = .05$	$P = 0.0$
Obturator foramen/Ilium shape	$P = .95$	$P = .05$	$P = 0.0$
Sacrum shape/Subpubic concavity	$P = .95$	$P = 0.0$	$P = .05$
True pelvis/Subpubic concavity	$P = .95$	$P = 0.0$	$P = .05$
Sacrum shape/Acetabulum	$P = .95$	$P = 0.0$	$P = .05$
Sacrum shape/Ventral arc	$P = .95$	$P = 0.0$	$P = .05$
Sacrum shape/Pubis shape	$P = .95$	P = 0.0	$P = .05$
Acetabulum/True pelvis	$P = .95$	$P = 0.0$	$P = .05$

TABLE 4—*Percentage of cases, for each trait, that underwent a reversal in sex assignment between trial one and trial two.*

Trait	Intraobserver Error
Ventral arc	0
Muscle markings	0
Dorsal pitting	0
True pelvis	0
No. sacral segments	3.2%
Obturator foramen	3.2%
Posterior view of sacrum	3.2%
Subpubic concavity	3.2%
Pubis shape	4.8%
Ilium shape	6.4%
Sacrum shape	6.4%
Sciatic notch	6.5%
Pelvic inlet	9.7%
Acetabulum	11.2%
Auricular surface	11.3%
Preauricular sulcus	11.3%
Ischiopubic ramus	11.3%

of two or three traits producing an accuracy of greater than 95% are presented in Tables 3 and 8.

Lastly, the search for bias in favor of one sex or another by examination of sex assignments compared to known sex yielded the following results. Using all pelvic traits, 72 assignments of sex, including retests, were verified through comparison to coffin plates and parish burial records. Only two incorrect assignments were made. One of these was a female aged 22 years and three months. This individual was assessed twice. The initial results indicated that the bone specimen belonged to a female, the second suggested male. The second incorrect case was extremely fragmentary and came from a woman, aged 46 years, who was incorrectly assigned as male.

TABLE 5—*Accuracy levels for each individual pelvic trait.*

Trait	N	% Correct	% Wrong	% Indeterminate	Rank
Sacrum shape	34	94.1	2.9	3.0	1
Obturator Foramen	32	93.8	6.2	0	2
Acetabulum	48	91.7	6.3	2.0	3
Preauricular sulcus	48	91.6	8.4	0	4
Ventral arc	38	86.9	0	13.1	5
Pubis shape	36	86.2	2.8	11.0	6
True pelvis	35	85.8	0	14.2	7
Sciatic notch	49	85.7	6.1	8.2	8
Subpubic concavity	37	83.8	5.4	10.8	9
Ilium shape	43	83.7	2.3	14.0	10
Ischiopubic ramus	40	80.0	5.0	15.0	11
Pelvic inlet	45	80.0	6.6	13.4	11
Auricular surface	49	73.5	14.2	12.3	13
Sacrum (post. view)	43	65.2	34.8	0	14
Muscle markings	44	56.8	2.3	40.9	15
Dorsal pitting	28	35.7	0	64.3	16
# sacral segments	33	6.1	0	93.9	17

TABLE 6—*The effectiveness ranking of pelvic traits.*

Trait	Accuracy rank	Precision rank	Total	Overall rank
Ventral arc	5	1	6	1
Obturator for.	2	5	7	2
True pelvis	7	1	8	3
Sacrum shape	1	10	11	4
Subpubic conc.	9	5	14	5
Pubis shape	6	9	15	6
Muscle markings	15	1	16	7
Dorsal pitting	16	1	17	8
Acetabulum	3	14	17	8
Preauricular sulcus	4	15	19	10
Sacrum (post. view)	14	5	19	10
Sciatic notch	8	12	20	12
Ilium shape	10	10	20	12
# sacral segments	17	5	22	14
Pelvic inlet	11	13	24	15
Ischiopubic ramus	11	15	26	16
Auricular surface	13	15	28	17

Discussion

The intraobserver error test revealed that only four traits exceed the acceptable error level or lack of precision of 10%. When considered individually, the degree of additional error is minimal (just over 1%). However, the combined impact of these criteria could significantly affect the outcome of a skeletal sex analysis, especially if the material was fragmentary and these difficult features were among the few traits still observable. It is therefore recommended that all criteria exceeding the 10% critical level of intraobserver error be excluded from future analyses.

