ORKNEY’S FIRST FARMERS

Reconstructing biographies from osteological analysis to gain insights into life and society in a Neolithic community on the edge of Atlantic Europe.

Volume 2 of 2

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Doctor of Philosophy

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University of Bradford

2012
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Oral, Dental and Periodontal Disease at Isbister

“Ulceration and sloughing of the edges of the gums takes place, leading to loosening and loss of the teeth...”

Colyer and Sprawson 1946:533

<table>
<thead>
<tr>
<th>Condition</th>
<th>Severity of Cases Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
</tr>
<tr>
<td>Periodontal disease</td>
<td>-</td>
</tr>
<tr>
<td>Ante mortem tooth loss</td>
<td>-</td>
</tr>
<tr>
<td>Ante mortem tooth loss in complete adult arcades (0/14 additional young adults)</td>
<td>12/27</td>
</tr>
</tbody>
</table>

Mandibular Pathology

<table>
<thead>
<tr>
<th>Condition</th>
<th>Severity of Cases Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
</tr>
<tr>
<td>Periodontal disease</td>
<td>-</td>
</tr>
<tr>
<td>Ante mortem tooth loss</td>
<td>-</td>
</tr>
<tr>
<td>Alveolar resorption</td>
<td>-</td>
</tr>
</tbody>
</table>

NB Severity will be greater than appears because several slight cases may belong to single individuals but could not be conjoined; absence could rarely be observed.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Slight</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Periodontal disease (after Ogden 2008)</td>
<td>Alveolar porosity, resorption slight only (stage 2)</td>
<td>Alveolar porosity clear resorption, (stage 3)</td>
<td>Extensive resorption, (stage 4)</td>
</tr>
<tr>
<td>Tooth loss</td>
<td>1-2 teeth lost</td>
<td>3-6 teeth lost</td>
<td>7+ teeth lost</td>
</tr>
</tbody>
</table>

Note that, unlike the maxillary lesions, alveolar resorption was recorded separately, because it was not obviously related to periodontal disease.

Mandibles exhibited remodelling with subsequent loss of evidence for infection.

It is possible that ante-mortem tooth loss will have resulted from trauma:
including violence and/or non-masticatory activity (Merbs 1983:177ff), although a combination of factors is likely, especially where a tooth was loosened by periodontal disease and was particularly vulnerable.

The prevalence of enamel hypoplasia seems low at Isbister compared with other pathological conditions but stressors may have resulted in early death rather than growth disruption (Wood et al. 1992). Similar features appear at Hazleton North (Rogers 1990).
The Isbister assemblage exhibited high prevalences of periodontal disease, ante-mortem tooth loss and palatal pitting but only minor dental attrition or calculus deposition and low prevalence of caries. The distinction of high prevalence in the medial incisors and posterior dentition compared with the lateral incisors and canines may relate to aetiology: anterior tooth loss ante mortem among the Sadlermiut was most likely to result from trauma (Merbs 1983:154ff). The posterior teeth may be more prone to attrition through chewing but neither the relative prevalences between the molars nor their attrition supports this: it is more likely related to infection. The higher prevalences of mandibular first and second molar loss over maxillae may relate to the contrastingly greater prevalences of maxillary premolar loss, although it is difficult to find any compelling explanation.

| Table 158. Ante Mortem Tooth Losses at Isbister (per permanent tooth socket). |
|------------------------------|--------|-----|-----|-----|-----|-----|-----|-----|
|                              | I1     | I2  | C   | P1  | P2  | M1  | M2  | M3  |
| Combined Maxilla             | 12.7%  | 6.6%| 7.1%| 14.9%|12.7%|12.3%|12.4%|23.0%|
| Combined Mandibular          | 10.6%  | 8.2%| 7.8%| 6.9%| 6.4%| 18.1%|20% | 18.5%|

NB The number of sockets may be inflated, mostly for the anterior dentition, because it could include unidentified juvenile fragments. Ante mortem tooth loss was scored only where there was evidence of healing.
Tooth loss occurred predominantly in the adults, rarely in young adults; it appears to have been more common in males than females but not sufficiently to confidently assume significance ($\chi^2=3.655$ with $\nu=1$: $p>0.05$). There is little apparent disparity between the left and right dentitions and this is therefore assumed to be coincidental (in overall maxillary dentitions, $\chi^2=0.677$ for sided males, $\chi^2=0.036$ for females ($p=0.41$ and $p=0.85$ respectively) but comparing male and female left side maxillary dentitions, $\chi^2=2.109$ ($p=0.15$), which accounts for much of the difference between the sexes).

