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REVIEW

The examination of skeletal remains

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Whenever skeletal remains are discovered, pathologists are frequently requested by the police to assist them in their investigation. In many instances, especially where complete or substantial portions of a human skeleton are recovered, a forensic pathologist can undertake most of the medical investigations alone, but for specialised techniques and where the case has criminal aspects, the assistance of an experienced physical anthropologist or anatomist may be required, as well as a forensic odontologist (dentist) and serologist. Where only small fragments, especially when burnt, are recovered, then the services of an anatomist may be very valuable.

The following questions need to be answered, wherever possible when skeletal remains are discovered:

Are the objects really bones?
Are they human or animal?
If human, how long since death and/or interment?
How many bodies represented?
Are the remains male or female?
What age was the person at death?
What was the stature (height) of the deceased?
Can the race be determined?
Any indication as to the cause of death?
Any features which may establish a personal identity?
Any accompanying artefacts to assist identity?
If buried, was it a legitimate or clandestine burial?

1. Are the objects really bones?

Occassionally the public or police may bring objects which superficially resemble bones, but which on close examination turn out to be other artefacts. Pieces of wood or even stone may look like bones. One of the authors was once presented with a perfect human radius, which turned out to be a plastic and plaster copy, part of a medical student's synthetic teaching set. Fossilised bones, where the organic material has been replaced by mineral are real bones, but of great antiquity and usually only found by archeologists.

2. Are they human or animal?

This can be a very difficult decision, especially if the bones are broken into relatively small fragments. Almost all intact bones or substantial parts of large bones can readily be distinguished by a medical practitioner as human or non-human from a knowledge of anatomy, but parts of a mid-shaft of a long bone, for example, may not be readily distinguishable. Similarly, the small bones of the carpus or tarsus or the digits of hand or feet may be extremely difficult to identify. Some animals, such as the bear, have a paw skeleton almost identical to that of the human hand. Even an anatomist may be hard-put to distinguish these and a veterinary or comparative anatomist may be required to give an opinion. If the bones are relatively fresh, usually within 5 or 10 years of death, it may be possible for a forensic serologist to prepare a protein extract and test the bone against human and various animal anti-sera. The old precipitin tube test is now out-dated, and methods of gel diffusion or electrophoresis are employed. The DNA technique is of no use in this respect, as species cannot be differentiated by their DNA.

3. If human, how long since death and/or interment?

This is a very important and difficult question, as bones which have been dead for more than 50-70 years are unlikely to be of much interest to the police, coroner or other investigative authority. Even if the death was homicidal, it is likely that the perpetrator is also dead. Thus given the difficulty of placing even an approximate date on skeletal remains, the most practical decision is whether or not the bones are "recent" or "ancient," the latter being taken to be 50-70 years. Even this crude distinction is extremely difficult and may be impossible. The appearance of bones, unless they are very recent, is much

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more dependent upon the environment in which they have lain, than the passage of time. Bones left in a dry environment, such as sand, will last far longer than bones in a damp, acidic situation. The authors have seen the complete destruction of a body, including the skeleton, within 20 years, when buried in damp peaty soil, where the water-table, of a low pH rose and fell sufficiently to destroy all tissues. Conversely, many bones of pre-historic age have survived perfectly intact, buried in dry stone chambers or in desert conditions.

Even a single bone may be in a totally different condition from one end to the other, if the environment varies over even a few centimetres. For example, a bone buried vertically in a pile of wet rock may disintegrate at the lower end, whilst the upper end may be in good condition. In relatively recent deaths, soft tissue will persist for a variable period. In temperature climates, periosteum, ligaments and tendons may survive on a bone protected from animal attack for two or three years or even longer, whereas in hot, damp climates such as the tropics, soft tissue may vanish within months, or even faster if animal predators, both mammalian, reptile or insect have access to the soft tissue.

Once soft tissues vanish, the appearance of the bone may still give a clue as to its fairly recent origin, within the last 5-20 years. .A recent bone is heavy, the surface may feel smooth or even slippery due to the presence of organic matrix and residual fat. Internally, the marrow may persist for a number of years. After 30-40 years, the bone tends to become lighter as the organic matrix is lost and the softer parts of the bone begin to crumble. Smaller bones and membrane bones such as ribs and skull will disintegrate faster than heavy, dense compact bone such as the shaft of the femur. Only experience can give even a rough estimate of bone age and even then because of the frequent lack of corroborative confirmation, experience is hard to gain. Many special techniques have been developed to try to date bone more accurately.' The total nitrogen content is greater than 4-5% in bones less than about 50 years since death in average temperate conditions. The number of amino-acids, initially about 15, drops with age and hydroxy-proline and proline tend to vanish at around 50 years. However, even after thousands of years, some amino-acids can be retrieved by analysis after hydrolysis of the residual protein, these usually being glycine and alanine.