TABLE 7—*The accuracy of each trait by age category.*

Feature	*n*	<25	*n*	25–44	*n*	45+
Subpubic conc.	7	85.8%	10	80.0%	16	81.3%
Ischiopubic ramus	7	57.2%	11	81.8%	18	83.3%
Ventral arc	7	71.5%	10	90.0%	17	94.1%
Pubis shape	6	83.3%	10	80.0%	16	87.5%
Dorsal pitting	6	50.0%	8	37.5%	11	36.4%
Sciatic notch	8	87.5%	11	81.9%	26	84.7%
Auricular surface	8	87.5%	11	63.7%	26	73.1%
Preauricular sulcus	7	85.8%	11	100.0%	26	88.5%
Ilium shape	8	62.5%	10	100.0%	21	85.7%
Pelvic inlet	8	75.0%	10	100.0%	23	73.9%
True pelvis	8	75.0%	7	100.0%	16	87.5%
Obturator foramen	7	100.0%	8	87.5%	14	100.0%
Acetabulum	8	87.5%	11	100.0%	25	88.0%
Muscle markings	7	42.9%	11	63.7%	22	58.9%
Sacrum	6	66.6%	9	100.0%	15	100.0%
No. sacral segments	6	16.7%	7	0.0%	16	6.3%
Post. view sacrum	8	25.0%	10	70.0%	21	71.5%[a]

[a]Statistically significant by Fisher's Exact Test.

TABLE 8—*Probability of estimating sex correctly combinations of three traits.*

Combination	Probability Correct	Probability No Decision	Probability Error
Pubis shape/Subpubic c/Acetabulum	$P = .96$	$P = 0.0$	$P = .04$
Pubis shape/Vent arc/Acetabulum	$P = .96$	$P = 0.0$	$P = .04$
Obt for/Subpubic c/True pelvis	$P = .95$	$P = .05$	$P = 0.0$
Obt for/Vent arc/Acetabulum	$P = .95$	$P = .05$	$P = 0.0$
Obt for/Vent arc/Pubis shape	$P = .95$	$P = .05$	$P = 0.0$
Vent arc/Subpubic c/Sacrum shape	$P = .95$	$P = 0.0$	$P = .05$
Vent arc/Subpubic c/True pelvis	$P = .95$	$P = 0.0$	$P = .05$
Pubis shape/Subpubic c/Sacrum shape	$P = .95$	$P = 0.0$	$P = .05$
Acetabulum/Subpubic c/Sacrum shape	$P = .95$	$P = 0.0$	$P = .05$
True pelvis/Subpubic c/Sacrum shape	$P = .95$	$P = 0.0$	$P = .05$
Pubis shape/Subpubic c/True pelvis	$P = .95$	$P = 0.0$	$P = .05$
Acetabulum/Subpubic c/True pelvis	$P = .95$	$P = 0.0$	$P = .05$
Acetabulum/Vent arc/Sacrum shape	$P = .95$	$P = 0.0$	$P = .05$
Pubis shape/Vent arc/Sacrum shape	$P = .95$	$P = 0.0$	$P = .05$
Pubis shape/Acetabulum/Sacrum shape	$P = .95$	$P = 0.0$	$P = .05$

While most of the criteria examined in this study were subjective, some were more subjective than others. Gauging acetabulum size visually, for example, may be preferable to measurement in that it is quicker. However, this study indicates that facility comes at the expense of precision. Similarly, even though this study utilized established descriptions of the difference between male and female-like manifestations of the preauricular sulcus to evaluate this trait, varying degrees of resorption were observed [*31*], making the interpretation difficult. Some overlap between the male and female features of the ischiopubic ramus does occur, and the results of other investigators [*16,32*] suggest that this particular trait is unreliable.

No single pelvic feature produced better results than those generated by the complete trait list (95.9%). The most accurate single indicator was sacrum shape (94.1%). On the other hand, three combinations of pelvic criteria produced higher levels of accuracy than the trait list as a whole: obturator foramen shape and presence of the ventral arc (98%); obturator foramen shape and true pelvis shape (98%); pubis shape and acetabulum shape and size (96%). Since acetabulum shape and size exhibited low precision, the first two combinations are considered more reliable. While combinations of three traits could equal and even slightly surpass the accuracy of the complete trait list, none could produce results superior to the obturator foramen/ventral arc and obturator foramen/true pelvis shape combinations of two traits. This is not entirely surprising since the first three criteria, ranked by a combination of highest accuracy and greatest precision are: ventral arc, obturator foramen and true pelvis shape (Table 5). Combining these three features does not increase accuracy above that obtained by the two combinations involving the obturator foramen. The ventral arc/true pelvis combination (95% accuracy), while an increase over the individual accuracies (86.9% and 85.8%, respectively) is not as useful as the combinations involving the obturator foramen. This suggests that true pelvis shape and the ventral arc are contributing similar information.

