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# Factors affecting the incidence of non-metrical skeletal variants

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## INTRODUCTION

Minor variations in the ossicles, foramina and ridges of the cranium have aroused the curiosity of anatomists for many decades (e.g. Le Double, 1903). It was Wood Jones (1930–1), however, who first proposed that the differing incidences of these minor variants which occurred in different races might be useful in anthropological studies. Laughlin & Jørgensen (1956) put this idea into practice and in 1967 Berry & Berry suggested that a wide range of these variants could be used to calculate a distance statistic between population samples. Yamaguchi (1967) developed a similar method. Since then a number of studies (theses and published works) have explored these ideas further; Kellock & Parsons (1970 *a*, *b*), with Australian Aborigines; Berry, Berry & Ucko (1967) and Knip (1970, 1971), with Egyptian material; de Villiers (1968), South African and Rightmire (1972), African Negro material; Berry (1974*b*) and Sjøvold (1974), material from North West Europe; Guadarrama (1973), South American; while Ossenberg (1970), Finnegan (1972) and several others, summarized by Corruccini (1974), have used North American material.

All these investigations have to some extent assumed that the chief factor governing the expression of these variants was the genetic make-up of the individual, and hence of the sample. This premise was based on findings in laboratory mice. Grüneberg (summarized, 1963) showed that minor skeletal variants were under complex multigenic control; while Searle (1954 *a*, *b*) and Deol & Truslove (1957) demonstrated the effects of maternal environment. For population studies, R. J. Berry (1963) and Howe & Parsons (1967) were satisfied that, provided a large number of variants was used, the overall effect was that genetical control predominated.

In man, suitable experiments to elucidate the degree of genetical control are obviously impossible. The most convincing way of supporting or disproving the genetic hypothesis is by demonstrating that other, non-genetical, factors are in operation. Recently Corruccini (1974) has put forward some data which suggests that sex, age and, perhaps, the weight of the skeleton are related to the presence or absence of minor cranial variants.

Significant inter-sex variation has also been reported in a number of theses quoted by Corruccini. Since the usefulness of anthropological analyses using these variants is markedly reduced if environmental factors significantly affect variant expression, it is important to determine whether or not Corruccini's observations can be confirmed in an entirely different sample. Also, any factors shown to influence the occurrence of

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multifactorially controlled traits are of interest since a similar type of multifactorial control may well underlie many pathological conditions (e.g. spina bifida cystica and talipes).

Suitable skeletal material for any investigation of this type is extremely hard to come by since the collection of large numbers of skeletons with their basic details has probably only been undertaken by the Smithsonian Institution (the Terry collection, used by Corruccini 1974). However, the crypt of St Bride's Church, Fleet Street, London, houses a large collection of identified skeletons. These have been studied in an attempt to determine what factors are chiefly responsible for variant expression.

## MATERIALS

The material examined comprised 186 crania from the collection of human skeletons unearthed from the crypt of St Bride's Church, Fleet Street, London, after the building was destroyed by bombs in World War II. The history of the church and its environs has been described in detail by Morgan (1973). The skeletons, which have been examined by several workers (Steel, 1960; Harvey, 1968), are unique, because each had been buried in a coffin with a coffin plate bearing the name, date of birth and date of death of the deceased. Most of the burials took place between 1800 and 1859, but some occurred in the second half of the 18th century. Although the coffins had decayed, the plates remained intact, and thus a large collection of accurately sexed, aged and dated material became available. The present study was limited to post-pubertal crania which were in such a condition as to allow accurate scoring of several variants. Vertebral variants, however, were recorded in a few younger skeletons.

## METHOD

Each cranium was scored for the presence or absence of 30 non-metrical variants. Most of these characters have been described previously (Berry & Berry, 1967) and are listed in Table 1. Variants 31, 32 and 33 were described by Finnegan (1972), who included several mandibular variants in his list, but these variants were not used on the St Bride's material. Finnegan (1974) described the use of a number of post-cranial variants. The present study has been almost entirely confined to cranial variants. Sacral and vertebral clefts, however, have been included because of their pathological interest. Variants occurring bilaterally were scored each time they occurred. Occurrence or non-occurrence of the variant in the skull as a whole was used when '$t$' tests were done (see below) and the results obtained were in accordance with those expected from bilateral scoring. To reduce subjectivity in scoring, all the new material was scored by myself. Data from other workers has been used in the male/female comparisons, but since males and females of each series were scored by the same person, the comparisons should not be subject to significant inter-observer irregularities.

Several crania with the same name were noted, presumably derived from members of the same family. By considering the dates of birth and death it was usually possible to determine which were likely to be genetically related to each other, and only one member of each of these family groups was included in the scoring. This arrangement

was less strictly adhered to in investigations 4 and 5 (below) as the numbers of crania in the 'abnormal' groups were so small. Here, equal numbers of relatives were included in both 'abnormal' and 'normal' groups. In the family study all available material from family members was used.

Where the investigation necessitated splitting the samples into several small groups, some rare variants were so infrequently represented that the variant had to be discarded.

Factors affecting the incidence of cranial variants were then investigated as follows:

(1) *Sexual differences*

Incidences for each variant were calculated for males and females separately. These incidences were compared with those from samples from Mexico (Guadarrama, 1973), North West coast American Indians (Finnegan, 1972) and Burma (Berry & Berry, 1967).

Contingency $\chi^2$ for sex was calculated for each character from each sample separately to determine for which variants sexual differences were apparent and to see whether these differences were consistent from sample to sample.