Bone dust obtained by sawing or the bone surface retains its positivity for blood pigment tests, such as the leuco-malachite green-peroxide test, for up to 100 years. Elution of bone dust by very weak ammonia, followed by concentration in a dessicator, may yield a solution which can be tested for immunological activity against a human anti-Coombs serum. This is usually positive for 5-10 years. More recently, DNA techniques have been applied to bone extract or residual bone marrow and positive results obtained after a long period, which can be matched against possible relatives, if these exist. Specialist publications must be consulted for these techniques.

More easily performed tests include ultraviolet fluorescence. If the shaft of a long bone such as a femur is sawn across and examined in the dark under an ultraviolet lamp, fresh bone will fluoresce across the whole surface from periosteum to marrow cavity. After the passage of time, the outer and inner rim will lose sufficient organic stroma to lose its fluorescence and usually after 30-50 years there is a "sandwich" effect with a zone of fluorescence in an annular ring around the marrow cavity with non-fluorescent zones each side. As time lengthens the fluorescent zone narrows, breaks up and finally vanishes at some point usually between 150-300 years. However, as with all changes, these are very environment-dependent.

A new technique currently being developed in Britain[2] depends upon the accumulation of radio-active isotopes, such as strontium and caesium in the bone consequent upon the fall-out atmospheric nuclear explosions. As the first such explosion was in 1945, any bone with a detectable amount of radio-isotope must have been alive since 1945, as long as passive percolation from soil water can be eliminated.

4. How many bodies represented?

This is an anatomical exercise and can only reveal the *minimum* number of bodies present. Sometimes human and animal bones are mixed together and need to be separated again by anatomical examination. The human bones are then sorted with any unpaired bones set aside, such as sternum, skull and sacrum. Vertebrae are difficult to match up and can rarely be used to separate different individuals unless there is marked difference in size so that the spines can be re-assembled or if there is marked difference in personal age or disease, such as marked osteoarthritic lipping. With paired bones, the femoral heads or whole femurs should be separated and identified as to left or right. The same should be done for other identifiable bones. Of course, it may not be possible to assign two bones to a single person, as they may be one bone each from two different persons.

However, this method will give a ***minimum*** number of persons present. In many instances it is fairly obvious that only one skeleton is represented, either wholly or in part.

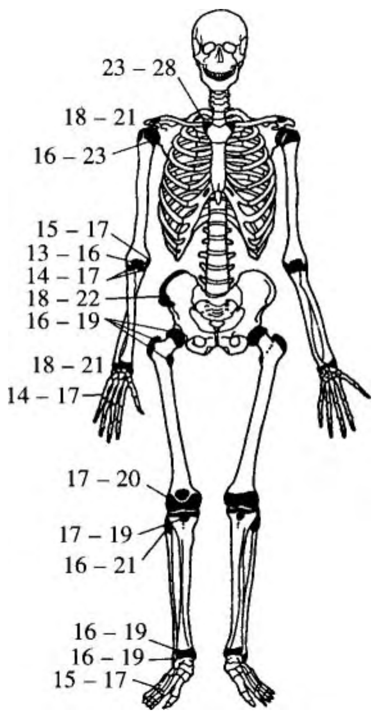
5. **Are the remains male or female?**

Sexing of skeletal remains depends upon the amount of bone present and which bones are recovered. If the skull or pelvis is present, then in post-pubertal remains, about a 95% accuracy can be expected. Where infant or pre-pubertal children are concerned, the problem is more difficult and may need the opinion of a specialist anatomist. Foetal bones are even more difficult, though there have been descriptions published to assist in identification.[3] The skull has many sexual differentiating features, though this is partly dependent upon race. For example, the skulls of persons from the Indian sub-continent tend to have some feminine features in both male and female, such as a high forehead, rounded skull and smoother surface. Though the details must be sought in forensic textbooks or specialist books such as Iscan and Krogman,[4] the major features in the skull to assist in sexing include the size of the mastoid, being large in the male. There are heavier eye-brow ridges in the male, a more rugged skull, especially at the posterior and inferior surface where the larger muscles are attached. The shape of the orbits is different, as well as the nasal-opening. The shape of the palate is somewhat different, the dental arch being more elliptical in the male and semi-circular in the female. The lower jaw is usually more massive in the male and has a squarer symphysis with a more prominent point to the chin. However, some of these features are more personal than sex-linked. The changes in the pelvis are well-known, the female pelvis being broader and flatter. The sub-pubic arch is much wider in the female, usually exceeding a right angle. The pelvic inlet is more oval in the female, whereas the male inlet is heart-shaped due to the forward protrusion of the sacrum. The female sacrum is short and wide, the upper half is almost straight. The curve occurs chiefly at the lower half of the bone, whilst in the male bone the curvature is distributed especially over its whole length, and the bone is longer and narrower than in the female. The articular surface for the ilium extends to the second piece of the sacrum in the female and usually to the third in the male. The acetabula are larger in the male, usually averaging 52 mm, as opposed to 46 mm in the female. These tend to face more laterally than the female, which are rather forward-facing. The greater sciatic notch in the ilium is much wider in the female than the male. There may be a pre-auricular sulcus in the female, especially if she has borne children. There are many mathematical methods for sexing the pelvis, such as the ischio-pubic index, which requires very accurate measurements. Other bones have less well marked sexual characteristics, though the femur is usually more massive and longer in the male. The vertical diameter of the femoral head usually exceeds 45 mm in the male, being rarely more than 42 mm in the female, according to Pearson and Bell,[5] though Dwight's[6] figures are 49 and 43 respectively. This illustrates the variability of different geographical and ethnic material.