**Table 159. Ante Mortem Tooth Losses Related to Age at Death.**

<table>
<thead>
<tr>
<th>Adults</th>
<th>I1</th>
<th>I2</th>
<th>C</th>
<th>P1</th>
<th>P2</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Left</td>
<td>5/42</td>
<td>4/37</td>
<td>3/35</td>
<td>2/35</td>
<td>6/34</td>
<td>7/33</td>
<td>8/32</td>
<td></td>
</tr>
</tbody>
</table>

In Young Adults

<table>
<thead>
<tr>
<th>Adults</th>
<th>I1</th>
<th>I2</th>
<th>C</th>
<th>P1</th>
<th>P2</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Left</td>
<td>0/15</td>
<td>0/16</td>
<td>1/16</td>
<td>0/16</td>
<td>0/15</td>
<td>0/15</td>
<td>0/15</td>
<td>1/13</td>
</tr>
<tr>
<td>Upper Right</td>
<td>0/15</td>
<td>0/15</td>
<td>0/15</td>
<td>0/15</td>
<td>0/15</td>
<td>0/15</td>
<td>0/15</td>
<td>1/13</td>
</tr>
<tr>
<td>Lower Left</td>
<td>0/11</td>
<td>0/11</td>
<td>0/10</td>
<td>0/12</td>
<td>0/12</td>
<td>0/12</td>
<td>1/13</td>
<td>0/13</td>
</tr>
<tr>
<td>Lower Right</td>
<td>0/11</td>
<td>0/11</td>
<td>0/11</td>
<td>0/12</td>
<td>1/12</td>
<td>0/12</td>
<td>0/12</td>
<td>0/11</td>
</tr>
</tbody>
</table>

**YA:A $\chi^2$**

<table>
<thead>
<tr>
<th></th>
<th>maxillary</th>
<th>mandibular</th>
<th>overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$P=0.01$</td>
<td>$P=0.01$</td>
<td>$P&lt;0.01$</td>
</tr>
<tr>
<td>Upper Left</td>
<td>6.605</td>
<td>5.754</td>
<td>8.788</td>
</tr>
<tr>
<td>Upper Right</td>
<td>3.790</td>
<td>5.684</td>
<td>6.137</td>
</tr>
<tr>
<td>Lower Left</td>
<td>1.019</td>
<td>2.085</td>
<td>2.928</td>
</tr>
<tr>
<td>Lower Right</td>
<td>6.815</td>
<td>2.165</td>
<td>8.579</td>
</tr>
<tr>
<td></td>
<td>$P=0.31$</td>
<td>$P=0.14$</td>
<td>$P=0.09$</td>
</tr>
<tr>
<td></td>
<td>$P&lt;0.01$</td>
<td>$P=0.65$</td>
<td>$P=0.01$</td>
</tr>
<tr>
<td></td>
<td>$P=0.02$</td>
<td>$P=0.02$</td>
<td>$P&lt;0.01$</td>
</tr>
</tbody>
</table>

**NB.** there is no independent age attribution for mandibles: only stage of M3 development and attrition, this may produce misleading results if there are abnormalities. Fisher's exact test was used to confirm the results where numbers were small. $\nu=1$ in each $\chi^2$ test; significant statistical results in bold.

Tooth loss occurred predominantly in the adults, rarely in young adults; it appears to have been more common in males than females but not sufficiently to confidently assume significance ($\chi^2=3.655$ with $\nu=1$: $p>0.05$). There is little apparent disparity between the left and right dentitions and this is therefore assumed to be coincidental (in overall maxillary dentitions, $\chi^2=0.677$ for sided males, $\chi^2=0.036$ for females ($p=0.41$ and $p=0.85$ respectively) but comparing male and female left side maxillary dentitions, $\chi^2=2.109$ ($p=0.15$), which accounts for much of the difference between the sexes).
Table 160. Ante Mortem Maxillary Tooth Loss in Adults, Related to Sex

<table>
<thead>
<tr>
<th>Position</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Upper Left</td>
<td>1/11</td>
<td>1/12</td>
</tr>
<tr>
<td>Upper Right</td>
<td>3/11</td>
<td>1/10</td>
</tr>
<tr>
<td>Lower Left</td>
<td>1/9</td>
<td>0/8</td>
</tr>
<tr>
<td>Lower Right</td>
<td>2/9</td>
<td>1/9</td>
</tr>
</tbody>
</table>

There is no compelling reason to infer side differences.