(2) *Age dependency*

The St Bride's material was separated into seven age groups, as follows:

| | | | |
|---|---|---|---|
| 1. | Under 29 inclusive | 15♂ | 8♀ |
| 2. | 30–39 inclusive | 7♂ | 13♀ |
| 3. | 40–49 inclusive | 11♂ | 11♀ |
| 4. | 50–59 inclusive | 15♂ | 12♀ |
| 5. | 60–69 inclusive | 22♂ | 26♀ |
| 6. | 70–79 inclusive | 12♂ | 15♀ |
| 7. | Over 79 | 5♂ | 7♀ |

The incidence of variants within these age groups was calculated for males and females separately and these incidences plotted against age group on a graph. As the number of crania falling into each age range was inevitably small, particularly in the younger age groups, the figures for males and females were pooled and plotted where no trend was indicated from the separated incidences. Student's '*t*' test was used to ascertain whether the mean chronological ages of skulls in which each variant occurred differed significantly from the mean age of those without the variant.

(3) *Effect of year of birth*

The St Bride's material was divided into four groups depending on the year of birth of the owner of the skull.

| | | | |
|---|---|---|---|
| 1. | Born 1720–49 | 18♂ | 17♀ |
| 2. | Born 1750–69 | 31♂ | 22♀ |
| 3. | Born 1770–89 | 18♂ | 25♀ |
| 4. | Born 1790–1820 | 15♂ | 19♀ |

The slightly irregular intervals were chosen to allow groups to be made up of reasonably uniform numbers of crania.

Any crania falling outside these dates were discarded. The incidences of the variants were calculated and treated as for the age correlation study. Age distributions within the groups were also noted.

(4) *Association with rickets*

The St Bride's collection had been intensively studied previously and the occurrence of rickets noted. Crania were divided into rachitic and non-rachitic, and the incidence of each variant for each group calculated. Since numbers in the rachitic group were small, male and female incidences were pooled. The $\chi^2$ test was used to examine heterogeneity between the two groups.

(5) *Spina bifida occulta*

The presence of this vertebral arch abnormality was recorded wherever noted.

Other minor vertebral anomalies were also noted, but the investigations described below were confined to skeletons with spina bifida occulta.

The incidence of all the cranial variants were calculated for skulls from spina bifida occulta and normal skeletons which had both skull and sacrum available. The incidence of the variants in the two groups were compared and tested for lack of homogeneity.

All investigations applied to the cranial variants were also applied to spina bifida occulta – i.e. its distribution according to sex, age, historical period and rickets.

(6) *Family studies*

In a few cases it was possible to establish family groupings in which the relationships could be inferred. In spite of the small numbers and uncertain relationships, family studies were undertaken to see if there was any increased tendency for certain variants to occur more frequently in certain families.

## RESULTS

(1) *Sexual differences*

Variants showing statistically significant sexual heterogeneity are shown in Table 1, where they are compared with samples from different parts of the world. It can be seen that sexual differences do occur, and appear to be common in the largest sample and rare in the Mexican sample. This may well be a statistical artefact because statistical significance is difficult to demonstrate in small samples. The consistency of these differences varied considerably. The highest nuchal line appeared more frequently in males from London and Burma but in both American samples it predominated in females. The foramen of Hüschke occurred more commonly in females in all samples. This was highly significant statistically for N.W. coast America and for Burma but insignificant in the London and Mexican samples. Absence of the mastoid foramen behaved similarly. The frequency of the ossicle at the asterion was highly significantly more common in males in both London and N.W. coast American Indians, but this was not apparent in the other groups. Frontal foramina likewise predominate markedly in males from the London and Burma samples, but not elsewhere. In three samples the epipteric bone occurred more commonly in females, but in only one sample did this trend reach statistical

Table 1. *Incidence of non-metrical variants in males and females from different world regions*