Due to the wider pelvis, the female femora tends to come down to the knees at a greater angle, so that the condyles are at a different angle to the shaft. If a male femur is placed on a flat surface so that both condyles are touching the table, then the angle with the shaft is usually more than 80 degrees, whereas the female tends to be less than 76 degrees. There are other sexual differentiating features in the sternum, the length of the blade of the sternum in the female being less than twice the length of the manubrium, compared with the male.

6. **What age was the person at death?**

Ageing of skeletal remains depends upon the period of life of the person. Up to the early 20's, fair accuracy can be expected and the younger the person the more accurate the estimate. With foetal and infant bones, the age may be estimated to within weeks, but as the growth processes slow down and cease, ageing becomes more difficult. In the foetus, the appearance of ossification centres is useful, for example the centre at the lower end of the femur. After birth, a general progression of epiphyseal fusion proceeds up until the third decade. The last epiphysis to fuse is usually that of the sterna1 end of the clavicle, between 23-28 years. However, caution must be employed because there are appreciable differences between temperate climates and tropical climates and between males and females, the latter in both cases fusing earlier,



Approximate dates (years) of epiphyseal union

FIG. 1: A guide to the age of epiphyseal union in the major centres. The commencement and completion of union takes several years. The table is only a guide for male subjects (female slightly earlier) in non-tropical climates: the two dates are partial and complete union (years). *Source: Knight BH. Forensic Pathology. Edward Arnold 1991.*[7]

Head of femur	16-19
Greater trochanter	16-19
Lesser trochanter	16-19
Head of humerus	16-23
Distal humerus	13-16
Medial epicondyle	15-17
Proximal radius	14-17
Proximal ulna	14-17
Distal radius	18-21
Distal ulna	18-21
Metacarpals	14-17
Acromion	17-19
Distal femur	17-20
Proximal tibia	17-19
Proximal fibula	16-21
Distal tibia	16-19
Distal fibula	16-19
Metatarsals	15-17
Iliac crest	18-22
Primary elements pelvis	14-16
Sternal clavicle	23-28
Acromial clavicle	18-21

sometimes by several years. The use of the appearance of ossification centres and the fusion of epiphyses can be employed by reference to the many tables produced by radiologists and by anthropologists which are reproduced in forensic textbooks[7] and in special volumes (Fig. 1). However, another problem is that visual as opposed to radiological fusion is not simultaneous: also fusion is a process, not an event, extending over several months or even longer, and is also very variable between individuals.

After the mid-part of the third decade, it becomes increasingly difficult to assess age. There is some controversy about the use of the fusion of cranial sutures, the general opinion being that they are generally very unreliable. The endocranial side of the sutures should be studied as these are less variable than the outer fusion. Even so, ageing cannot be made within at least a decade by this method.

The use of the changing pattern of the pubic symphysis has been thoroughly investigated by McKern and Stewart[8] and by Gilbert and McKern.[9] Although fairly accurate to within five years, this requires extensive experience rarely possessed by pathologists. This is a matter for physical anthropologists if the issue is very important.