Table 161. Dental Attrition in Adults at Isbister: Grouped as Slight/Moderate/Heavy (after Smith's {1,2}:{3,4,5}:{6,7,8}) and ante mortem loss (below in bold)

<table>
<thead>
<tr>
<th></th>
<th>I1</th>
<th>I2</th>
<th>C</th>
<th>P1</th>
<th>P2</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(7)</td>
<td>(3)</td>
<td>(4)</td>
<td>(7)</td>
<td>(7)</td>
<td>(6)</td>
<td>(7)</td>
<td>(11)</td>
</tr>
<tr>
<td></td>
<td>(6)</td>
<td>(4)</td>
<td>(3)</td>
<td>(8)</td>
<td>(6)</td>
<td>(7)</td>
<td>(5)</td>
<td>(6)</td>
</tr>
<tr>
<td></td>
<td>(5)</td>
<td>(4)</td>
<td>(3)</td>
<td>(3)</td>
<td>(2)</td>
<td>(6)</td>
<td>(8)</td>
<td>(8)</td>
</tr>
<tr>
<td>Lower Right</td>
<td>0:2:3</td>
<td>0:6:0</td>
<td>2:13:0</td>
<td>19:12:3</td>
<td>7:20:1</td>
<td>4:28:8</td>
<td>12:17:6</td>
<td>14:14:0</td>
</tr>
<tr>
<td></td>
<td>(5)</td>
<td>(4)</td>
<td>(4)</td>
<td>(3)</td>
<td>(4)</td>
<td>(11)</td>
<td>(11)</td>
<td>(9)</td>
</tr>
</tbody>
</table>

NB. Age variation cannot be examined since dental condition was used in age at death estimations; there was no apparent sex-related variation; fully developed loose teeth are included and the number of low scores may be exaggerated through including juveniles. The number of ante mortem losses (brackets, bold) seems unrelated to severe attrition.
Calculus and attrition were examined for relationships with periodontal disease. The crude prevalences suggest that severity of either is not causally related. Rank correlation was applied to the scores tooth by tooth in the maxillae. The only location where correlation was significant in adults was the left first molar (‘26’). There are more significant correlations between calculus or attrition and periodontal disease in the young adult age group than older adults. The right maxilla showed correlations with attrition but this probably indicates simultaneous development, not causality. Calculus was occasionally recorded on roots and frequently at the cervical region, which suggests prior gingival recession.

Slightly different inferences may be drawn from calculus on occlusal surfaces, as visible on the first molars of mandible IS(6795) (Figure 192 below). Such

<p>| Table 162. Dental Calculus in Adults at Isbister: Grouped as None/Slight/Moderate/Heavy (scored after Buikstra and Ubelaker 1994:56); ante mortem loss below in bold |
|---------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|</p>
<table>
<thead>
<tr>
<th>I1</th>
<th>I2</th>
<th>C</th>
<th>P1</th>
<th>P2</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Upper Left</strong></td>
<td>1:1:0:0</td>
<td>-</td>
<td>5:4:0:0</td>
<td>6:2:0:0</td>
<td>8:7:0:0</td>
<td>12:14:2:0</td>
<td>13:8:0:0</td>
</tr>
<tr>
<td></td>
<td>(7)</td>
<td>(3)</td>
<td>(4)</td>
<td>(7)</td>
<td>(7)</td>
<td>(6)</td>
<td>(7)</td>
</tr>
<tr>
<td><strong>Upper Right</strong></td>
<td>-</td>
<td>2:0:0:0</td>
<td>5:4:0:0</td>
<td>5:1:0:0</td>
<td>6:2:0:0</td>
<td>15:11:3:0</td>
<td>13:7:2:0</td>
</tr>
<tr>
<td></td>
<td>(6)</td>
<td>(4)</td>
<td>(3)</td>
<td>(8)</td>
<td>(6)</td>
<td>(7)</td>
<td>(5)</td>
</tr>
<tr>
<td><strong>Lower Left</strong></td>
<td>-</td>
<td>4:0:0:0</td>
<td>4:2:0:0</td>
<td>19:4:1:0</td>
<td>17:5:0:0</td>
<td>23:9:1:0</td>
<td>16:6:0:0</td>
</tr>
<tr>
<td></td>
<td>(5)</td>
<td>(4)</td>
<td>(3)</td>
<td>(3)</td>
<td>(2)</td>
<td>(6)</td>
<td>(8)</td>
</tr>
<tr>
<td><strong>Lower Right</strong></td>
<td>3:0:0:0</td>
<td>0:2:0:0</td>
<td>6:2:0:0</td>
<td>23:1:0:0</td>
<td>19:2:0:0</td>
<td>23:10:0:0</td>
<td>20:4:0:0</td>
</tr>
<tr>
<td></td>
<td>(5)</td>
<td>(4)</td>
<td>(4)</td>
<td>(3)</td>
<td>(4)</td>
<td>(11)</td>
<td>(11)</td>
</tr>
</tbody>
</table>

NB. Age variation cannot be examined since dental condition was used in age at death estimations; there was no apparent sex-related variation; fully developed loose teeth are included and the number of low scores may be exaggerated through including juveniles. The number of ante mortem losses (bracketed in bold) seems unrelated to severity of calculus.
calculus is only likely to form where there is no abrasion from opposing teeth. This is therefore likely to indicate absence of a tooth in the relevant position in the opposite jaw (or possibly some form of obstruction or paralysis that prevents occlusion). These deposits clearly contraindicate later attrition of the tooth.