| | St Bride's, London | | Burma | | North West coast of America | | Mexico | |
|---|---|---|---|---|---|---|---|---|
| | ♂ | ♀ | ♂ | ♀ | ♂ | ♀ | ♂ | ♀ |
| N | 89 | 93 | 26 | 25 | 149 | 137 | 28 | 34 |
| | (%) | (%) | (%) | (%) | (%) | (%) | (%) | (%) |
| 1. Highest nuchal line present | 18·9 | 8·7* | 17·3 | 8·0 | 16·5 | 36·5** | 8·3 | 25·8* |
| 2. Ossicle at lambda present | 8·3 | 7·9 | 19·2 | 8·0 | 7·3 | 10·2 | 36·4 | 28·4 |
| 3. Lambdoid ossicle present | 28·7 | 17·1* | 34·6 | 24·0 | 27·5 | 24·0 | 64·0 | 66·7 |
| 4. Parietal foramen present | 62·7 | 60·4 | 50·0 | 50·0 | 43·2 | 50·0 | 47·7 | 51·6 |
| 5. Bregmatic bone present | 1·3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6. Metopism | 2·5 | 4·1 | 0 | 0 | 2·0 | 3·6 | 3·7 | 2·9 |
| 7. Coronal ossicle present | 0 | 0 | 1·9 | 0 | 0 | 0 | 20·8 | 17·2 |
| 8. Epipteric bone present | 4·9 | 12·6* | 17·3 | 12·0 | 6·0 | 9·5 | 0 | 6·5 |
| 9. Fronto-temporal articulation | 0 | 0 | 0 | 6·0 | 1·0 | 2·2 | 0 | 0 |
| 10. Parietal notch bone present | 8·4 | 5·1 | 5·8 | 10·0 | 18·1 | 14·2 | 3·4 | 10·3 |
| 11. Ossicle at asterion present | 15·9 | 5·2** | 9·6 | 10·0 | 17·1 | 9·4** | 9·1 | 6·7 |
| 12. Foramen of Hüschke present | 7·2 | 11·2 | 11·5 | 38·0** | 25·5 | 40·1** | 5·1 | 7·7 |
| 13. Mastoid foramen exsutural | 36·7 | 36·9 | 48·1 | 44·0 | 38·9 | 33·9 | 53·6 | 50·0 |
| 14. Mastoid foramen absent | 1·3 | 2·5 | 0 | 16·0** | 17·4 | 24·6* | 6·1 | 13·2 |
| 15. Posterior condylar canal patent | 21·5 | 31·0 | 57·7 | 31·2* | 16·5 | 14·6 | 47·1 | 39·1 |
| 16. Condylar facet double | 0 | 0·6 | 2·1 | 0 | 0 | 0·3 | 0 | 0 |
| 17. Precondylar tubercle present | 3·6 | 6·4 | 5·8 | 14·0 | 5·3 | 9·4 | 16·7 | 1·9 |
| 18. Anterior condylar canal double | 21·6 | 22·7 | 17·3 | 2·0* | 15·4 | 20·8 | 11·8 | 11·8 |
| 19. Foramen ovale incomplete | 0·7 | 0·6 | 6·0 | 10·4 | 3·7 | 3·6 | 0 | 8·3 |
| 20. Foramen spinosum open | 2·0 | 4·2 | 7·8 | 12·8 | 14·4 | 16·9 | 0 | 15·2 |
| 21. Accessory lesser palatine foramen present | 69·2 | 58·9 | 34·7 | 29·2 | 36·4 | 30·7 | 47·4 | 59·5 |
| 22. Maxillary torus present | 1·4 | 7·8* | 0 | 0 | — | — | 0 | 0 |
| 23. Palatine torus present | 29·0 | 48·1* | 0 | 0 | 9·3 | 20·4** | 7·1 | 0 |
| 24. Zygomatico-facial foramen absent | 12·0 | 12·9 | 17·6 | 18·0 | 14·5 | 13·9 | 12·5 | 29·7 |
| 25. Supra-orbital notch closed | 13·8 | 17·0 | 19·2 | 8·0 | 49·3 | 35·0** | 51·2 | 50·8 |
| 26. Frontal foramen present | 69·0 | 45·5** | 42·3 | 22·0* | 19·7 | 15·3 | 79·1 | 87·0 |
| 27. Anterior ethmoid foramen exsutural | 13·6 | 7·5 | 26·2 | 25·0 | 41·6 | 31·4* | 12·5 | 14·3 |
| 28. Posterior ethmoid foramen absent | 3·2 | 2·7 | 0 | 0 | 1·5 | 4·7* | 16·7 | 7·7 |
| 29. Accessory infraorbital foramen present | 2·2 | 4·8 | 6·4 | 8·7 | 12·5 | 7·9 | 18·2 | 12·5 |
| 30. Auditory torus present | — | — | — | — | 1·3 | 0** | 12·6 | 9·7 |
| 31. Os Japonicum present | — | — | — | — | 0 | 0·3 | 0 | 0 |
| 32. Inca bone present | — | — | — | — | 4·6 | 2·9 | — | — |
| 33. Paramastoid process independent | — | — | — | — | 44·1 | 34·4** | 14·3 | 0 |

* Significant at 0·05 level.
** Significant at 0·01 level.
These values have been calculated by a different method (using angular value $\theta$) for North West coast of America (see Finnegan, 1972).

Table 2. *Age distribution of non-metrical variants in crania from St Bride's, London (sexes pooled)*

| | Age in years | | | | | | |
|---|---|---|---|---|---|---|---|
| | Under 29 | 30–39 | 40–49 | 50–59 | 60–69 | 70–79 | Over 80 |
| N | 23 | 20 | 22 | 27 | 48 | 27 | 12 |
| | (%) | (%) | (%) | (%) | (%) | (%) | (%) |
| 1. Highest nuchal line present | 29·0 | 8·8 | 12·1 | 11·1 | 17·4 | 4·2 | 7·1 |
| 2. Ossicle at lambda present | 15·0 | 20·0 | 5·3 | 5·0 | 7·0 | 5·0 | 0 |
| 3. Lambdoid ossicle present | 25·0 | 27·6 | 17·6 | 21·1 | 21·8 | 21·3 | 22·2 |
| 4. Parietal foramen present | 60·5 | 71·9 | 52·5 | 60·0 | 58·7 | 73·5 | 60·0 |
| 8. Epipteric bone present | 3·3 | 18·8 | 5·9 | 8·8 | 7·1 | 15·6 | 0 |
| 10. Parietal notch bone present | 10·5 | 20·0 | 5·7 | 6·7 | 4·9 | 0 | 10·0 |
| 11. Ossicle at asterion present | 11·8 | 9·1 | 6·1 | 13·0 | 7·4 | 18·4 | 5·3 |
| 12. Foramen of Hüschke present | 0 | 2·6 | 7·3 | 6·1 | 11·8 | 16·7 | 20·8 |
| 13. Mastoid foramen exsutural | 44·7 | 44·1 | 13·9 | 28·3 | 35·7 | 46·9 | 45·0 |
| 15. Posterior condylar canal patent | 13·2 | 25·6 | 20·0 | 39·0 | 30·5 | 19·2 | 35·0 |
| 17. Precondylar tubercle present | 2·5 | 7·5 | 2·4 | 2·2 | 6·7 | 9·3 | 0 |
| 18. Anterior condylar canal double | 20·0 | 35·0 | 20·5 | 22·7 | 20·7 | 16·7 | 27·3 |
| 20. Foramen spinosum open | 0 | 0 | 2·6 | 2·6 | 3·4 | 7·5 | 4·5 |
| 21. Accessory lesser palatine foramina | 46·4 | 52·9 | 70·3 | 69·0 | 72·7 | 64·6 | 61·1 |
| 22. Maxillary torus present | 17·2 | 9·7 | 2·6 | 0 | 1·4 | 9·1 | 0 |
| 23. Palatine torus present | 41·2 | 29·4 | 36·8 | 28·6 | 45·9 | 45·8 | 50·0 |
| 24. Zygomatico-facial foramen absent | 22·7 | 8·0 | 9·4 | 15·8 | 15·0 | 2·6 | 10·5 |
| 25. Supra-orbital notch closed | 3·6 | 6·7 | 23·1 | 20·9 | 16·9 | 16·7 | 5·0 |
| 26. Frontal foramen present | 57·7 | 71·4 | 40·5 | 61·5 | 54·4 | 60·9 | 55·0 |
| 27. Anterior ethmoid foramen exsutural | 12·5 | 16·1 | 15·2 | 9·8 | 7·1 | 9·3 | 0 |
| 28. Posterior ethmoid foramen absent | 6·2 | 0 | 2·7 | 9·5 | 0 | 2·2 | 0 |
| 29. Accessory infraorbital foramen present | 4·2 | 0 | 11·5 | 2·9 | 0 | 8·3 | 6·2 |