Another method recently developed are

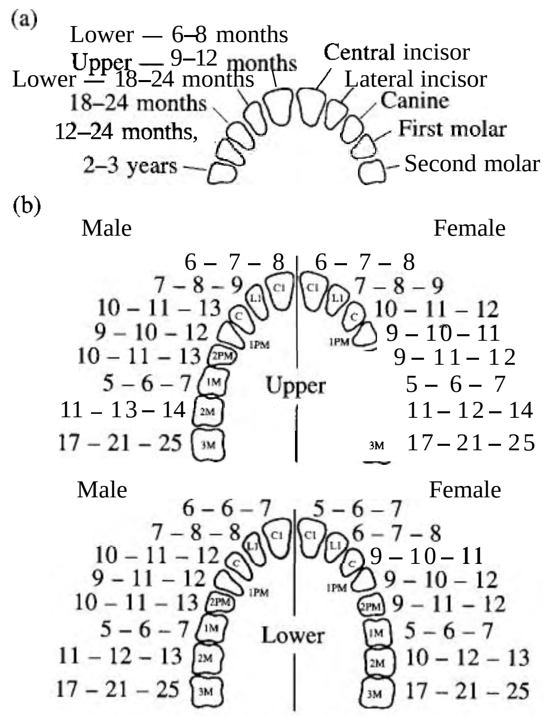


FIG. 2: (a) Dates of eruption of deciduous teeth (average times) (b) Times of eruption of permanent teeth; three dates are shown (years) for early, average and late eruption, rounded to the nearest year. *Source: Knight BH. Forensic Pathology. Edward Arnold 1991.'*

changes in the costochondral junction, but again accuracy is not great. The other feature useful for ageing is, of course, the teeth. The deciduous teeth erupt up to about 2-3 years when all the "milk" teeth have appeared. The permanent teeth erupt from about 5 years to 25 years, though again the dates of eruption vary according to sex and geography (Fig. 2). Standard textbooks on forensic odontology,[10] as well as forensic medical textbooks usually give adequate data for the pathologist to estimate the approximate age, but the use of a forensic odontologist is necessary if the issue is important. Recently, odontologists have devised a method of measuring the progressive laevo-rotation of normally dextro-amino-acids in teeth as an index of personal age.

Secondary changes occur in the teeth with age and wear, used by the Gustafson[11] technique and its later modifications.[12] This depends on the semi-numerical method using six dental changes:- attrition, paradentosis, secondary dentive formation, cementum opposition, root resorption and translucency. In adult life, this method can predict age to within 3% in up to 38% of cases.

7. What was the stature (height) of the deceased?

This again is an anatomical exercise, depending upon which bones are present. If the complete skeleton is present, then careful arrangement of the axial skeleton, leaving gaps between the vertebrae for the thickness of the intervertebral discs and also between other long bones for the articular cartilage, may allow direct measurement of the whole skeleton. This can never be accurate to within about 5 cm due to the impossibility of accurately spacing the dried bones. It must be remembered that even post-mortem measurement of an intact non-skeletalised corpse, may give an increase of 2.5 cm compared with the known

TABLE 1: The stature tables of Trotter & Gleser (1977) as quoted by Krogman and Iscan. All lengths are in cm, valid only for Americans between 18 and 30 years of age. Femur and tibia are maximum lengths. SE = standard error. ***Source: Knight*** BH. ***Forensic Pathology. Edward Arnold 1991.***[7]

White Males	SE	Black Males	SE
3.08 × Hum + 70.45	4.05	3.26 × Hum + 62.10	4.43
3.78 × Rad + 79.01	4.32	3.42 × Rad + 81.56	4.30
3.70 × Ulna + 74.05	4.32	3.26 × Ulna + 79.29	4.42
2.38 × Fem + 61.41	3.27	2.11 × Fem + 70.35	3.94
2.52 × Tib + 78.62	3.37	2.19 × Tib + 86.02	3.78
2.68 × Fib + 71.78	3.29	2.19 × Tib + 85.65	4.08
1.30 × (Fem + Tib) 63.29	2.99	1.15 × (Fem + Tib) + 71.04	3.53
1.42 × Fem + 1.24 × Tib + 59.88	2.00	0.66 × Fem + 1.62 × Tib + 76.13	3.49
0.93 × Hum + 1.94 × Tib +	3.26	0.90 × Hum + 1.78 × Tib + 76.29	3.49
0.27 × Hum + 1.32 × Fem + 1.16 × Tib + 58.57	2.99	0.89 × Hum + 1.01 × Rad + 0.38 × Fem + 1.92 × Tib + 74.56	3.38