Other than severe calculus, a major causative factor in periodontal disease is severe dental attrition. Both were rare in the Isbister assemblage but even where attrition was considerable, there was not necessarily periodontal disease (e.g. mandible IS(7271), Figure 193 below). These observations indicate some other causative factor for the ante mortem tooth loss and periodontal disease recorded at Isbister.
Table 163. Rank Correlation of Dental Pathology (Spearman’s ρ).

<table>
<thead>
<tr>
<th>Tooth</th>
<th>Age Group</th>
<th>Calculus vs. Periodontal disease</th>
<th>Attrition vs. Periodontal disease</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ρ</td>
<td>ν</td>
</tr>
<tr>
<td>13</td>
<td>YA</td>
<td>0.729</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>0.259</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>BOTH</td>
<td>0.328</td>
<td>18</td>
</tr>
<tr>
<td>16</td>
<td>YA</td>
<td>0.413</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>-0.214</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>BOTH</td>
<td>0.328</td>
<td>18</td>
</tr>
<tr>
<td>17</td>
<td>YA</td>
<td>0.818</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>0.271</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>BOTH</td>
<td>0.680</td>
<td>15</td>
</tr>
<tr>
<td>18</td>
<td>YA</td>
<td>0.438</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BOTH</td>
<td>0.129</td>
<td>10</td>
</tr>
<tr>
<td>25</td>
<td>YA</td>
<td>0.714</td>
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</tr>
<tr>
<td></td>
<td>A</td>
<td>0.529</td>
<td>4</td>
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<tr>
<td></td>
<td>BOTH</td>
<td>0.189</td>
<td>10</td>
</tr>
<tr>
<td>26</td>
<td>YA</td>
<td>-0.024</td>
<td>9</td>
</tr>
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<td></td>
<td>A</td>
<td>0.670</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>BOTH</td>
<td>-0.188</td>
<td>19</td>
</tr>
<tr>
<td>27</td>
<td>YA</td>
<td>0.721</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>-0.102</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>BOTH</td>
<td>0.157</td>
<td>15</td>
</tr>
<tr>
<td>28</td>
<td>YA</td>
<td>0.330</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BOTH</td>
<td>0.185</td>
<td>10</td>
</tr>
</tbody>
</table>

NB. The age groups have distinct distributions of severity so that correlation may occur over a limited range. The teeth also present different exposure to pathological processes because they erupt at different ages and this is likely to be significant in this sample with young ages at death. Only significant ρ results have p shown, far more are have p<5% than expected.
Table 164. Modal Values and Ranges of Pathology Scores (Ranges in Brackets).

<table>
<thead>
<tr>
<th>Tooth</th>
<th>Age Group</th>
<th>Attrition</th>
<th>Calculus</th>
<th>Periodontal Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>YA</td>
<td>4 (3-5)</td>
<td>2 (1-2)</td>
<td>1 (1-3)</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>5</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>BOTH</td>
<td>5</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>YA</td>
<td>3 (2-4)</td>
<td>1 (1-3)</td>
<td>2 (1-3)</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>6 (3-7)</td>
<td>2 (1-3)</td>
<td>2 (1-4)</td>
</tr>
<tr>
<td></td>
<td>BOTH</td>
<td>3 (2-7)</td>
<td>1 (1-3)</td>
<td>2 (1-4)</td>
</tr>
<tr>
<td>17</td>
<td>YA</td>
<td>2 (2-3)</td>
<td>1 (0-3)</td>
<td>2 (1-4)</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>4 (2-7)</td>
<td>1 (1-2)</td>
<td>2 (2-4)</td>
</tr>
<tr>
<td></td>
<td>BOTH</td>
<td>2 (2-7)</td>
<td>1 (0-3)</td>
<td>2 (1-4)</td>
</tr>
<tr>
<td>18</td>
<td>YA</td>
<td>2 (1-2)</td>
<td>1 (0-2)</td>
<td>0 (0-2)</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>3 (2-5)</td>
<td>1 (0-2)</td>
<td>3 (2-4)</td>
</tr>
<tr>
<td></td>
<td>BOTH</td>
<td>2 (1-5)</td>
<td>1 (0-2)</td>
<td>0 (0-4)</td>
</tr>
<tr>
<td>25</td>
<td>YA</td>
<td>2 (2-3)</td>
<td>2 (0-2)</td>
<td>2 (0-3)</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>3.5 (2-6)</td>
<td>1 (0-2)</td>
<td>2 (1-3)</td>
</tr>
<tr>
<td></td>
<td>BOTH</td>
<td>2 (2-6)</td>
<td>2 (0-2)</td>
<td>2 (0-3)</td>
</tr>
<tr>
<td>26</td>
<td>YA</td>
<td>3 (3-4)</td>
<td>2 (1-2)</td>
<td>2 (0-3)</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>6 (3-7)</td>
<td>1 (0-2)</td>
<td>2.5 (2-4)</td>
</tr>
<tr>
<td></td>
<td>BOTH</td>
<td>3 (3-7)</td>
<td>2 (0-2)</td>
<td>2 (0-4)</td>
</tr>
<tr>
<td>27</td>
<td>YA</td>
<td>2 (2-3)</td>
<td>1.5 (0-2)</td>
<td>1.5 (0-3)</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>3.5 (2-7)</td>
<td>1.5 (0-2)</td>
<td>2 (2-4)</td>
</tr>
<tr>
<td></td>
<td>BOTH</td>
<td>2 (2-7)</td>
<td>1 (0-2)</td>
<td>2 (0-4)</td>
</tr>
<tr>
<td>28</td>
<td>YA</td>
<td>2 (0-2)</td>
<td>1 (0-2)</td>
<td>0 (0-3)</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>3.5 (2-5)</td>
<td>1 (1-2)</td>
<td>2 (2-4)</td>
</tr>
<tr>
<td></td>
<td>BOTH</td>
<td>2 (0-5)</td>
<td>1 (0-2)</td>
<td>2 (0-4)</td>
</tr>
</tbody>
</table>

