CHAPTER III

Identification and Individualization

III. A. Rationale

The basic, but by no means only, question asked of skeletal material is "Who was this person?". Answering the question is usually done in two steps: **IDENTIFICATION** and **INDIVIDUALIZATION.** The first term is misleading and the second, obscure, and so are elaborated upon below.

Identification

Here the forensic anthropologist looks at the bones and teeth for characteristic inherited features or basic biological traits which indicate sex, age at death, race, and stature. With these determined he can narrow the range of possible persons from whom the remains derive to a small, but still numerous, subset of the whole population (for example, "a white male, 20-25 years old, 5 feet 8 inches to 6 feet 2 inches tall . . .").

To this 'police blotter' description may be added more or less accurate estimations of time elapsed since death and whether there is evidence of long distance travel of the body from some other locale (typically by water). This important information can only be obtained through careful observation of the find locale, noting contextual relationships such as distance from high water level of nearby creeks, rivers or lakes, and local environmental factors such as moisture, plant cover and insect infestation. Thus one might be able to add to the above description ". . . who died approximately

12 to 18 months ago, likely a considerable distance upstream from the find locale."

This completes the first phase of the forensic anthropologist's examination. The specialist should then provide the contributing law enforcement agency with this basic information for matching with records of missing persons. Often there will be one or two such persons who closely match the remains.

Incompatability with one of the diagnosed characteristics of the remains and that of a missing person is quite possible especially with respect to stature, less so in terms of race (but certainly if the remains were very fragmentary). Most forensic anthropologists will not mind advising the investigating officer on the relative imprecision or certainty of a particular interpretation. It is then up to the investigating officer to obtain as much premortem information of the kind likely to be preserved in hard tissues, concerning those missing persons. These premortem records can then be compared with information about the "individual" characteristics of the remains, derived from the second phase of analysis. (Chapter III.C. describes a variety of useful premortem records.)

Individualization

As is well known, no two individuals are identical, not even "identical" twins, if one looks closely enough. In terms of skeletal material, uniqueness, while not preserved to the same degree as in the whole body, is potentially there to be seen for a variety of reasons. Basic is the individuality derived from the unique combination of circumstances affecting the growing and adult human form during the individual's lifetime. For example, the minutiae of detail seen in premortem bone radiographs (x-ray pictures) have been successfully compared by specialists for matching traits in postmortem radiographs of the same bones (Fig. 12). Thus a person can acquire novel traits of the hard tissues, or modify inherited ones in sufficient number and in such combinations that they are virtually, if not absolutely, unique to that individual. The prime example of this is **DENTAL RESTORATIONS** (Gustafson 1966). A successful identification may involve several exchanges of information between the detachment and the forensic anthropologist as the list of matching missing persons is progressively reduced.

In summary, all people possess two identities: the **BIOLOGICAL IDENTITY** defined by age, sex, race and stature; and the personal

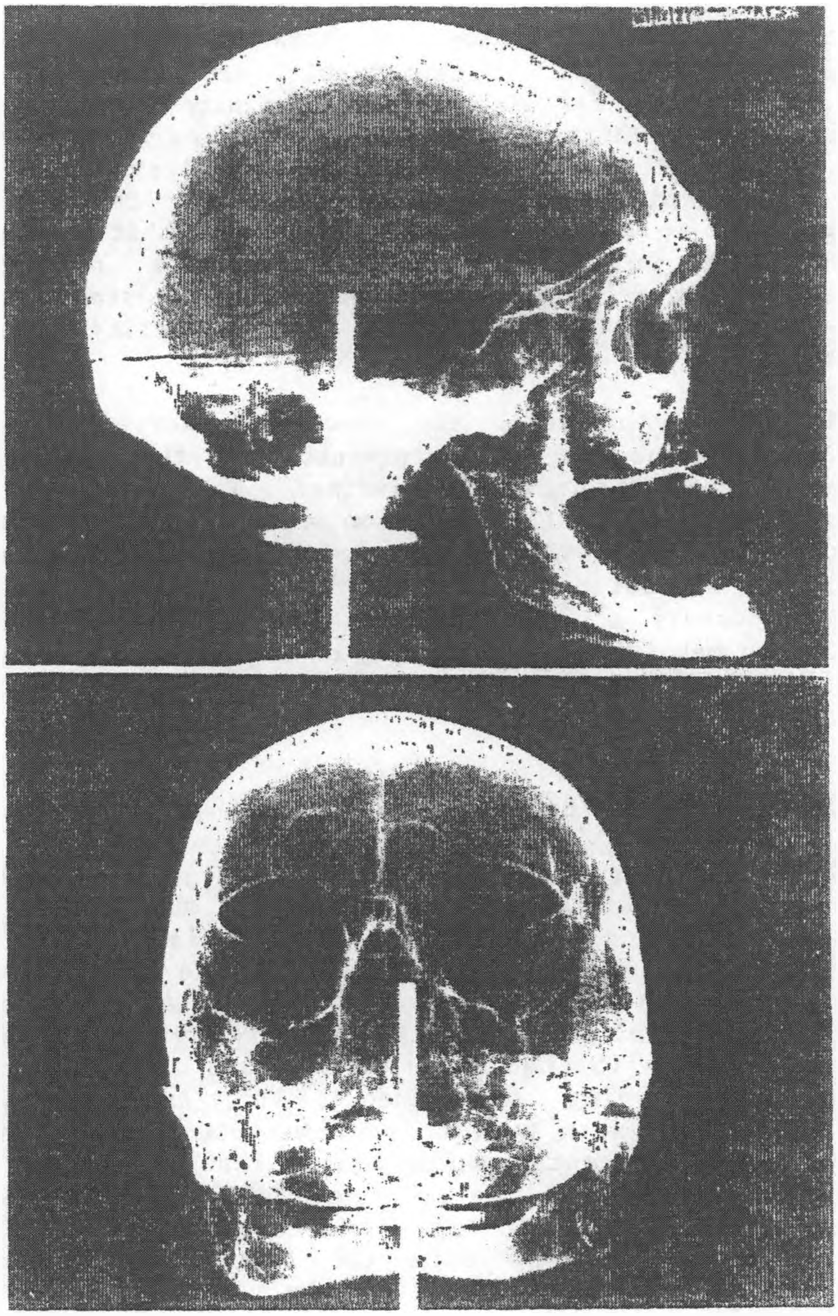

Figure 12. Radiographs showing individualizing features of the cranium: a) lateral view showing the distinctiveness of the external cranial contour, b) anterior view showing the distinctiveness of the flocculations forming the frontal sinus pattern (Case 81-29).

identity, the embodiment of which is the individual's name. In the case of **SKELETONIZED** remains or those which have been rendered visually or otherwise unidentifiable (for example, burned or mutilated), the process of identification proceeds from establishing the biological identity to determining the personal identity. The former provides the investigating officer with suggested possibilities and probabilities regarding the latter. The actual conclusion as to personal identity requires that the investigator possess some manner of premortem record or **IDIOSYNCRATIC** observation to which can be compared similar postmortem records or observations. (In the case of the **FETUS**, identity is derived from the parents.)