White Females	SE	Black Females	SE
3.36 × Hum + 57.97	4.45	3.08 × Hum + 64.67	4.25
4.74 × Rad + 54.93	4.24	3.67 × Rad + 71.79	4.59*
4.27 × Ulna + 57.76	4.30	3.31 × Ulna + 75.38	4.83
2.47 × Fem + 54.10	3.72	2.28 × Fem + 59.76	3.41
2.90 × Tib + 61.53	3.66	2.45 × Tib + 72.65	3.70
2.93 × Fib + 59.61	3.57	2.49 × Fib + 70.90	3.80
1.39 × (Fem + Tib) + 53.20	3.55	1.26 × (Fem + Tib) + 59.72	3.28
1.48 × Fem + 1.28 × Tib + 53.07	3.55	1.53 × Fem + 0.96 × Tib + 58.54	3.23
1.35 × Hum + 1.95 × Tib + 52.77	3.67	1.08 × Hum + 1.79 × Tib	3.58
0.68 × Hum + 1.17 × Fem + 1.15 × Tib + 50.122	3.51	0.44 × Hum + 0.20 × Rad + 1.46 × Fem + 0.86 × Tib + 56.33	3.22

living height, due to loss of contracting muscle tone.

More commonly, anatomical tables are used to calculate the height. Tables such as Dupertuis and Hadden[13] may be used, though all tables are calculated for certain ethnic groups at a period which may not be identical to the stature of more modem populations with better nutrition. For example, the commonly used tables of Trotter and Gleser[14] are taken from American casualties in World War II and the Korean War, but obviously will not correspond to other ethnic groups in more modem times. An update of Trotter and Gleser's data was produced by Krogman and Iscan in 1977[4] (Table 1).

The first formula available was that of Rollet.[15] Rollet evolved his formula from the measurements of long bones of 50 male and 50 female cadavers, first in their wet state and then, ten months later, in their dry state. During this period the bone had lost 2 mm of their original length. In 1889 Pearson[16] published his regression formula, but Pearson's tables are now considered least accurate for modem populations over a century later.

Dupertuis and Hadden[13] analysed figures from dissecting-room subjects – mixed (American) white and (American) Negro subjects - and came to the conclusion that corpse and living statures were virtually identical, a view that is not held today.

Trotter and Glesser[14] revealed that the world population was getting taller to the extent that for accuracy a fresh formula was required. They concluded that 2.5 cm increase in corpse (as to living) stature was correct.

With reference to foetal bones, Sydney Smith's[17] criteria are useful even today.

Diaphysis of femur	×	6.71	=	Stature
Diaphysis of tibia	×	7.63	=	Stature
Diaphysis of humerus	×	7.60	=	Stature
Diaphysis of radius	×	9.20	=	Stature
Diaphysis of clavicle	×	11.30	=	Stature
Diaphysis of lower jaw	×	10	=	Stature

The long bones must be measured for accuracy in a Hepburn osteometric board. The maximum length should be measured in all cases, save in those of the femur, which is to be measured in the oblique position, i.e. from the line across the condylar tips to the top of the head and the tibia which is also to be measured in an oblique position, the spine being excluded, from the tip of the medial condyle to the lateral platform of the head (Fig. 3).

Whatever table is used, the directions for measuring the bone must be carefully adhered to. The length of the bone varies according to the points used at each extremity. Old dry bones will be slightly shorter than recent material even where there is no articular cartilage present. Again the use of such tables must be made with reference to standard textbooks for the original publications. Even the most careful measurements still have an inbuilt error of several centimetres. Where more than one long bone is present, calculations should be made on all of them, though it is likely that the leg bones will give a more accurate estimate than the upper limb. Krogman and Iscan[4] indicated that a 95% confidence rate applies only if twice the standard error is accepted each side of the favoured height - in an average man, this means a variation of over 12 cm, which is likely to be too great to be of much use in forensic identification.

8. Can the race be determined?

There are three major ethnic groups, namely Mongoloid, Negroid and Caucasian. There are great variations between each race, with overlap of certain characteristics. Identification of race from skeletal material is relatively uncertain, especially as much ethnic mixing has occurred in recent decades, especially in Europe and USA. However, certain features may be useful. Another Mongoloid trait is the tendency for an enamel extension to course towards or between the buccal roots of the molars. In many Mongoloid groups, a posterior concavity of the upper incisor teeth, described as "shovel-shaped", is often present. These may be found in up to 93% of Japanese, 85% of Chinese and 68% of Esquimaux. It is almost never seen in Whites and only up to 15% in American Negroes. In Mongoloid skulls, the wide zygomatic arches are related to the high cheek bones obviously seen externally in the face, where the transverse facial width is greater than the width of any other part of the head. Negro skulls tend to be dolichocephephalic (long-headed) and the Mongoloid brachycephalic (round-headed) with white races overlapping both types. In people from the Indian sub-continent, there is often a rounded wide skull but this cannot be differentiated from Caucasian features, of which the Indian peoples are a sub-group. The Negro eye-socket is lower and wider compared with a higher rounder eye-socket of the Mongoloid. The Negro nasal aperture is wider, with relative projection (prognathism) of the lower face and jaw. The femur in Negro