NB only sockets with *in situ* teeth are included for periodontal disease; only *in situ* teeth are included for calculus and attrition.
As well as the classic descriptions of scurvy (de Vitry c1240; de Joinville c1300; Cartier (in Hakluyt) 1600; Lind 1753; Huxham 1747), scurvy is particularly noted in older dentistry textbooks, reflecting periods when nutrition was inadequate (e.g. Cahn 1941:189-191; Colyer and Sprawson 1946:533; Farmer and Lawton 1966:599). It has been disputed as causative of periodontal disease, since irritants provoke the inflammatory responses (Manson 1975:43; Kerr and Ash 1978:259). Scurvy creates conditions in which bacteria can invade the periodontal region but numerous other factors confuse clinical observations (Alvares 1997) and scurvy has tended to be dismissed (Fish 1952:52; Kerr and Ash 1978:259), ignored (Regezi and Sciubba 1989) or considered secondary in some modern texts (Williams et al. 1992). Plaque bacteria are likely to have been ubiquitous however and bleeding and swelling of gums have been demonstrated to result from avitaminosis C without interaction with other vitamins or iron (Hodges et al. 1971). Scurvy must be considered a likely cause of the periodontal disease and ante mortem tooth loss observed at Isbister.
Oral Conditions at Banks

As at Isbister, periodontal disease was identified at Banks. In two cases (BSR(143) and BSR(195)), the Banks maxillae also showed development of sinusitis (see Figures 194 and 195).

In one of these cases (BSR(143)), maxillary sinusitis is likely to have been a consequence of infection tracking through a molar root (Figure 194 above) but in the other (BSR(823)), there is no such link (Figure 195) although there was also pitting of the anterior maxilla surface in the perinasal region.
Other common features of oral pathology included ante mortem tooth loss and winging (e.g. Figure 196 above).

Table 165. Adult Ante Mortem Tooth Losses at Banks (per permanent tooth socket).

<table>
<thead>
<tr>
<th></th>
<th>I1</th>
<th>I2</th>
<th>C</th>
<th>P1</th>
<th>P2</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Left</td>
<td>1/5</td>
<td>1/6</td>
<td>2/5</td>
<td>2/4</td>
<td>1/5</td>
<td>1/5</td>
<td>0/3</td>
<td>0/1</td>
<td>8/34</td>
</tr>
<tr>
<td>Upper Right</td>
<td>0/5</td>
<td>1/6</td>
<td>0/5</td>
<td>1/5</td>
<td>1/3</td>
<td>1/5</td>
<td>1/2</td>
<td>1/2(2/3?)</td>
<td>6/33</td>
</tr>
<tr>
<td>Lower Left</td>
<td>0/6</td>
<td>0/6</td>
<td>0/6</td>
<td>1/6</td>
<td>1/6</td>
<td>2/7</td>
<td>0/6</td>
<td>0/6</td>
<td>4/49</td>
</tr>
<tr>
<td>Lower Right</td>
<td>0/6</td>
<td>0/6</td>
<td>0/5</td>
<td>0/5</td>
<td>0/5</td>
<td>1/6</td>
<td>0/5</td>
<td>0/5</td>
<td>1/43</td>
</tr>
<tr>
<td>Total</td>
<td>1/22</td>
<td>2/24</td>
<td>2/21</td>
<td>4/20</td>
<td>3/19</td>
<td>5/23</td>
<td>1/16</td>
<td>1/14</td>
<td>29/159</td>
</tr>
</tbody>
</table>

NB. There is insufficient evidence to explore age or sex relatedness.