The methods by which the specialist derives the biological identity are necessarily determined by the completeness and condition of the recovered remains. The following discussion however, will consider the situation where the entire human skeleton is potentially retrievable. The techniques are described for two reasons: to emphasize the necessity for controlled, systematic and complete recovery of the remains, with associated materials, and secondly, to make the investigating officer appreciative of what the forensic anthropologist can and cannot do even with well-recovered remains.

III. B. Biological Identity

There are four basic aspects to biological identity -- age, sex, race, and stature. The accuracy with which these are determined reflects, firstly, the reliability of the methods employed to derive them, and secondly, the completeness of the remains. Thus the skull is less trustworthy as an indicator of sex than is the pelvis. Additionally, the reliability of a particular technique varies with changes in one or more of the basic biological characteristics being determined. For example, methods for revealing age at death tend to provide more accurate estimates for children and adolescents, while the reliability of sex and racial diagnoses increases with age to a maximum for adults. As well, age and stature are highly correlated during infancy and childhood and one can be used to estimate the other. The assumptions and limitations of each method will not be discussed in detail; rather their significance with respect to proper recovery technique is emphasized.

III. B. 1. *Age*

When dealing with unidentified remains, the forensic anthropologist cannot determine true or **CHRONOLOGIC AGE**, which is an attribute of the personal identity accorded great significance by society. Rather the specialist determines the maturational state of the remains, deriving a **PHYSIOLOGIC AGE** to which, on the assumption that the person is not abnormal but fairly typical, an equivalent chronologic age is assigned. The difference between chronologic and physiologic age increases from conception to old age, due to the interaction between the individual's genetic make-up and his or her developmental environment. However, because of this variation it is imperative that the recovery be complete so that all skeletal and dental elements which show progressive changes with increasing age can be used to derive the final estimate of age at death.

Over the years, standards of tissue maturation during growth and adulthood based on samples of normal individuals of known age have been developed. These "**NORMATIVE STANDARDS**" allow skeletal and dental material to be assigned an age with known degrees of precision. This precision varies with the tissue and region studied, for any given age group. Table 1 provides a list of suitable hard tissue criteria applicable to particular age categories in order of their reliability (1 is best, 2 is less so, etc.). Some comments regarding a few of these methods, with excavation procedures in mind, should be made.

DENTAL FORMATION (Fig. 13) provides a highly accurate age estimate up to adolescence. It is not necessary that the teeth be retained in their sockets to derive the estimate. If teeth are obviously missing (that is, if the root sockets are empty) every effort should be made to recover them. Since teeth grow from the crown to the root, the root portion on forming teeth is very fragile. The teeth of infants and **PERINATAL** remains are very small and demand a discerning examination of the matrix or place of deposition.

OSSIFICATION is the process in which bone forms directly or by replacing cartilage during growth. The skeleton is formed from **PRIMARY** and **SECONDARY** centres of ossification (Fig. 14). Primary centres grow to become the major bones of the skeleton and small isolated bones of the extremities. Secondary centres (epiphyses) form near the growing ends of major bones. Primary and secondary centres ultimately fuse together with the cessation of growth in a particular area.

The order of appearance of ossification centres and their subsequent growth changes are good indicators of age in younger children. This applies particularly to the hand and wrist region for which various standards are available. For these standards to be of use in finding the age of a skeletonized individual, it is essential

TABLE 1

Relative Accuracy of Age Indicators by Age Category

	Perinatal	Birth To Puberty	Adole[illegible]ence	Young Adult	Mid-Adult	Old Adult
Dental formation	1	1	2			
Limb bone length	2	3	3			
Ossification	3	2				
Dental eruption		4	4			
Epiphyseal fusion			1	1		
Pubic symphysis changes				2	1	
Dental attrition (wear)				3		
Dental microstructure					2	1
Bone microstructure					3	2
Degenerative changes						3
Suture closure						4

that the separate ossification centres be correctly identified. This can be most reliably done by noting the physical relationships among the centres prior to their recovery. To the inexperienced they will appear as small nodules of bone of irregular shape. Extreme care in their recovery is necessary for they can be easily overlooked.

Epiphyseal **FUSION** can be a reliable age indicator for adolescents and young adults. An epiphysis represents a secondary centre of ossification and can be found at either end of long bones, many of the hand and foot bones, the collarbone and others. Fusion is the process by which cartilage separating a major bone from an epiphysis is replaced by bone thereby "fusing" the two together.

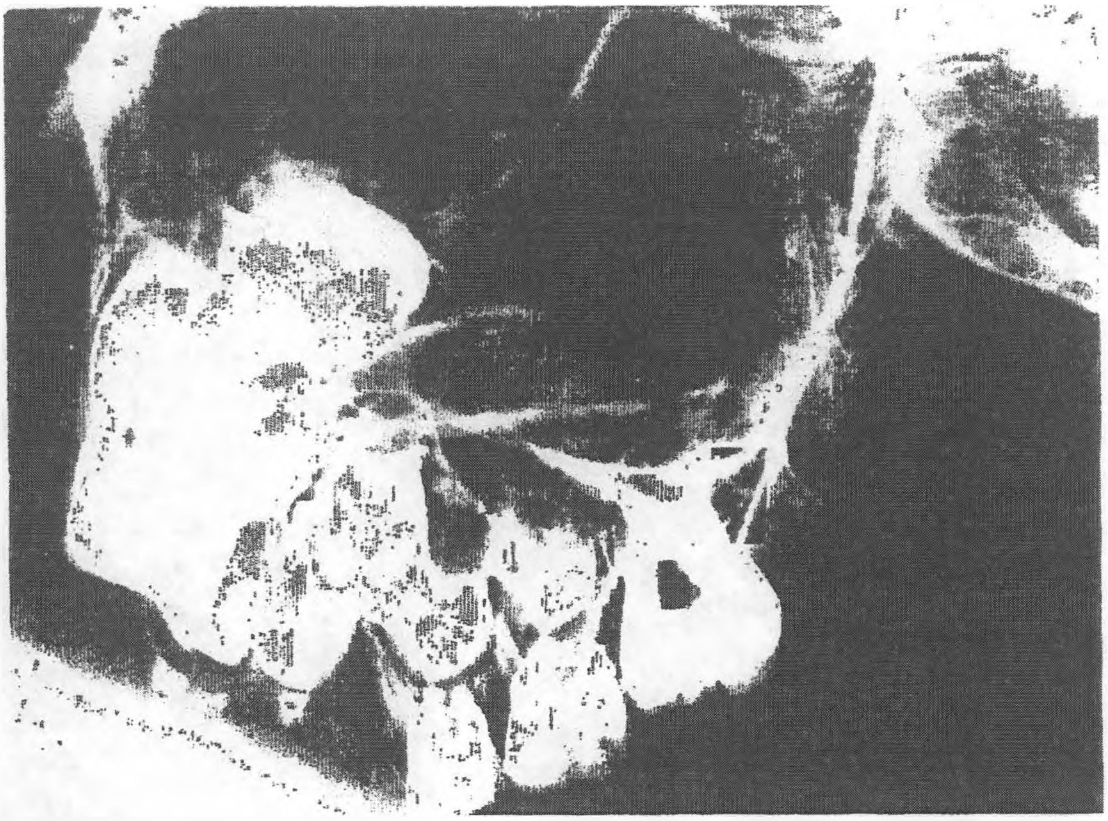

Figure 13. Lingual (tongue) view of right upper jaw. This is a child aged 5 years, 7 months showing erupted, unerupted and forming teeth -- all very useful age indicators for this age category (Case 80-2, North American native male).