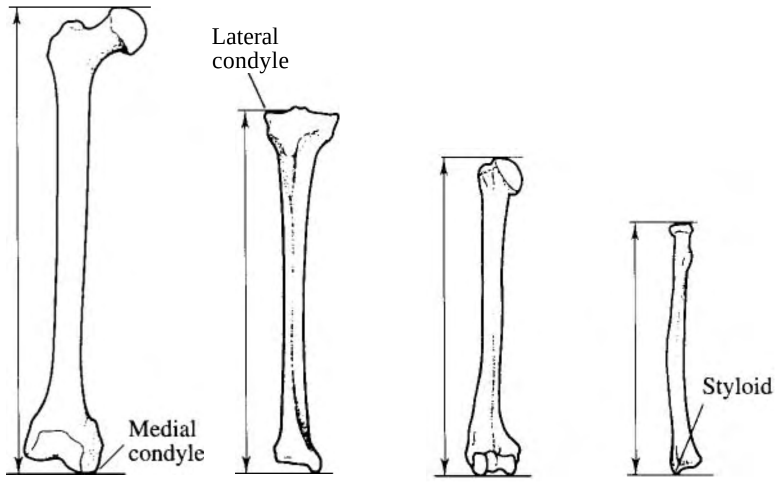


FIG. **3:** Dimensions of dried bones for estimations of stature (Trotter and Gleser, and Dupertuis and Hadden). The right side bone is used for preference. TIBIA: Maximum length between tip of medial malleolus and face of lateral condyle. The intercondylar eminence is not included. FEMUR: With the bone lying anterior surface upwards, the maximum length is measured from the medial condyle to the most proximal part of the head. HUMERUS: Maximum over all length from the posterior margin of the trochlea to the upper edge of the head. RADIUS: From the tip of the styloid process to the head, lying with the posterior surface upwards. All bones should be measured either with an osteometric board or, if one is not available, on a flat bench with the maximum lengths taken between two vertical, parallel boards placed in contact with the bone ends. If the bones are not dry, but have articular cartilage in place, the following should be substracted from the measured length before applying the formulae; (Boyd & Trevor): radius and humerus 3mm each, tibia 5mm and femur 7mm. ***Source: Knight*** BH. ***Forensic Pathology. Edward Arnold 1991.'***

races tends to be straighter, with less antero-posterior bowing. Negro long bones, especially those of the legs tend to be longer than those of the other two races for equal total body length, but these differences are not very reliable.

The specialist literature has many methods for racial determination, such as the technique using cranial measurements. Iscan and Krogman's textbook should be consulted for details.

9. Any indication as to the cause of death?

It is rare for a cause of death to be obvious from examination of skeletal material. Most of the modes of death, whether natural or unnatural, leave no stigmata upon the bones, apart from direct violence. Most natural disease is not relevant, as even bony disease may be unrelated to the cause of death. Occasionally some tumours of bone or primary bone disease such as Albers-Schonberg disease, rickets, osteomalacia etc. may be found, but this is usually of little help in determining the immediate reason for death. Most modes such as stabbing, strangulation, poisoning etc, cannot be investigated in the skeleton. Theoretically, some poisons may be detected in the bone, up to a relatively short time after death. For example, barbiturates have been detected in a buried body - albeit with remaining soft tissues - some seven years after death. It is also possible to detect heavy metals etc, but this can rarely be claimed as the inevitable cause of death. Where a missile such as a bullet is still embedded in the skeleton, almost positive proof can be obtained. These rare events may be visible on inspection or may require radiology. One author once confirmed a shotgun wound of a shattered skull by X-ray demonstration of minute traces of lead on the inside of the cranium. Where there is severe bone damage, it is often very difficult to differentiate ante-mortem injury, possibly causing death, from post-mortem artefacts. Bones, whether buried or concealed elsewhere, may be mechanically damaged by the passage of time or during the recovery process. Even bones lying passively in the ground for a long period may be eroded by stones and rock lying on top of them without actual impact. Bones are uncovered by mechanical diggers or by persons digging with pick-axes etc, so injury is very common. Sometimes pathologists are tempted to ascribe fractures of the skull to ante-mortem violence, when there is no real justification for this. In either case, the fractures will not show any healing, as an injury which occurred so long before death as to allow for new bone growth is hardly likely to be the cause of death. Evidence may also be found of fractures of long bones or ribs, but again the same problems exist in differentiating pre- from post-mortem damage. However, where a bone, especially the skull, shows a burnished edge from a sharp weapon, such as an axe or sword, then this obviously is far more likely to be ante-mortem and the cause of death. Where bones are broken, careful inspection should be made to see if the broken edges are fresher than the rest of the bone, suggesting recent post mortem damage. However, if the post-mortem damage was a considerable period before discovery, the appearances cannot assist. Where bones are found burnt, again it is virtually impossible to tell whether this was ante-mortem or post-mortem.