Sample size is insufficient to compare the results with Isbister but there are no obvious significantly different features.
Summary of Oral Conditions in Neolithic Skeletal Collections

In general, there is considerable periodontal disease and ante-mortem tooth loss but they were not caused by attrition or calculus, neither of which was commonly severe (Tables 161, 162, 163, 164 above). Oral health was nonetheless clearly poor. Evidence for non-masticatory jaw use is rare and seems idiosyncratic (but this view could be due to poor recovery of anterior teeth). The best explanation for this oral disease is scurvy, which is also consistent with other features observed and the absence of other features that might result in such high prevalence of periodontal disease, abscess and tooth loss.

### Table 166. Adult Oral Pathology from Rousay Tombs

<table>
<thead>
<tr>
<th>Condition</th>
<th>Cases observed with severity scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
</tr>
<tr>
<td>Periodontal disease (maxillae)</td>
<td>-</td>
</tr>
<tr>
<td>Ante mortem tooth loss (maxillae)</td>
<td>2xY, 11xR</td>
</tr>
<tr>
<td>Ante mortem tooth loss in complete adult maxillary arcades</td>
<td>2xY</td>
</tr>
<tr>
<td>Ante mortem tooth loss (mandibular)</td>
<td>-</td>
</tr>
<tr>
<td>Ante mortem tooth loss in complete adult mandibular arcades</td>
<td>-</td>
</tr>
</tbody>
</table>

L=Lairo; Y=Yarso; R=Rowiegar; numbers indicate multiple cases.
Evidence of Metabolic Diseases

"... it is possible that mild degrees of sub-scurvy are common, and this should always be considered when a gingivitis for which no satisfactory explanation can be found is encountered."

Colyer and Sprawson 1946:534

Examples of Metabolic Disorders at Isbister

The most commonly reported pathological feature related to metabolic or deficiency disorders is cribra orbitalia – pitting of the orbit roof caused by expansion of haematopoietic bone volume through the cortex (Figure 197 below). This may be related to iron deficiency anaemia although other aetiologies have been suggested and the underlying cause is usually indeterminate (e.g. Stuart Macadam 1982, 1989; Ortner 2003:369-375; Brickley and Ives 2008:2-3; Walker et al. 2009). In the Isbister assemblage, cribra orbitalia was recorded in 44 individuals, mostly juveniles but also (healing) in adults.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Cribra orbitalia</th>
<th>No Cribra orbitalia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>A</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>YA</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>OC</td>
<td>4</td>
<td>2.5</td>
</tr>
<tr>
<td>YC</td>
<td>4</td>
<td>0.5</td>
</tr>
<tr>
<td>I</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Table 167. Relationship of Cribra Orbitalia to Age and Sex at Isbister (individuals).
Cribra orbitalia was examined for relatedness with sex and age (Table 167 above). For adult sex, $\chi^2 = 0.252$ (p>0.5) and for age groups $\chi^2 = 2.01$ (p<0.25). There is no clear contrast in numbers of males and females in which the condition is manifest. Juveniles appear to have a greater prevalence of the condition (9/12 compared with 15/27). This was to be expected because juveniles develop the condition, which heals over with age.

Similar porotic lesions were observed ectocranially, in the area bounded inferiorly by the temporal line and nuchal crest in 22 individuals, mostly adults (see Figure 198 below). They exhibited a spectrum from clear, well-defined

![Figure 197. Cribra orbitalia. Top left shows a focal example; top right is more extensive; bottom left appears to have been active at death; the others appear smoother and have been remodelled by healing.](image)
pores (likely to be from an active lesion at death) to a smoothly stippled ‘orange peel’ appearance (possibly advanced healing). A common observation in the same crania was of a vermiculate or porotic appearance on the surface of the superior orbital margins. It seems likely that this is a related condition, although often considered ‘normal’ (e.g. Mann and Hunt 2005:Figure 3), the vermiculate appearance may indicate a developmental stage from porosity. Sometimes described as porotic hyperostosis, diagnosis of these lesions is disputed because of uncertain aetiology and frequent lack of apparent cranial thickening (e.g. Stuart-Macadam 1989; Mann and Hunt 2005:22-26). Analogy with cribra orbitalia and similarity with more severe and more clearly hyperostotic cases implies haematopoietic volume expansion at the expense of cortical bone (e.g. Ortner 2003) but it might reflect idiopathic inflammation superficially.