significance. The oral tori appear to predominate in females in London and the N.W. coast of America (palatine tori only) but since they occurred so rarely in the other samples, this question could not be pursued.

(2) *Age dependency*

The distribution of the variants according to age group is shown in Table 2. Where the male and female distributions are of interest they are shown graphically (Fig. 1). In the following account the mean ages are followed by their standard errors.

Mean age of sample = 54·6 ± 1·4 years,
mean age of 87 ♂ crania = 52·8 ± 2·1 years,
mean age of 92 ♀ crania = 56·3 ± 1·9 years.

There were no statistically significant differences in mean ages of crania with and without a variant except for the foramen of Hüschke.

Mean age of 25 crania with variant = 66·5 ± 2·6 years,
mean age of 157 crania without variant = 51·7 ± 1·6 years.

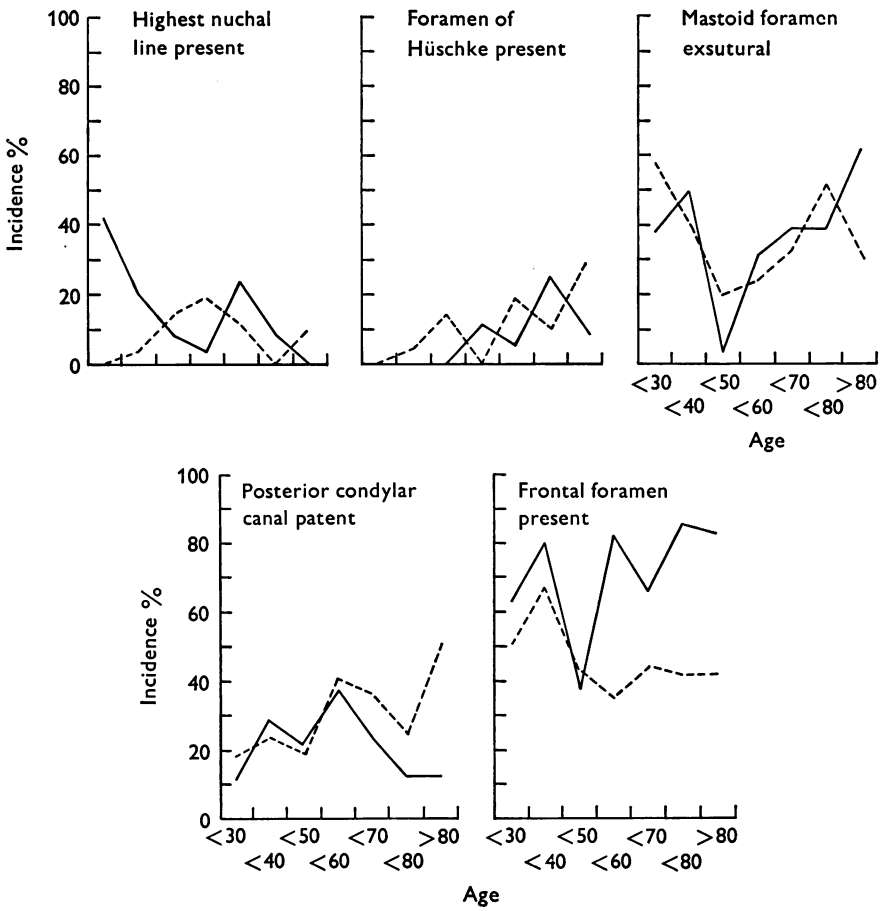


Fig. 1. Showing incidence of 5 variants in males (——) and females (– – –) in different age groups.

Thus crania with a foramen of Hüschke were highly significantly older than those without ($P < 0{\cdot}001$).

For two variants the difference between the two mean ages approached statistical significance.

(i) Mean age of 55 crania with posterior condylar canal patent = $58{\cdot}6 \pm 2{\cdot}3$ years, mean age of 124 crania without posterior condylar canal patent = $52{\cdot}9 \pm 1{\cdot}7$ years,
difference: 5·7 years; S.E. 3·0.

(ii) Mean age of 38 crania with supra-orbital notch closed = $58{\cdot}5 \pm 2{\cdot}2$ years, mean age of 141 crania without supra-orbital notch closed = $53{\cdot}5 \pm 1{\cdot}6$ years, Difference: 5·0 years; S.E. 2·8.