10. Any features which may establish a personal identity?

The previous sections can help to establish the general grouping of sex, age, stature, race etc, but do not put a name to the skeletal remains. After the preliminaries listed above have been investigated, a careful evaluation of any individualistic features should be made. These include old injuries and disease. Old fractures with bone deformity and callus formation should be carefully noted and radiography performed. It is extremely difficult to age callus in terms of the interval between injury and death, callus usually forming within about two weeks of injury though this may be very much delayed. However, re-modelling of the bone may take months or years and in fact may never restore the bone to its original shape. Congenital defects should be noted, such as a shortened leg or asymmetry of the limbs or any abnormality of shape of the skull. Any prostheses or surgical intervention in the skeleton should be carefully investigated, with full photography and radiology. Hip prostheses, femoral pins, plating of long bone fractures or skull plates and any other surgical procedure including spinal fixation are rare but very useful personal indications.

The use of DNA profiling to match a bone with suspected family members is now available. Both in fresh or archeological material, either marrow or bone can be used, sometimes employing PCR techniques to amplify the available DNA for comparison.

Where a possible candidate for the skeleton is known - or a group of candidates - then exhaustive search for their medical records, especially X-rays, may reveal information which can give an absolute identity. For example, in a recent homicide in Britain, one author discovered an old callus of the mid shaft of the right femur in a body which had been buried in a garden for two years. The potential identitee was traced and hospital records found from a traffic accident five years earlier in which a description of the fractured leg was obtained, together with clinical radiographs at intervals during the healing process. Radiography of the exhumed bone matched exactly with the callus seen on the clinical radiographs, even to the correspondence of a small spur of bone pulled off the callus by muscle tension. Where ante-mortem radiographs of a potential identitee are available, then many possibilities exist for matching the skeleton with the records. Where the skull is available, then virtually 100% match can be obtained, even apart from the teeth. Every person has a different pattern of the frontal sinuses which is unique, being different even in identical twins. Lateral views of the skull allow comparison of the pituitary fossa and adjacent areas, which again are usually unique. Even bones such as the clavicle may be matched by the cancellous pattern inside the compact cortex. This is also true for the cancellous architecture in the head of the femur and humerus, though as remodelling occurs with age or injury, these patterns are not so permanent as in the skull.

As with intact bodies, dental identification is, of course, one of the most effective means of placing a name upon the remains. The forensic odontologist can assist in general features such as estimating the age of the person and sometimes the race. He may also have some input into sexing, as there are a few factors which can point to sex, though they are not very reliable, for example the fact that the mandibular first molar often lacks a fifth cusp in the female, which is almost always present in the male. Forensic dentistry comes into its own in identifying skeletal material when matching dental characteristics with the dental records of a potential identitee. Extractions, fillings, bridge-work, dentures etc. can be used to establish a completely reliable match, as long as dental records are available. This is a very specialised area and although in the absence of a forensic dentist, a forensic pathologist may be able to match obvious characteristics, where the case has criminal aspects or is otherwise very important, it is essential for the teeth to be examined by someone with specialist expertise.

The technique of super-imposition has been and is still being used. Facial reconstruction is increasingly used to establish identification. "Photo-fit" techniques are useful, in matching a skull with a facial photograph. Static overlays have now given way to dual video images, superimposed on a monitor. Considerable experience is required for their use. Snow ***et al***[18] demonstrated that by using modelling clay in standard tissue thickness at prescribed anatomical land marks on the facial area of a skull molded a "life-like" appearance, a technique developed further by Richard Naeve in Manchester. 3-D computer graphs for facial reconstruction is being used in some centres.[19,20]

11. Any accompanying artefacts to assist identification?

This is as much a matter for the police or investigating authority as for the pathologist, as objects found with or near the skeleton naturally can be of great assistance, especially in establishing a personal identity. If the body has been there long enough to skeletalise, probably other more fragile artefacts will also have rotted away, including clothing, but metallic objects such as rings, watches, jewellery, etc may still remain. In some cases, persistent plastic or other hard material may survive. In several cases seen by one of the authors in bodies recovered from the sea-shore, there were crude buttons carved from bone associated with the remains, which were commonly made by sailors in bygone years from food bones. This helped confirm the fact that these were probably drowned seamen washed up on the shore and buried above high water mark.

In some land burials, rusted or corroded coffin nails have been found in amongst the bones, indicating that the body originally was inside a wooden coffin, the time of which had rotted away.