![Figure 198. Typical ectocranial pitting locations: posterior, superior to nuchal crest.](image)

This is likely to be a variably healed manifestation of hypervascularity, possibly from iron deficiency anaemia or non-specific inflammation. Cranial porosity is often apparent in osteological illustrations but rarely described, presumably because it appears relatively normal and trivial. It may reflect hyperostosis
although there was no indication of any severe or even moderate case in these collections other than two cases of cranial thickening in which both tables and trabecular bone were implicated (IS(2653) and IS(2642) pp348f below).

Cranial porosity appears to have been described in Neolithic bone as early as the mid nineteenth century (Thurnam 1965a:259). There is no clear contrast in numbers of males and females in which the condition is manifest $\chi^2=0.065$ ($p>0.75$). There is a clear contrast in numbers of adults and children in which the condition is manifest $\chi^2=14.7$ ($p<0.001$). This suggests that the porotic appearance of the posterior parietals and occipital superior to the nuchal crest develops with age. The prevalence may be inversely related to cribra orbitalia, which could support the suggestion that the ‘orange peel’ appearance is not hyperostosis, or that the condition manifests differently with greater bone volume. Infection seems inconsistent with the age relationship.

Males are more likely to exhibit supraorbital pitting than females $\chi^2=4.2$ ($p<0.05$). This could support an interpretation of some activity-related condition. For age groups, $\chi^2=6.30$ ($p<0.025$ adults vs. juveniles) and indicates that the

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Calvarial Porosity</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>A</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>YA</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>OC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>YC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
condition probably develops with age. It does not increase with advancing age because there is no significant difference between young adults and adults ($\chi^2 = 0.049$).

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Supraorbital porosity</th>
<th>No Supraorbital porosity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>A</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>YA</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>OC</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>YC</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

*Post-meatal Porosity*

Post-meatal pitting (e.g. Figure 199) may indicate an inflammatory response to auditory canal infections: no other clear indication of otitis media were observed, nor abnormalities such as external auditory exostoses. Relationships with age and sex were investigated (Table 170 below).
There is no contrast in numbers of males and females in which the condition is manifest (p=0.262). Post-meatal porosity may be accepted as randomly manifested with respect to sex. For age groups, p=0.03 and suggests that the condition has some association with increasing age.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Postmeatal porosity</th>
<th>No postmeatal porosity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>A</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>YA</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>OC</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>YC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Palatal Pitting and Remodelling

Palatal pitting (e.g. Figure 200) indicates an inflammatory response, perhaps most likely to be a complication of scurvy, though possibly related to idiopathic periodontal disease or oral trauma.
There is a slight difference in proportions of males and females in which palatal pitting is manifest but this could be random (p=0.426). The null hypothesis, that the condition is randomly manifested with respect to sex may be accepted. For age groups the difference is also insignificant.

**Table 171. Palatal Pitting Related to Age and Sex at Isbister.**

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Palatal pitting</th>
<th>No palatal pitting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>A</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>YA</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>OC</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>YC</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

There is a slight difference in proportions of males and females in which palatal pitting is manifest but this could be random (p=0.426). The null hypothesis, that the condition is randomly manifested with respect to sex may be accepted. For age groups the difference is also insignificant.

**Sphenoid Porosity**

Pitting of the ectocranial surface of the greater wing of sphenoid (e.g. Figure 201) was observed to have a high prevalence at Isbister (see Table 172).

There is a difference in numbers of males and females in which the condition is manifest (Table 172 below). It is possible that females exhibit porosity of the sphenoid more than males, which could reflect dietary differences implied by
the stable light isotope results and might have made females particularly vulnerable to deficiency diseases. $\chi^2 = 1.81$ (p>0.10), which would not give high confidence in rejecting a hypothesis of randomness. There is no evidence for any relationship with age. This supports an interpretation of sphenoid porosity as pathological rather than developmental.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Sphenoid porosity</th>
<th>No sphenoid porosity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>A</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>YA</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>OC</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>YC</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>I</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

**Haemorrhagic Cranial Lesions**

Haemorrhagic lesions were observed as superficial woven (or newly healed) bone superiorly within the orbit (e.g. Figure 202). Bone deposits of this sort are typically due to ossification following soft tissue haemorrhage such as results in scurvy but may be traumatic (Ortner 2003:385ff; Brickley and Ives 2008:56ff).

**Figure 202. Cranium IS(7114). Inferior aspect of the orbit showing the porotic and proliferative areas (black and white arrows respectively).**
Figure 203. Cranium IS(4588), showing superficial woven bone and a vermiculate orbital margin, tentatively interpreted as evidence of scurvy.

Figure 204. Cranium IS(7209), from a child about 4 years old at death. All sutures present display bands of porosity more extensive than normal. There are plaques of woven bone superficially in the orbits and cranial thickening caused by the deposition of woven bone laminae endocranially (see also figures following).