Standards for finding age from epiphyseal fusion are based on the degree of fusion and therefore when excavating it is imperative that bones with epiphyses be handled with care. Rough handling can break off an epiphysis especially during the early stages of fusion.

Determining the age of adults is more difficult. Useful in males up to the age of 40 years is the progressive remodeling of the facing surfaces of the pubic bones of the pelvis where they meet in the mid-line (PUBIC SYMPHYSIS) (Stewart 1979). Another technique for determining age relies on the changes in microstructure of long bone shafts (Thompson 1979) and teeth (Maples 1978) as seen in thin-sections viewed microscopically (Fig. 15). Less reliable indeed, but nevertheless of some value in age estimation of older

Figure 14. Hand-wrist ossification in a six year old boy. Note the four carpal (wrist) centres of ossification and various unfused epiphyses.

Figure 15. Photomicrograph of cross-section from left femur. (Case 81-4, 56 year old male). Detailed are the Haversian system and other microstructural components used as age indicators: 1) Haversian system (= secondary osteon), 2) Osteon fragment, 3) Circumferential lamellar bone.

adults, are skull **SUTURE** closure (Workshop 1980) and degenerative osteoarthritic changes (Fig. 16).

Assuming the recovery of relatively complete remains, the imprecision of an age estimate increases from a matter of weeks at birth to more than a year during middle childhood; two to three years during adolescence; five to ten years in young adults and finally one to two decades in old adults.

III. B. 2. *Sex*

From the viewpoint of identification, diagnosis of the sex of the skeletal remains will substantially reduce the number of people from whom the remains might have come. An experienced forensic anthropologist can often determine sex of the remains in the field, particularly when dealing with pronounced skeletal expressions of male or female. However such immediate knowledge of sex is seldom required or warranted and a thorough laboratory analysis is recommended.

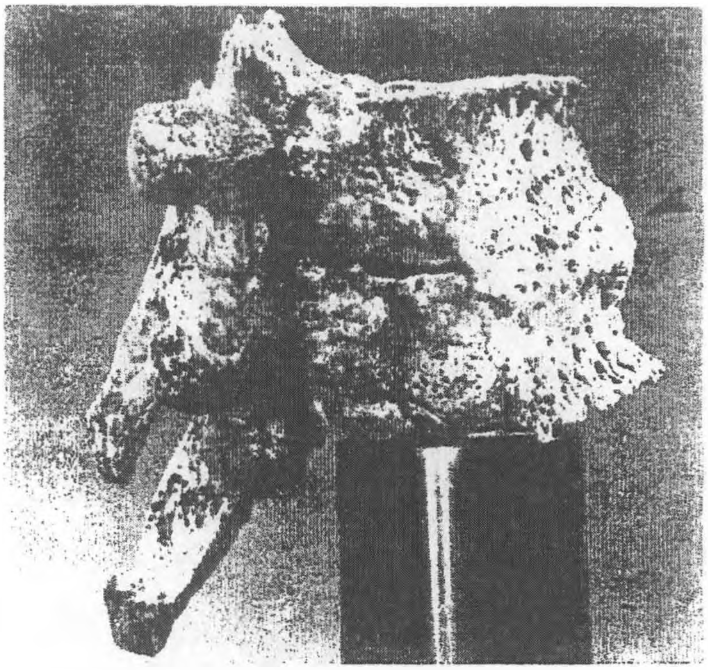

Figure 16. Advanced arthritic lipping of vertebrae. This has lead to fusion of thoracic vertebrae 8 and 9. (Case 81-4, subject medically examined for back pain some years prior to death.)

Many techniques and criteria for finding the sex of a human skeleton have been proposed. The best are those based on the pubic portion (Os pubis) of the pelvis which is modified for childbirth in mature females (Fig. 17). It is generally agreed, however, that the probability of correct sex determination from a **MORPHOLOGICAL** and/or **METRICAL ANALYSIS** of the adult (that is, post-pubescent) skull and pelvis, considered together is on the order of 95 percent. The pelvis preserves relatively poorly whether it is on the surface or buried. When only the skull or other non-pelvic skeletal elements are recovered, sex determination is less accurate and the analyst must consider how racial and idiosyncratic factors affect the degree to which sex is marked, or disguised, on the skeleton. Table 2 (after Bass 1971, Krogman 1962 and Stewart 1979) lists some of the traits used in determining the sex of the male skull, and by exclusion, the female (see also Fig. 18).