(3) *Historical distribution*

The distribution of the variants according to year of birth is given in Table 3, and the age of the crania within each of these cohorts is shown in Fig. 2.

Table 3. *Distribution of non-metrical variants according to year of birth (sexes pooled)*

| | Year of birth | | | |
|---|---|---|---|---|
| | 1720–49 | 1750–69 | 1770–89 | 1790–1820 |
| N | 35 | 53 | 43 | 34 |
| | (%) | (%) | (%) | (%) |
| 1. Highest nuchal line present | 10·2 | 12·0 | 15·7 | 17·7 |
| 2. Ossicle at lambda present | 1·3 | 6·7 | 6·5 | 6·5 |
| 3. Lambdoid ossicle present | 33·9 | 16·7 | 19·4 | 24·6 |
| 4. Parietal foramen present | 61·3 | 65·3 | 62·2 | 56·7 |
| 8. Epipteric bone present | 13·2 | 10·6 | 5·0 | 6·1 |
| 10. Parietal notch bone present | 14·0 | 2·1 | 4·2 | 12·3 |
| 11. Ossicle at asterion present | 10·7 | 9·6 | 11·0 | 9·4 |
| 12. Foramen of Hüschke present | 16·4 | 9·7 | 8·5 | 3·2 |
| 13. Mastoid foramen exsutural | 45·9 | 37·1 | 27·0 | 42·3 |
| 15. Posterior condylar canal patent | 26·6 | 31·3 | 22·5 | 25·9 |
| 17. Precondylar tubercle present | 6·1 | 6·7 | 5·2 | 5·2 |
| 18. Anterior condylar canal double | 15·6 | 25·0 | 28·9 | 22·4 |
| 20. Foramen spinosum open | 0 | 4·0 | 4·3 | 0 |
| 21. Accessory lesser palatine foramina | 68·5 | 63·8 | 67·2 | 62·2 |
| 22. Maxillary torus present | 5·4 | 3·2 | 1·5 | 11·3 |
| 23. Palatine torus present | 29·6 | 41·7 | 36·4 | 38·5 |
| 24. Zygomatico-facial foramen absent | 11·1 | 11·7 | 10·7 | 16·3 |
| 25. Supra-orbital notch closed | 7·4 | 15·6 | 21·7 | 13·0 |
| 26. Frontal foramen present | 50·0 | 66·7 | 51·6 | 50·0 |
| 27. Anterior ethmoid foramen exsutural | 4·1 | 9·1 | 11·9 | 16·0 |
| 28. Posterior ethmoid foramen absent | 0 | 5·5 | 1·4 | 4·0 |
| 29. Accessory infraorbital foramen present | 2·4 | 0 | 7·0 | 0 |
| No. of skulls from each age group: | | | | |
| Under 29 | 1 | 2 | 2 | 16 |
| 30–39 | 2 | 4 | 5 | 8 |
| 40–49 | 3 | 2 | 8 | 6 |
| 50–59 | 4 | 9 | 12 | 2 |
| 60–69 | 11 | 21 | 12 | 2 |
| 70–79 | 7 | 12 | 4 | 0 |
| Over 80 | 7 | 3 | 0 | 0 |

Only one variant (foramen of Hüschke present) showed a statistically significant difference between the means of year of birth in those with and without the variant.

Mean year of birth of all crania = $1768{\cdot}3 \pm 1{\cdot}8$ years,
mean year of birth of 83 ♂ crania = $1766{\cdot}5 \pm 2{\cdot}5$ years,
mean year of birth of 83 ♀ crania = $1700{\cdot}2 \pm 2{\cdot}5$ years,
mean year of birth of 13 rachitic crania = $1770{\cdot}7 \pm 6{\cdot}1$ years,
for 23 crania with foramen of Hüschke, mean year of birth = $1757{\cdot}3 \pm 4{\cdot}1$ years,
for 143 crania without foramen of Hüschke, mean year of birth = $1770{\cdot}1 \pm 1{\cdot}9$ years.

Thus individuals with crania with this variant were born significantly earlier than those without ($P < 0{\cdot}01$).

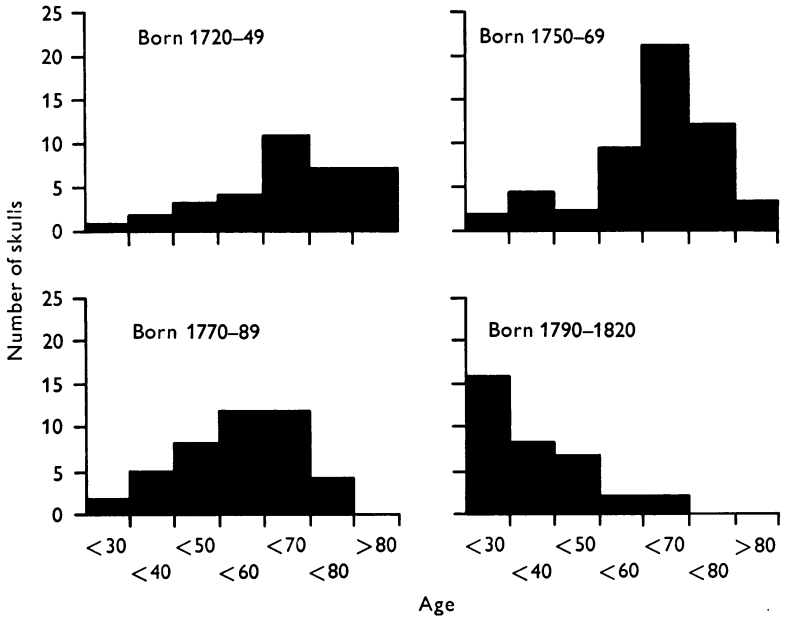


Fig. 2. Showing age distribution of skulls born in each historical period.