12. If buried, was it a legitimate or clandestine burial?

This depends upon the part of the world in which the remains are found, as in many cultures, bodies are buried legitimately without a coffin, as in most Islamic countries. However, elsewhere, the presence of a coffin obviously indicates a legitimate burial and not the secretive burial of a homicide or the accidental death of a person whose body was never recovered. As in the section previously, the presence of coffin nails, which in ancient times were made of crude iron or bronze, may indicate the presence of a coffin even after the wood has rotted.

In some such burials, even if the metal has corroded completely, the copper from bronze nails may stain the bone surface a bright green colour due to copper carbonate. This is an indication of a legitimate coffined burial. Similarly, the site of recovery of bones is important, as in Europe, many bones come to light as a result of disturbance of old burial grounds, either for building or road construction. If old records indicate that a cemetery was at the site, then the finding of bony remains becomes less sinister.

Conclusion

The finding of skeletal remains is a common happening and the forensic pathologist is frequently called upon to examine the remains. It is theoretically much better for the pathologist to examine the bones at the site before they are disturbed, but this rarely happens, the bones being recovered by the public, workmen or police and brought in a jumbled condition to the pathologist. Using a systematic process of elimination such as that suggested in this paper, the maximum information can be obtained. Even so, it is common for the bones never to be identified and even the length of time the person has been dead remains unknown, due to lack of corroborative information. However, only by repeated and careful examination of a number of skeletal remains, can the pathologist hope to gain any experience. Probably the most important thing to bear in mind is the danger of being too dogmatic, especially about the date of the remains and not to mislead the investigating authorities by over-optimistic opinions.

REFERENCES

1. Knight B. Methods of dating skeletal remains. Med Sci Law 1969; 9: 247-52.
2. MacLaughlin-Black SM, Herd RJM, Willson K, Mayers M, West IE. Strontium-90 as an indicator of time since death: a pilot investigation. Forensic Sci Int; 1992; 57: 51-6.
3. Fazekas IG, Kosa F. Forensic foetal osteology. Akademiai Kiado Budapest, 1978.
4. Krogman WM, Iscan MY. The human skeleton in forensic medicine. 2nd ed. Thomas, Springfield, 1986.
5. Pearson K, Bell J. A study of the long bones of the English skeleton. I. The femur. Draper's Co Research Mem University of London Biom. Series X, 1917-1919.

6. Dwight T. The size of the articular surfaces of the long bones as characteristic of sex: an anthropological study. J Anat 1904-1905; 4: 19-32.
7. Knight BH. Forensic Pathology. London: Edward Arnold, 1991.
8. McKern TW, Stewart TD. Skeletal age changes in young American males, analysed from the standpoint of identification. Headquarters QM Res & Dev Command, Tech Rep EP - 45, Natick, Mass, 1957.
9. Gilbert BM, McKern TW. A method for aging the female os pubis. Am J Phys Anthropol, 1973; 38: 31-8.
10. Whittaker D, McDonald R. Atlas of forensic dentistry. London: Wolfe Medical Publications, 1989.
11. Gustafson G. Forensic Odontology. London: Staples Press/New York: Elsevier, 1966.
12. Johanson G. Age determination in human teeth. Odontologisk Rev 1971; 22 (Suppl 21): 1-126.
13. Dupertuis CW, Hadden JA. On the reconstruction of stature from long bones. Am J Phys Anthropol 1951; 9: 15-55.
14. Trotter M, Gleser CC. A re-evaluation of estimation of stature based on measurements of stature taken during life and of long bones after death. Am J Phys Anthropol 1958; 16: 79-123.
15. Rollet F. De la mensuration de os longs du membres. Medical Doctorate Thesis Paris, First series 43: 1-128.
16. Pearson K. Mathematical constributions to the theory of evolution. V. On the reconstruction of the stature of pre-historic races. Philosophical transactions of the Royal Society, London. 192: 169-244.
17. Smith S. Forensic Medicine. 17th ed. London: J & A Churchill, 1940.
18. Snow CC, Gatliff BP, McWillians KR. Reconstruction of facial features from the skull: an evaluation of its usefulness in forensic anthropology. Am J Phys Anthropol 1970: 33: 221-7.
19. Vanezis P, ***et al.*** Application of 3-D-computer graphics for facial reconstruction and comparison with sculpting techniques. Forensic Sci Int 1989; 42: 69-84.
20. Mon JP, Linney AD, Grindrod SR, Aridge Sr, Clifton JS. Three-dimensional visualisation of the face and skull using computerised tomography and laser scanning techniques. Eur J Orthod 1987; 9: 247-53.