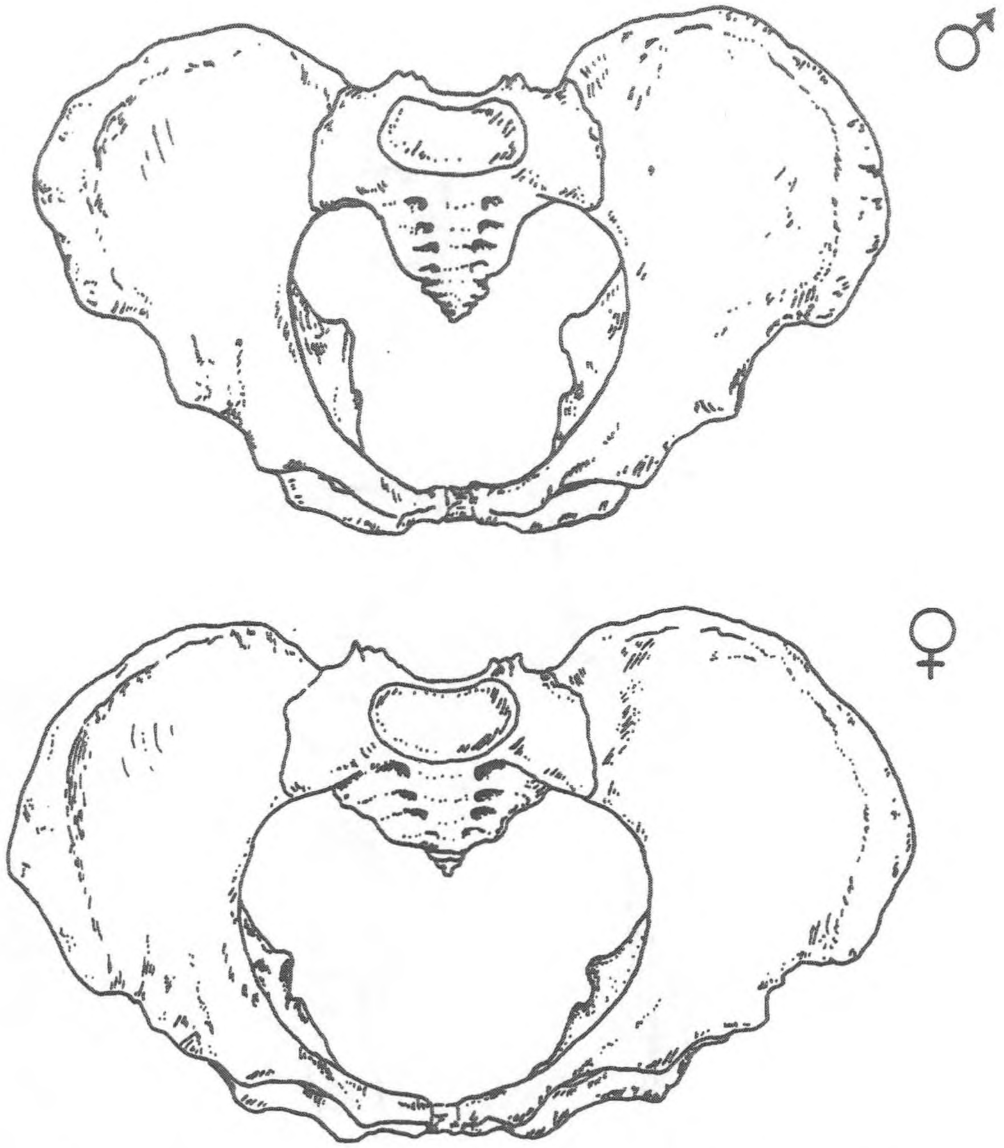

Figure 17a. Sex differences in the pelvis, superior view of pelvic girdle. Note that the pelvic opening is heart shaped in males due to encroachment by bony processes while in the female the opening is more oval and open for childbirth. (From W.M. Bass (1971), *Human Osteology*, Missouri Archaeological Society, Columbia, Missouri, used with permission of author and publisher.)

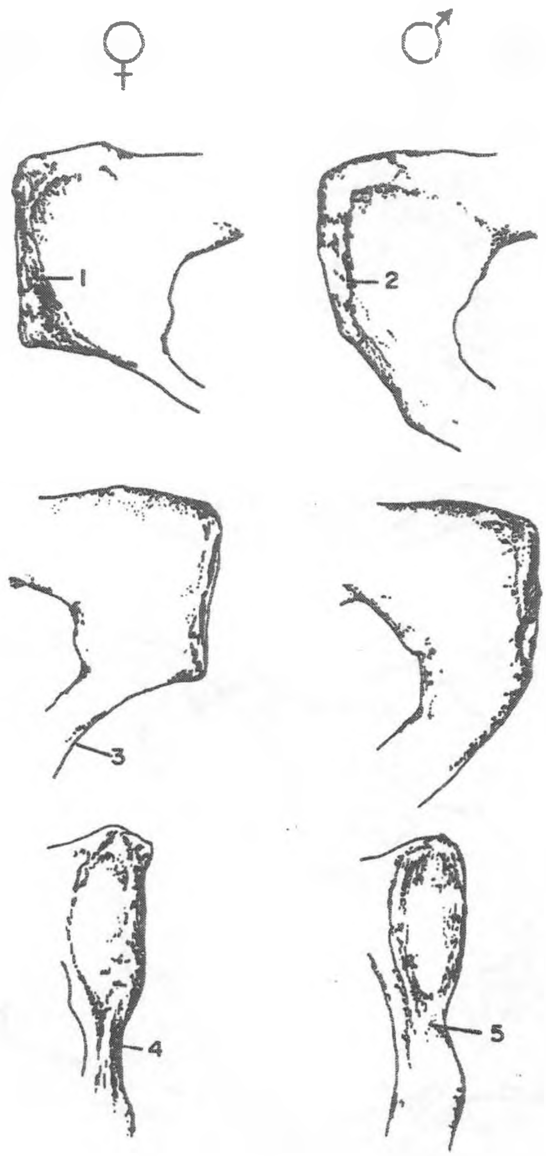

Figure 17b. Sex differences in the pubic bone. Note in the ventral view (at top) that the ventral arc in the female (1) is more distinct and directed more sideways than that of the male (2). The middle pair of figures shows the presence of a subpubic concavity in the female (3) and its absence in the male. The final pair shows that the facing surface in the mid-line below the pubic symphysis (medial aspect of ischio-pubic ramus) is thin and ridged in the female (4) but thick and rounded in the male (5). (From Phenice, T.W. (1969). A newly developed visual method of sexing the Os Pubis. *American Journal of Physical Anthropology* 30:297-302, used with permission of Alan R. Liss, Inc.).

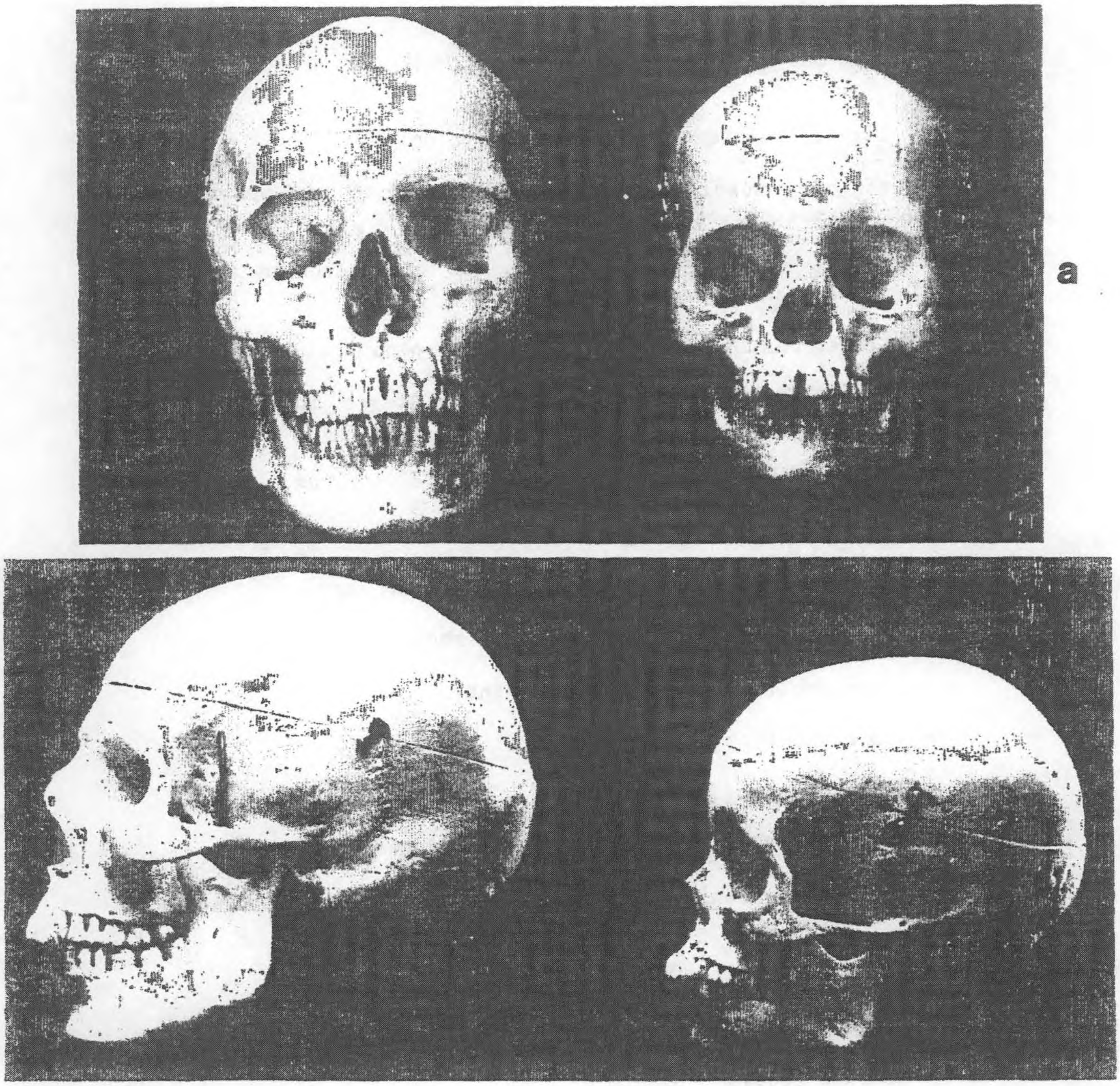

Figure 18. a) Frontal view of a male (left) and a female skull.
b) Lateral view of a male (left) and a female skull (see also Table 2). Sex differences are more marked in these specimens than is usual.