(4) *Association with rickets*

No differences even approaching statistical significance were found between the 15 rachitic skulls and the 167 normal skulls.

(5) *Spina bifida occulta*

165 sacra were scored; 28 showed clefts and abnormalities of either the first or fifth piece of the sacrum, giving an incidence of 17·0 %.

One vertebral column showed a bony abnormality likely to be associated with spina bifida cystica, but skin cover must have been intact because the child lived for 7 years. Five vertebral columns showed clefts of the atlas or axis, one of these being coincident with a sacral cleft.

Thus vertebral anomalies occurred in 33 vertebral columns, giving an incidence of 20·0 %.

*Variant incidences.* Incomplete foramina spinosa occurred considerably more frequently ($P < 0{\cdot}005$) in skeletons with spina bifida occulta than in normals. No other evidence of heterogeneity between the two groups was found.

*Sex distribution.* 15 affected skeletons were male, 13 affected skeletons were female.

*Age distribution.* The mean age of affected skeletons = $50{\cdot}5 \pm 3{\cdot}8$ years, which is not statistically significantly different from the population mean of $54{\cdot}6 \pm 1{\cdot}4$ years.

*Historical distribution.* Affected skeletons had a mean year of birth of $1771 \pm 4{\cdot}3$ years which is not significantly different from the population mean year of birth $1768 \pm 1{\cdot}8$ years.

*Rickets.* There was no difference between normals and affected skeletons with regard to the distribution of rickets.

(6) *Family studies*

Ten different families were thought to contain two or more related individuals. In the majority of these only two or three skeletons were available, but one family comprised eight apparently related members spread over three generations.

No 'within family' clustering was apparent for any variant in the small families. In the eight membered family there was clustering of only one variant: the foramen of Hüschke occurred in three of the eight crania, being bilateral in two of these.

The average age at death of the material from this family was only 44 years, so the clustering cannot be explained on a geriatric basis.

*Spina bifida occulta.* No dramatic evidence of clustering within families was found for this condition.

A boy with a cervical cleft had a probable relative in the grand-parental generation with spina bifida occulta, but two other males of the intermediate generation were unaffected.

The man who had both cervical and sacral clefts was recorded as having two children, one with a sacral cleft and one with a separate upper sacral arch.

## DISCUSSION

### *Sexual differences*

Although the original search for different variant incidences in the two sexes (Berry & Berry, 1967) revealed not a single statistically significant difference, later workers (see above) have found sexual differences in their samples. This finding is confirmed by the new material presented here. The 1967 study erred in taking male skulls from both Egyptian and Burmese samples in order to increase the numbers available for statistical analysis. If consistent sexual dimorphisms existed they should have been revealed by this method, but on hindsight it can be seen that the few dimorphisms present in the small Burmese sample were diluted out of statistical significance by the addition of the Egyptian material. There has also been a reappraisal of the situation in mice. Many laboratory studies in the past produced no evidence of sexual dimorphisms, but recent work on wild living house mice has shown that the incidence of several variants was affected by the sex of the animal (Berry & Jakobson, 1975).

In non-human primates the variants seem to be evenly distributed between the sexes. In galagos, only 1 variant of 20 was found to be statistically significantly more common in males (Berry, 1974*a*), while in gorillas only 2 out of 32 characters showed heterogeneity (Berry & Berry, 1971). Interestingly, one of these was the predominance of epipteric bones in males, the opposite trend to that noted above in the human samples.

Nevertheless it appears to be established that sexual differences in variant incidence do occur in human crania. However, Table 1 demonstrates that there is little consistency in the occurrence of these dimorphisms, and a variant predominating in males in one sample may predominate in females in another. This is particularly well illustrated by the highest nuchal line and, unless cultural factors are brought into

consideration, it is very difficult to explain. The variant is unsatisfactory in other respects, being difficult to score objectively, particularly in poor material, so its use could well be abandoned.

The foramen of Hüschke is significantly more common in females in Burma and the North West coast of America. In London the trend is in the same direction, but by no means reaches significance, the same being true of Corruccini's (1974) Negro sample. Finnegan (personal communication) believes this to be due to earlier ossification of the female skeleton, and different timing of the development of the external auditory canal, in male and female infants. However, since this character shows age dependence (see Table 2) it will be discussed again later.

There is no ready explanation for the persistent female predominance of 'absent mastoid foramina'. Corruccini's (1974) samples show a similar slight female preponderance in both Negroes and Whites.

Other general trends are the sometimes significant male predominance of presence of the ossicle at the asterion and the female predominance of the presence of the epipteric bone, another sutural bone. The aetiology of sutural bones has been well discussed (Bennett, 1965; Ossenberg, 1970) but it is not sufficiently understood to enable these slight sexual dimorphisms to be explained.

The distribution of tori between the sexes is complicated by the fact that auditory tori were only present in the American samples, where they predominated in males; whereas maxillary tori predominated in females in London, the only sample in which they occurred. Palatine tori predominated in females in both North West coast America and London, but earlier workers reported varying results for both palatine and mandibular tori (Hrdlicka, 1940; Miller & Roth, 1940; Moorees, Osborne & Wilde, 1952; Mayhall, Dahlberg & Owen, 1970).