When this analysis is compared to that of Sutherland and Suchey [*32*] and McLaughlin and Bruce [*33*], it becomes evident that there is a certain degree of variability in the levels of accuracy that may be achieved by different researchers employing the same criteria on different populations. Therefore, despite the fact that this investigation discovered that the greatest accuracy for the pelvis was achieved by combining the results of only two traits, we do not advise researchers to focus solely on these features when assessing the sex of an individual from the skeleton. At the other extreme, the complete pelvic trait list produced an accuracy of 95.9% and had an unacceptably high level of intraobserver error (11.3%). Thus, it would appear that the best results, and likely the most widely applicable results, could be obtained by employing some subset of all criteria. A review of the individual levels of accuracy (Table 5) indicates that some features produce results only slightly better than those expected by chance and, as indicated previously, other traits have low precision (Table 4) such that they should be excluded from analyses. Table 6 ranks the pelvic criteria according to both high accuracy and precision. The first six traits (ventral arc, obturator foramen, true pelvis shape, sacrum shape, subpubic concavity and pubis shape) all have intraobserver error levels below 5% and are capable of successfully assigning sex in over 83% of cases. Thus, these features are most highly recommended for use in determining sex from the bony pelvis. In cases of indecision, the results of this study indicate that emphasis should be placed on the obturator foramen/ventral arc and obturator foramen/ true pelvis shape combinations.

It was discovered that, contrary to St. Hoyme [*28*] but in keeping with St. Hoyme and İşcan [*13*], anterior features of the pelvis were more useful in correctly assigning sex than were posterior features (three of the anterior features are in the top five of ranked traits). In contrast to the observations of Tague [*31*], the preauricular sulcus scored very high on accuracy (91.6%) but due to low precision (11.3%) (intraobserver error) it placed 10th overall. This was one of the higher ranking traits for features of the posterior pelvis. Tague's [*31*] assessment of the inaccuracy of dorsal pitting was upheld in this study (35.7% correct), although the precision of this feature was excellent (0% intraobserver error). So while it may be easy to assess dorsal pitting this trait is not a particularly useful criterion for determining sex.

St. Hoyme [*28*]) appears to have been correct about the importance of the sacrum in skeletal sex determination. Coleman's [*27*] assertion that there is no difference in the growth of the male and female sacrum is questionable in light of its capacity to show sex-related characteristics. However, Coleman's [*27*] claim that features dependent upon two functional divisions (the false and true pelvis) are less sexually dimorphic than those dependent upon only one was borne out by this study. Both the sciatic notch (accuracy = 85.7%) and the pelvic inlet (accuracy = 80%) exhibited relatively low levels of accuracy and poor precision (6.5% and 9.7% intraobserver error, respectively.).

Although Coleman [*27*] noted no evidence of significant sexual differentiation in growth of the acetabulum, this feature can be extremely accurate (91.7%) but it is difficult to assess (11.2% intraobserver error) indicating that if a researcher chooses to include acetabulum size in an analysis, it should be evaluated metrically. The time saved through a morphological assessment of this feature cannot compensate for the low precision which results.

St. Hoyme [*28*] indicated that the obturator foramen was of little value as a sex indicator, yet, in this study it ranked 2nd overall (Table 6). In contrast, the development of muscle markings proved to be ineffectual (56.8% accuracy), although they were observed consistently (0% intraobserver error). This suggests that they may contribute to a general impression of the true sex, but on their own, these features produce results only slightly better than that expected by chance alone.

This investigation reproduced the original rankings of the Phenice criteria for sex determination [*16*]. When precision and accuracy are combined, the ventral arc ranks first (accuracy 86.9%, intraobserver error 0%); subpubic concavity second with an overall rank of 5 (accuracy 83.8%, intraobserver error 3.2%); and the ischiopubic ramus third with an overall rank of 16 (accuracy 80%, intraobserver error 11.3%). This study differs from Phenice [*16*] with regard to the accuracy that may be achieved by combining the three features. Phenice observed 96% accuracy for the combined criteria, whereas this analysis managed to obtain only 88% accuracy. This is still higher than the average results reported by Lovell [*18*], 83% accuracy using 50 hip bones, and by McLaughlin and Bruce [*33*], 70% accuracy using 273 skeletons.

It has been proposed that some features, such as the ventral arc, do not become distinctive until the third decade [*32*] while others, such as the subpubic concavity, the preauricular sulcus and dorsal pitting lose their characteristic appearance with age [*20,24*]. There was no statistically significant difference between the levels of accuracy achieved in any of the three age categories of this sample, despite a perceived pattern which suggests that estimated sex is most accurate for the 25 to 44 year category. The sample sizes of age cohorts are relatively small in this study. The investigation of the effects of age on morphological features would benefit from further research.

Similarly, despite the apparent age-related increase in accuracy of four of the traits a Fisher's Exact probability test indicates that this pattern is significant only in the case of the posterior view of the sacrum ($P = 0.031$). The observed decrease in accuracy with age of the subpubic concavity and dorsal pitting are likewise not significant.

With regard to the question of bias in morphological sex determination from the pelvis, this study produced only two errors of misclassification when sex assignment based on morphological traits was compared to documented sex. While it is encouraging that the number of errors was low, their infrequency precludes judgment about the occurrence of bias of sex assignment. However, for these two cases, the direction of bias is toward males as was predicted.

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Address requests for reprints or additional information to
Tracy Rogers
Dept. of Archaelogy
Simon Fraser University
Burnaby, B. C. V5A 1S6
Canada