TABLE 2

Traits* of the Male Skull

CRANIUM

- larger, heavier with thicker vault walls
- rougher, muscle markings more pronounced (temporal lines, supramastoid crest, nuchal lines)
- larger cheek bones and occipital condyles (where backbone joins base of skull)
- larger mastoid process and external occipital protuberance
- foramina in skull base tend to be larger and base is more "sculptured"
- foramen magnum (between occipital condyles) more oval
- larger sinuses, teeth and palate
- orbits tend to be rectangular, less circular
- supraorbital margin rounded, not sharp
- supraorbital ridges often present
- no frontal or parietal bossing
- more receding forehead
- nasal sill is sharp, with pronounced nasal spine
- nasal root tends to be larger (not in natives or orientals)

MANDIBLE

- larger overall
- chin area squared off, perhaps double-pointed
- corpus (body) tends to be deep
- ascending portion (ramus) higher, broader
- eversion (out turning) of the angles of the jaw
- pronounced coronoid processes

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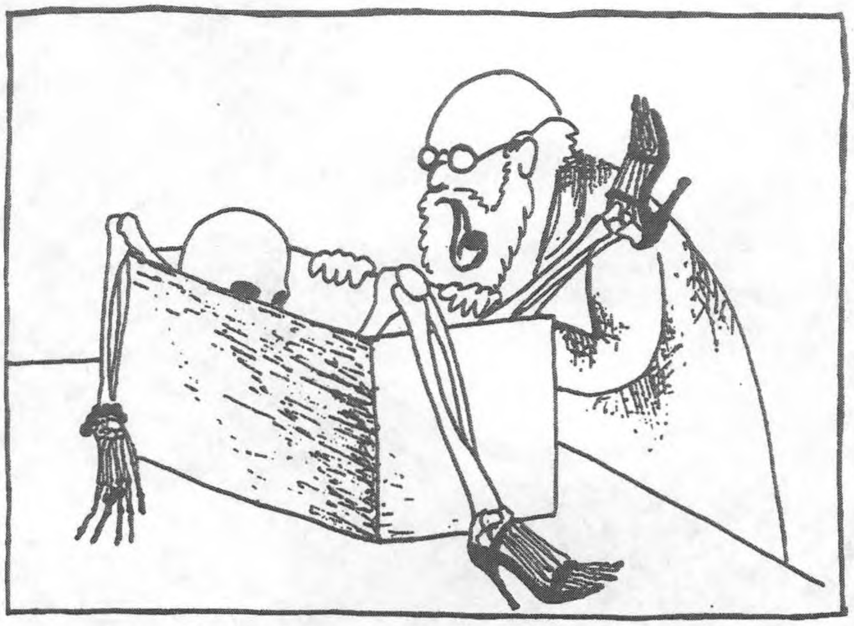
* Many of the anatomical terms used here are defined in the Glossary.

It should be mentioned that sex is not strongly expressed on the skeleton until puberty, when changing hormonal levels produce secondary sexual characteristics in the maturing skeleton.



"Hmm... sexing this is going to be a problem."

Some individuals acquire indirect skeletal indicators of sex. For example, habitual pipe smoking may produce a distinctive wear pattern on teeth or dentures. A person's occupation, for example, heavy manual labour, may leave a clue to sex on the bones in the form of strong muscle attachment areas. As well, both the investigating officer and the forensic anthropologist should look for non-skeletal indicators of sex; for instance, wedding bands and **INTRAUTERINE** contraceptives (Fig. 19).

III. B. 3. *Race*

The determination of race is a significant and justifiable pursuit when identification is sought. The subject of what constitutes a race is a large and justifiably difficult one. There are both biological and social definitions of race. For our purposes it may be sufficient to appeal to the reader's own sense of the meaning of the term noting that 'class' differences, a term sometimes used by the police as synonomous with race, is more specifically directed at expressing ethnic (cultural) differences. Thus the forensic anthropologist uses the term race in a very broad