Such lack of consistency seems to characterize the sexual distribution of the non-metrical variants under review. It confirms the idea that they are the outward manifestation of the activity of genetic, epigenetic and even overtly environmental forces, and are a long way from the primary site of gene action. This does not invalidate their usefulness as anthropological tools because, if sufficient variants are used, the proportion of the genome represented by them is so much greater than when single gene characters alone are used. Where possible, however, it would seem wiser to include equal numbers of crania of each sex in samples under investigation. When, as so often happens, this ideal cannot be reached, sexual dimorphisms may well dilute each other or act in opposite directions in different samples, so that, provided an adequate number of variants are used, the final distinction between the samples is likely to be unaffected by sexual dimorphisms. The opposite, however, may occur, so that an apparently large difference between two samples may occasionaly be due to the summation of differences in distribution of variants with imbalanced sex ratios.

*Age dependency*

The lack of adequate material of known chronological age makes it almost impossible to judge the age dependency of non-metrical variants. Adult skeletons are almost impossible to age accurately, and in any collection young and middle-aged material is almost certain to be less common than elderly material. Since the variants' behaviour tends to differ from population to population, as was discussed above,

pooling of material is not feasible and so unsatisfactorily small numbers of crania in each age group have to be accepted.

Table 2 demonstrates that the St Bride's material shows very little age dependency among the variants. The only variant showing a statistically significant increase in incidence with increasing age is the foramen of Hüschke, the trend being evident in both males and females (Fig. 1). Since elderly females tend to be over-represented in many civilian cranial samples, this could explain the female predominance in the incidence of this variant, as was discussed above. Why this variant should be more common with increasing age is not clear; post-menopausal osteoporosis might be an acceptable explanation for females, but not for males. Corruccini's (1974) material showed no age dependency for this variant.

Two other variants tend to show some (though statistically insignificant) age dependency. 'Posterior condylar canal patent' (its 'hypo-ostotic' form) tends to occur in the older skulls. The opposite, however, occurs with the supra-orbital foramen, where the closed 'hyperostotic' form has the higher mean age. The strikingly high incidence of highest nuchal line in young males apparent in Figure 1 is based on small numbers, and is most likely a sampling effect.

In general, however, age dependency is not a problem. Ossenberg (1970) reached a similar conclusion, although she observed a slight tendency for 'hyper-ostotic' traits to be age progressive whereas 'hypo-ostotic' traits tended to be mildly age regressive. Corruccini (1974) reported significant differences between 'older' and 'younger' samples for several traits, but there was no consistency in their occurrence, and their importance seemed to depend on the statistic used. Using 61 variants, and 4 samples, random error could account for half these dependencies, and it is impossible to know which are real and which are chance findings. Finnegan (1974, personal communication) found such slight age regression in post-cranial traits that it could be neglected in practice. This lack of age dependence in adult life is perhaps to be expected if the variants are considered to be in-built characteristics of the skeletal system of the individual: however, some traits may be very late in appearing. Korey (1970) found correlations with age for several characters if prepubertal material was used, but Buikstra (1972) showed that these disappeared if all individuals under 12 years of age were excluded and if youthful material showing partial trait expression is included along with older material showing the complete trait. She considers that ossification processes underlying certain traits, e.g. 'incomplete foramen spinosum' and 'double anterior condylar canal', are not completed until adult life, but are indicated by partial bridging in younger skulls.

In conclusion, it seems that age correlations need not be considered when dealing with adult material, with the possible exception of the foramen of Hüschke; but caution is essential when prepubertal material is studied.

*Effect of year of birth*

Only the foramen of Hüschke showed any statistically significant tendency to be related to the birth cohort of its skull, those having the variant tending to be born earlier than those without. Since younger crania predominate in the later cohorts (Fig. 2), this effect is most likely to be a simple consequence of the age-dependency shown by this particular variant. It is conceivable that malnutrition, affecting chiefly

those born in the earlier years of the period under review, could have been responsible for failure of ossification. But against this hypothesis is the fact that the crania from skeletons with frank rickets had a mean year of birth slightly *later* historically than the mean for the St Bride's series as a whole: and also the association of the foramen of Hüschke with age is much stronger statistically than is the relationship with birth cohort.

This lack of effect of year of birth is by no means surprising. Brothwell (1965) has demonstrated variation in incidences of several variants traced over several thousand years, whereas only slight changes were found in Egyptian samples over 5000 years (Berry *et al.* 1967). Work on mice living wild on a genetically isolated island showed that certain variants waxed and waned in their incidence over the ten years of the study (Berry & Jakobson, 1975). Any trends found in the small numbers sampled from the population of the city of London over a hundred years would most likely reflect environmental pressures, provided that foreign immigration can be discounted.

The crania belong to an era when considerable change must have been occurring in the Fleet Street area, as the industrial revolution and urbanization were progressing rapidly at this time. During the period under review diets were altering, with sugar consumption per person quadrupling. The population of London increased twenty-fold while Public Health measures were virtually non-existent (Harvey, 1968). None of these factors, however, appears to have affected the incidence of the variants, although one would have liked to have had larger numbers of crania to examine.

*Association with rickets*

There were no statistically significant associations between the variants and crania from rachitic skeletons, although it must be admitted that the numbers were very small. So far as it goes, however, this result supports the view that the presence or absence of the variants largely relates to the inherent make-up of the individual. Since modelling of bone is so much affected in rickets, certain of the variants might well have been vulnerable. However, once again the smallness of the numbers studied must be emphasized.