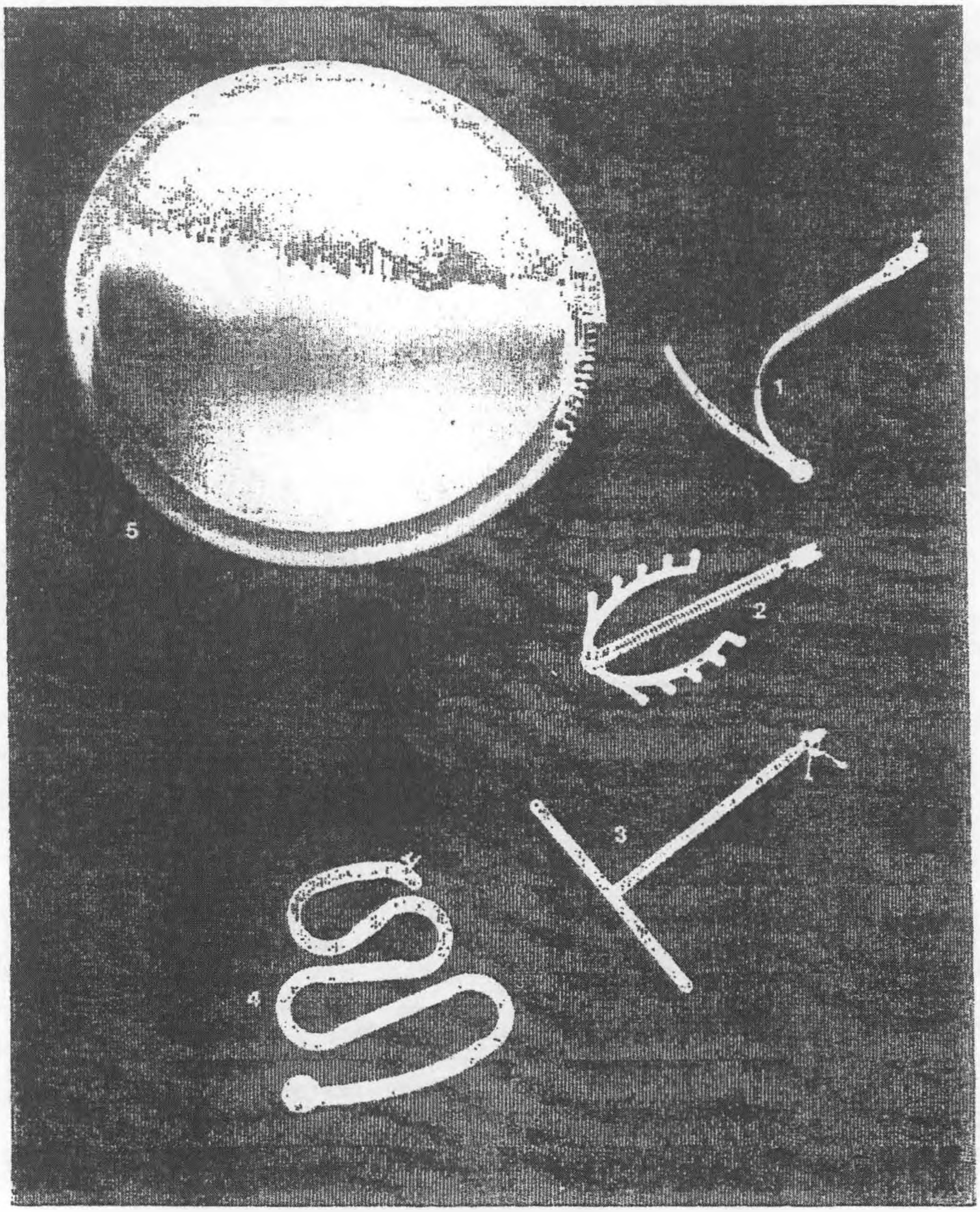


Figure 19. Sample of contraceptives used by females. Roughly 10% of females of reproductive age employ such contraceptive devices which may be preserved with skeletal remains.
Intrauterine: 1) Cu 7, 2) Multiload Cu 250, 3) Gyne-T, 4) Lippes Loop
Extrauterine: 5) Diaphragm (cut area exposes spring).

sense to differentiate what are commonly known as white, black, and yellow racial stocks. The physical differences implied by these terms are noted solely for the purposes of identifying human remains. Establishing race from the hard tissues is tenuous at best, and the excavator should always attempt to locate samples of hair and skin in areas where these tend to preserve (for example, where head and shoulder blades contact the ground, and in closed hands).

Techniques for estimating race from skeletal material are almost all based on observations and measurements of the skull and **DENTITION**. Table 3 provides a rather uncritical list of such traits for the three major racial stocks. Metrical techniques for determining race from skulls are described in Giles and Elliot (1962). Their accuracy appears to diminish when applied to Canadian Natives.

No single trait denotes race and not all traits are equally diagnostic. Few physical anthropologists would feel comfortable assigning race at a finer level than one of the three major racial stocks. The problem is compounded by racial admixture (crossing of racial stocks). Most studies of racial differences in the skeleton relate to American Blacks and Whites. Little work has been done in this area on Canadian natives, and on differentiating them from Japanese or Chinese Canadians, or even from Whites.

A few of the traits listed in Table 3 involve structures which are either very fragile (**NASAL SPINE**, cheekbones) or easily separated from the rest of the remains (upper incisors). Obviously, great care in skeletal recovery is demanded.

III. B. 4. *Stature*

Taller people owe their height in part to longer legs, which usually are associated with longer arms. Reliable estimates of stature are based on the observed relationship between the length of particular lower or upper limb bones and overall height. Standards have been derived and mathematical formulae made available which utilize the lengths of one, or preferably more, complete long bones to predict stature.

The most commonly used standards for predicting stature have been usefully summarized by Trotter in Stewart (1970). This publication provides formulae and tables describing the relationship between stature and length of each of the individual long bones from the arm and leg amongst various racial stocks and for both sexes. As well, the techniques for measuring the bones are described. The

TABLE 3

Criteria[1] of Race in the Skeleton

AREA/TRAIT	CAUCASOID Northern European derived White	NEGROID American BLACK	MONGOLOID Canadian INDIAN[2]
General Impression	rugged and ovoid	smooth and oval	smooth and rounded
Neurocranial Vault			
Length	long	long	long
Breadth	narrow	narrow	broad
Height	high	low	middle
Sagittal contour	round	flat (post-bregmatic depression)	arched
Forehead	sloping	steep	--[3]
Occipital profile	rounded	very rounded	angulated
Nuchal muscle	strong	slight, variable	moderate
Face			
Breadth	narrow	narrow	very wide
Height	high	low	high
Profile	straight	prognathic	middle
Brow	"beetling" glabella	smooth	--
Orbit	(tri)angular	rectangular	rounded
Interorbital	narrow	wider	--
Cheek bones	receding	--	broad, wide, outwardly sloping
Nasal opening	narrow and high	wide and low	narrow and high
Nasal root	deep	--	--
Nasal bones	salient	less so	very salient
Nasal spine	strong	small	--
Sub-nasal margin	sharp	guttered	sharp
Palate shape	narrow	wide	fairly wide

TABLE 3 (continued)

AREA/TRAIT	CAUCASOID Northern European derived White	NEGROID American BLACK	MONGOLOID Canadian INDIAN[2]
Miscellaneous Traits			
Femur	antero-posteriorly rounded, twisted	straight, flat untwisted	--
Dental	--	crenulated enamel	incisor shovelling

1. Criteria from teaching materials prepared by Dr. T.W. McKern, from Krogman (1962), and Stewart (1979).

2. The following traits, while not always present in native skulls, are frequently observed in combinations of two or three traits. In conjunction with those listed above, they are useful indicators of race: slit-like skeletal ear opening, **TYMPANIC DEHISCENCE**, mandibular torus (raised bony ridge on inside of lower jaw below teeth). In archaeological specimens of native Indians, squatting facets at the ankle joint, strong dental wear, and a **MYLOHYOID BRIDGE** are commonly observed.

3. -- = unreported.

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investigator should predict stature from the single bone or combination of bones which is known to have the smallest range of variability. Not surprisingly the best combination from which to predict stature is from the leg (femur and tibia).

Additional standards are available from which the preserved lengths of broken long bones can be used to predict total bone length and from which, in turn, an estimate of stature can be obtained (Steele in Stewart, 1970). The latter estimates are obviously less reliable.

Stature estimates are only accurate to within 12 to 20 centimeters (5 to 8 inches) with 95 percent confidence depending on race and sex. Even these are useful, especially if the predicted stature is quite tall or short. In one of our cases a complete skull and a portion of the FEMORAL shaft (thigh bone) were recovered. Stature was estimated from predicted total bone length to be between 6 feet and 6 feet, 3 inches but with a reliable error range of 5 feet, 8 inches to 6 feet, 9 inches. A search of missing persons records for the area yielded only one individual close to the indicated height -- 5 feet, 10 inches. A positive identification was obtained from this person's dental records matched to the recovered skull.

III. C. *Personal Identity*

Having established the biological identity, more or less reliably, determination of the personal identity can be attempted. This involves comparing even more detailed observations of the remains with premortem records from each individual whose bones these might be. This "short list" is usually obtained from the missing persons file of the local law enforcement agency, extracting only those who, should they be dead, have been missing sufficiently long that their bodies could be decomposed to the extent seen on the remains *and* who exhibit the appropriate biological characteristics of age, sex, race, and stature.