*Spina bifida occulta*

A particularly interesting finding was the very high incidence of this condition, so that, if it is considered together with other minor vertebral abnormalities, the combined incidence reached 20%. Jørgensen & Vesely (1974) noted 'spina bifida' in 2 of 14 adult Greenland Eskimo skeletons from the seventeenth to eighteenth century and stated that lower spinal deformities were frequent in Eskimos.

In Britain, similar high values have been reported by Laurence (1970) in living inhabitants of Wales. These anomalies were recognized from X-rays taken for various medical reasons. He delineated two distinct groups of vertebral anomalies, which he termed mild and severe (although both were apparently symptomless).

These incidences, which were collected as part of a study on the incidence of vertebral anomalies in first degree relatives of spina bifida cystica (S.B.C.) patients, are shown in Table 4.

If control adults only are considered, the incidence rate is surprisingly similar to

Table 4. *Incidence of spinal anomalies*

| | Mild anomaly (%) | Severe anomaly (%) |
|---|---|---|
| Adults | | |
| Controls | 20 | 1 |
| Parents of S.B.C. patients | 20 | 4 |
| Children under 20 | | |
| Controls | 36 | 8 |
| Sibs of S.B.C. patients | 54 | 26 |

the findings of the present study. Since X-rays cannot be as discerning as actual inspection of the bones it is to be expected that some very minor defects noted in the St Bride's bones would be missed in radiographs. Wales, however, is a high incidence area for spina bifida cystica (Carter, David & Laurence, 1968) so if this condition is related to the minor anomalies a higher incidence of these anomalies would be expected in Wales than in London (Carter & Evans, 1973). Laurence, however, does not accept that 'mild' vertebral anomalies, including spina bifida occulta are, in fact, continuous with spina bifida cystica, though he proposes that 'severe' anomalies are related to the pathological condition. He reaches this conclusion because of the three to fourfold increase in the incidence of 'severe' anomalies in first degree relatives of patients with spina bifida cystica, while there is no increase in 'mild' anomalies in parents and much less increase in 'mild' than in 'severe' anomalies in sibs.

If, however, these bony variants are considered as forming a wide spectrum of anomalies from those barely scoreable up to those incompatible with life, an increase of 'severe' minor anomalies would be expected in relatives of pathologically affected individuals if multifactorial control of the bony variations is assumed, since in these families the expression of the anomalies would be shifted in the 'severe' direction.

The equal sex ratio and lack of effect of age or historical period on the occurrence of spina bifida occulta might have been expected, but the association with incomplete foramen spinosum was surprising. This may indicate a real tendency to incomplete closures throughout the skeleton, although there was no evidence of any association with other variants of this type. One might expect, on this basis, to find an increased incidence of failure of midline fusions (e.g. metopism), but this was not apparent. No correlations of any importance between the cranial traits have been found (Berry & Berry, 1967; Benfer, 1970), except in the case of some sutural bones (Hertzog, 1968). No other searches for correlations between cranial and post-cranial traits have been published and indeed it seems unlikely that such searches would be productive.

*Family studies*

With the very small amount of family material that was available it was not really surprising that no convincing evidence of clustering of variants within families was found.

If such clustering had been found it would have suggested a simple, single gene

type of control of variant expression, which would be at variance with the complex multifactorial control described above for mice. Using material from parents and children from 122 Liverpool families it has been possible to show significant 'within family' correlations for the presence or absence of a number of minor variants of the dental crown (Berry, 1975), but an investigation of this type would be very difficult for skeletal material, though Sjøvold is attempting such a study in a Swedish village.

In an Irish sample of 37 skulls an unusually high incidence of bregmatic bones was found. The labels showed that all those skulls having this rare variant came from the village of Collierstown (Co. Neath) and of the four crania from the village three had a bregmatic bone. The usual incidence of this variant in North European populations is about 1%. It would seem likely therefore that the material came from a family with an unusually high tendency to develop this sutural bone.

When spina bifida occulta is considered the very high sample incidence makes it difficult to demonstrate significant 'within family' clustering. The case in which the father had a cervical cleft and a cleft sacrum and the two offspring had sacral anomalies suggests that in certain families there is a greater tendency to these anomalies than others. The spina bifida cystica family studies of Laurence discussed above would support this.

In conclusion it may be stated that there is no evidence that the non-genetical factors investigated here have any great effect on the expression of the variants. The irregular influences of sex in differing samples underscore the belief that the factors controlling their manifestation are both numerous and complexly intertwined, but, in practice, the sexes should be scored separately when possible. There seems to be little evidence for the suggested correlation of the variants with age in adult crania, only one variant out of thirty being age-related in the present investigation: the other factors studied showed negligible age influence. The high incidence of sacral spina bifida occulta is intriguing as it seems it must have a bearing on the comparatively common pathological spina bifida cystica, but no real light is thrown on the aetiology of the condition. The single high-incidence family, however, suggests that inherited tendencies are at work.

Although much more precise evaluation of non-genetical factors is desirable, this study upholds the belief that genetical factors, although far removed from the final anatomical detail, are the major determinants of variant expression, a conclusion also reached by Corruccini (1974). These variants therefore provide a valuable genetical tool for the physical anthropologist.

## SUMMARY

Non-metrical variants of the human cranium have been studied in 186 London crania of known age, sex and date of birth. The incidence of several variants was different in the two sexes, and these results were compared with those of other workers from different parts of the world. Few variants persistently favoured one sex: the majority behaved inconsistently.

Age dependency was only demonstrated for one variant, while year of birth, presence of rickets, and spina bifida occulta, showed negligible influence on variant incidence.

20% of vertebral columns examined included an anomalous vertebra, usually sacral spina bifida occulta. Although family studies were largely inconclusive, this investigation provides no reason to doubt the basic genetical control of these variants.

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