IT IS STRONGLY RECOMMENDED THAT WHENEVER A PERSON IS REPORTED MISSING, THE LOCAL LAW ENFORCEMENT AGENCY COLLECT ALL PREMORTEM RECORDS FOR SECURE STORAGE UNTIL SUCH TIME AS MATCHING REMAINS MAY BE FOUND. Dental and hospital radiographs often are not saved for more than two years after an examination.

The information from which personal identity can be determined is derived from two sources: directly from the remains themselves and, more rarely, from associated materials either unique to the individual or identifiable by family or friends as belonging to the individual. These sources are dealt with separately below.

Lack of positive identification is usually due, not to the uninformativeness of the remains, but to the absence of suitable and detailed premortem records. Transients passing through an area and meeting their death may go unidentified. Their absence from home will not likely have been reported and certainly there will be no premortem records held locally. Only widespread dissemination of the description of the remains provided by a forensic anthropologist can help to solve this problem. It is the investigating officer's responsibility to search for premortem records as widely and as far back in time as possible.

There is a rich variety of premortem records: medical/dental records and charts, dentures, clinical and dental radiographs, insurance medicals, military service documents, photographs, portraits, school health reports, worker's compensation files, police booking records, and even recollections by family members and associates. Some chiropractors record useful information on the timing and extent of injuries, particularly to the spine. On occasion, dental casts of living close relatives (for example, a **SIBLING**) may be useful for comparison of genetically controlled dental characteristics.

The results of such a comparison between pre- and postmortem records will yield one of several possible conclusions. These are: 1) inconsistencies are such that the suspected identity is repudiated; 2) lack of both correspondences and inconsistencies does <u>not</u> show one way or the other if the remains pertain to the missing person, 3) some consistencies are evident but are insufficient proof of identity; or 4) consistencies are present in such a <u>variety and degree</u> that identification is positive.

It must be emphasized that not always is a host of detailed correspondences between the remains and premortem records necessary for a positive identification. This situation arises when the list of locally missing persons is very small and the remains show a significant correlation with one distinctive individual. For example, in one case the remains were diagnosed as those of a native child, likely male, who died five to ten years previously, at the age of 5.6 +/-0.8 years (ascertained from tooth formation as seen radiographically). Only one such child, a native boy aged 5.62 years, had been reported missing eight years before. The correspondences, though few, were such that a positive identification was justified and the case closed.

In that techniques and expertise for complete skeletal recovery are available, failure to establish the identity should never be due to poor recovery methods. We recently had a case where a virtually complete skeleton, wrapped in a blanket, was encountered in a newly-extended graveyard! Between discovery and recovery the skull disappeared, along with, in this case, any chance of positive identification.

III. C. 1. *Individuality in Skeletal Remains*

To the uniqueness inherent in the hard tissues of all individuals (for example, extra teeth or **FRONTAL SINUS** patterns) may be added <u>acquired</u> features which in combination render the remains unique. Foremost among the latter are dental restorations and extractions which provide the majority of positive identifications in general forensic cases. Other sources are physiologic and pathologic insults to the body (for instance, **GROWTH ARREST LINES** in bones and teeth, osteoarthritis), non-pathologic trauma (for example, premortem fractures), operative procedures (plastic surgery, amputations), and habit or occupation (either of which may reflect socio-economic status of the individual).

How many characteristics of an individual have to be determined in order to distinguish that person from all others? Fingerprint specialists claim 6 to 16 correspondences between a suspect's print and that found at the scene of a crime are sufficient to indicate they could only have come from one person. Forensic odontologists have developed a similar approach based on details of dental work (Keiser-Nielsen 1980).

All positive identifications in the forensic sciences, whether of fingerprints, teeth, bullets or handwriting, are based on showing that the combination of identifying variables exhibited by an object renders that object unique and distinguishable from all other like objects in a defined parent population. There are two essential ingredients here: *variables which occur jointly* and a *parent population of finite size*.

Now consider the task of the investigator of a fingerprint left at a robbery or a bite mark left on a victim. After the contact leaves its trace, the finger or mouth moves on to rejoin a huge universe of like objects. In this situation, where the parent population remains so large as to be virtually without bounds, a positive identification can only be had by demonstrating that the particular combination of many variables (such as minutiae of ridge characteristics) is a unique occurrence. The presence of any one variable is assumed to be independent of any other variable, such that the investigator can find the probability of the variables occurring jointly by multiplying their individual frequencies of occurrence (expressed as a decimal) together. For example, 12 independent characteristics each of which occurs in fewer than 1 in 4 persons, say, will have a joint probability of co-occurrence in $(1/4)^{12}$ cases; i.e., 1 in 17 million persons approximately. So in all of Canada, with a population of 25 million, the investigator would expect only 1 or 2 instances of such a combination of variables. This "multiplication rule" is valid only for independent variables whose joint occurrence is purely a chance event. Fingerprint identification is based on this assumption. Emphasis is on finding a lot of rare variables while the parent population is treated as virtually infinite.

Now consider the case of a plane crash where, despite the usual loss of all identifying ridged skin characteristics, bodies are still able to be identified positively. This is possible because, even though the identifying variables may be few (say a healed fracture and a caesarian scar) and even though they are not independent (e.g., both the scar and fracture are sex-linked) their occurrence jointly, in a person of the right sex, age and so on is unique since the size of the parent population is limited to the crew and passengers. Here, emphasis is on the parent population.

III. C. 2. *A New Approach to Human Remains Identification*

The authors wish to advocate a new strategy for obtaining a positive identification of skeletonized human remains. This approach which uses joint probability is summarized in the following pages. We feel that the method is explicit and statistically defensible permitting the investigator to gauge the probability that a positive identification is correct. For the approach to work, the forensic anthropologist has to have the cooperation of the police.

In order to obtain a positive identification, fundamentally the investigator has to be able to determine:

a) the size of the parent population from which the remains have to be distinguished;

and

b) the probability with which an observed number of identifying variables will occur in combination.

So for example let us say the police have found a skeleton and it has been studied by the forensic anthropologist, who has shown the skeleton exhibits a particular combination of potentially identifying features. In addition, this postmortem information matches, with no inconsistencies, a premortem record from a person the police think could represent the remains. How can the forensic anthropologist know if this is likely to be a positive identification? Now if there are only a limited number of dead persons, say 1000, who could have contributed the remains (=the parent population) and if it can be shown that the particular combination of identifying variables can be expected to occur in let us say less than 1 in 1000 persons, then the forensic anthropologist can make a statistically logical argument that the premortem/postmortem match is probably a positive identification. In fact, the degree of probability can be stated as described below.

Forensic anthropologists appear to have been reluctant to attempt positive identifications because apparently it was felt they had knowledge neither of the size of the parent population nor of the frequency of the identifying variables, whether considered singly or in combination. This is a misconception nurtured by the prevailing lack of communication between the police and the forensic anthropologist. The police, naturally enough, look upon identification problems from the 'fingerprint' point of view, where the source of the evidence usually remains a part of a large universe of like objects -- the general population. Death and decomposition, however, irrevocably remove the source of the evidence -- in this case a person -- from the general population to a *much* smaller population of dead persons most of whom will be described by the *list of missing persons*. In British Columbia, for example, with a population of 2.7 million, only 967 were reported missing as of December 13, 1982. Since we can safely assume that the fraction of the missing persons population which is not dead but is simply "runaways" exceeds the unknown number of unreported dead, the size of the missing persons file will be a generous overestimate of the size of the parent population from which a single skeleton must be distinguished.

We can now turn to the second and more difficult requirement for obtaining a positive identification of a skeleton, that of predicting the probability with which a number of identifying variables will occur in combination. If all our variables were *independent* of each other we could simply proceed to multiply together the frequencies with which each variable is known to occur singly, to find the joint probability. Unfortunately, the data base of identifying variables available to the forensic anthropologist contains *dependent* variables such as age and sex, where for example, if one is very old one is more likely to be female. Similarly, stature is dependent on age, sex and race. To handle this problem the forensic anthropologist has to be able to treat linked (dependent) variables as a single unit; i.e., he has to be able to observe, not predict, what proportion of the parent population shows a particular combination of age, sex and so on. This information cannot be obtained from general census data because the missing persons population is a biased selection from the general population; composed, at least in British Columbia, of more males, more young adults, more non-whites and so on. But remarkably, and fortunately for forensic anthropology, the vital information on dependent variables *is* contained in the missing persons file where age, sex, race, stature, time and locality of disappearance are usually noted. The forensic anthropologist must have access to the *composition* of the missing persons population in the area so as to be able to assign a frequency figure to the combination of dependent variables observed on the remains.

The forensic anthropologist will collect data on three sorts of identifying variables: 1) *independent* single traits such as the interval of time when death occurred; 2) a core group of highly correlated variables as noted above which are *dependent* on each other, particularly age, sex, race, stature and locale, which must be treated as a single entity whose frequency of occurrence cannot be predicted but must be observed from analyses of the missing persons file; and, 3) variables which while dependent on variables of age, sex, race and locale are, otherwise, *independent* of other such variables. To illustrate this last group of variables we can imagine a skeleton which shows arthritis of the spine, a healed fracture of the left wrist, a naturally missing wisdom tooth and size ten boots. Manifestly, while backache and foot size are independent of each other they are not independent of age and sex. Thus, the forensic anthropologist will have to collect epidemiological data on the incidence of variables like broken left wrists in samples where age, sex, race and locality are known.

It should be stressed that incidence data, such as 1 in 17 males has broken his nose at some time, are necessarily derived from a sample other than the sample which contributed the remains. It must be made an explicit assumption that the incidence of the identifying variable will be the same in both samples. This judgement can be questioned by the police or the courts and can be defended by the experienced forensic anthropologist on the grounds that there is no reason to suspect otherwise.

The approach to human remains identification advocated here is summarized below and illustrated in Table 4 using a fictitious although realistic example.

The method may be summarized as follows:

1. Collect postmortem data -- male, white, 35 to 55 years old, who died more than 1 but less than 2 years ago in the Lower Mainland of British Columbia and who shows arthritic changes in the back, a well-healed fracture of the left wrist, a missing wisdom tooth and has size ten boots.

2. Obtain a complete missing persons record for at least the province or state so as to determine: a) a maximum size for the parent population from which the remains have to be distinguished (=967); and, b) the size of that portion which shares the dependent traits of age, sex, race and locality (n=54).

3. Collect epidemiological data on the relevant independent

variables (see above) in terms of that portion of the general population of 35 to 55 year old white males from the Lower Mainland who show them (=.65, .043, .20, .35).

4. Find portion of missing person population which disappeared 12 to 23 months ago (=.27).

5. Find joint probability (p) of independent traits co-occurring in a single individual by multiplying their individual incidences together (.65 x .043 x .20 x .35 x .27 = .00053, or once in 1893 persons).

6. The number of persons in the residual parent population which can be expected to show the observed combination of independent variables is found by multiplying n x p = λ = 54 x .00053 = .029; i.e., much less than a single instance.

7. Assuming that one has found a match between the postmortem evidence and a premortem record, the probability that this is a positive identification (where λ = .029) can be found from Kingston's equation: $1 - \lambda/4 = 1 - .007 = .993$ (Cullason 1969).

8. Thus, one can go to court and argue on explicit grounds that, in this case, the probability that the remains are from a suspected person is more than 99%.

Please note that we have presented above only an overview of a method (Skinner 1983) which we hope will come to be recognized as a useful technique for obtaining positive identifications of human remains. For the approach to work the police must provide the forensic anthropologist with access to the composition of the missing persons file for the area.

III. C. 3. *Indicators of identity in associated materials*

Apart from recovery of physical (non-skeletal) evidence of a criminal act such as bullets and cartridge cases, complete excavation may result in the retrieval of other non-skeletal items which can provide a positive identification.

Such artifacts may be clinical (e.g., hearing aids, heart pacemakers, dental or surgical applicances, female contraceptives, glasses, contact lenses) or they may be identifiable by relatives or associates (e.g., clothing, pocket contents, jewelry). Furthermore, in certain circumstances, it is conceivable that calcified organ contents (for example, gall stones), fetal remains **IN UTERO**, or

TABLE 4

Human Remains Identification from Joint Probability

Postmortem Observation	Variable	Premortem Incidence[a] (Missing persons = 967)
	Core Group of Dependent Variables	
Male	SEX	N = 54, from analysis of missing persons file
35 to 55 years old	AGE	
White	RACE	
Lower Mainland	LOCALE	
	Independent (but linked to core group)	
Back arthritis	PATHOLOGY	.65[b]
Healed break, left wrist	MEDICAL PROCEDURE	.043[c]
Missing wisdom tooth	MORPHOLOGY	.20[d]
Size ten boots	ARTIFACT	.35[b]
	Independent*	
12 to 23 months ago	DEATH INTERVAL	.27

CALCULATIONS

1. Joint probability ($p = .65 \times .043 \times .20 \times .35 \times .27 = .00053$).
2. Residual parent population (N) = 54.
3. Frequency with which identifying variables predicted to occur in combination ($\lambda = N \times P$) = $54 \times .00053 = .029$.
4. Probability of positive identification[e] = $1 - \lambda/4 = 99.3\%$.

NOTES

a. Unless otherwise specified, data are from Canadian Police Information Centre (CPIC), December 13, 1982.
b. Arbitrary over-estimate.
c. Hamilton (1982).
d. Pedersen (1949) in Bass (1971).
e. Cullason (1969).

*see footnote at end of chapter

other organic matter (for example, hair, skin, nails, stomach contents, **FECES**) might be recovered.

In our experience completely skeletonized remains which have not been exposed for more than six months will be found still associated with head hair; which after all is a dead tissue resistant to decay. Hair has a number of obvious characteristics (colour, length and curl) which taken together are quite personal.

*Strictly speaking, while elapsed time since death is largely an unpredictable interval of time deriving from (usually) accidental death and accidental discovery of the remains and thus is an independent occurrence, the missing persons file contains a number of young "runaways" whose elapsed time since'death'(=disappearance) is dependent on variable of age. Consequently it is more feasible to treat elapsed time since death as a dependent variable as in the 'core' group of traits from Table 4.