Figure 205a. IS(7209): frontal-sphenoid suture, showing pitting.  
Figure 205b. IS(7209): micrograph (x40) of porotic bone surface in Figure 205a.
Although abnormal endocranial bone growth has usually been interpreted as rachitic (e.g. Ortner 2003:394ff), the aetiology would not seem consistent and this example does not exhibit loss of cortical bone (Figures 207, 208 above). These lesions indicate haemorrhage, more likely symptomatic of infantile scurvy, although this may be comorbid with rickets. An alternative diagnosis of the haemorrhagic lesions might be ‘shaken baby syndrome’ but this is perhaps unlikely because a child might not survive the severity apparent here.

The age distribution of skeletal elements suggests that there was only a single
neonate interred in the Isbister tomb. Paired femora and a right tibia (IS(1735), IS(5009) and IS(1732)) were consistent with an age at death of under three months (Maresh 1970). This infant had excessive plaque-like woven bone deposits, associated with muscle attachment sites. Properly, this condition is idiopathic but the most likely aetiology is scurvy. The widespread nature of the lesions suggests an underlying metabolic condition and may indicate haemorrhage associated with poor connective tissue. No cranium was identified for any neonate in the OM collection but fragments consistent with an individual approximately 0-3 months of age were identified on a visit to NMS. The largest was a left frontal fragment exhibiting cribra orbitalia and with an 18 x 12mm ectocranial deposit of porous woven bone superficially over the entire surface, forming a large boss 13mm superior to the orbital margin (Figure 209 below).

Figure 209. IS(NMS) frontal fragment exhibiting large ectocranial woven bone deposit (normal surface arrowed, woven bone above).

Figure 210. Infant femora IS(1735) (left) and IS(1732) (right).
IS(4623) is the left scapula of a young juvenile with an area of porous woven bone in the supraspinous fossa and striate woven bone along the posterior part of the spine (Figure 212 below). Although it is non-specific, this has been recorded associated with scurvy (Ortner et al. 2001).

Skeletal manifestations of infantile scurvy are very similar in appearance to bone undergoing normal growth (Brickley and Ives 2006:55ff). For this reason, although several long bones appeared to exhibit larger than normal areas of woven bone near the metaphyses (eg. Ortner et al. 2001, fig. 8), they were not confidently identified as scorbutic. The most pathognomic lesion may be porosity of the greater wing of sphenoid (Figures 200, 204, 205 above), which is associated with an increased vascularity - but abnormal cortical porosity, occasionally accompanied by hyperplasia is the fundamental lesion (Ortner et al. 2001). 66% of cases with porosity of the greater wing of sphenoid at Isbister
also demonstrated porosity at the lambdoid region; 97% had orbital porosity and 61% orbital hypertrophic lesions (Ortner et al. 2001). Abnormal maxillary suborbital, alveolar and palatal porosity were considered to be particularly associated with scurvy “the only plausible diagnostic option for this particular type and pattern of lesions” (Ortner et al. 1999:328).

A particularly compelling case for juvenile scurvy is provided by cranial fragment IS(7209). The proliferative bone deposits in the orbits indicates an advanced condition with haemorrhaging around the eye (Figure 206); bands of porous woven bone around the sutures ectocranially relate to growth of poorly ossifying cartilage (Figures 204, 205); and the multiple endocranial laminations are examples of repeated meningeal haemorrhage (Figures 207, 208).

Plaques of periosteal bone deposition were observed widely on the diaphyseal surfaces of longbones, in some instances (e.g. IS(2361), a fibula shaft) with discrete layers one upon another. One juvenile at least has a clear layer of periosteal bone separate from the normal bone surface (Figure 211).

Maxillary alveolar resorption was found to have occurred frequently in the Isbister population, typically associated with periodontal disease and antemortem tooth loss. Cribrar orbitalia was observed in all the sub-adult and in many young adult individuals (17 cases observed). Forty-four cases of orbital porosity or bone plaques were recorded in total. Diffuse porosity of the external cranial vault was also frequently observed in the same individuals, limited to the area superior to the temporal and nuchal lines (22 cases). Eight instances were
observed of endocranial bone plaque formation. Scurvy leads to haemorrhage within the soft tissues with the haemorrhagic blood ossifying in some cases, potentially producing the bone plaques observed. Haemorrhaging can occur within the medullary cavity and this may be the cause for the cases of thickened porotic long bone cortex (Figure 214 below).

Superficial bone plaques were recognised at all stages of formation from porous woven bone through to well-remodelled lamellar bone, occasionally suggesting repeated morbidity with periodic healing. More common was a vermiculate appearance of the supra-orbital region and an 'orange-peel' appearance of the superior vault surface. Although idiopathic and without obvious hyperostosis, this may be the remodelled appearance of hypervascularity from scorbutic inflammation and should be compared with other possible indicators.

In scurvy, heavy loss of blood can lead to anaemia, thus contributing to cribra orbitalia in juveniles. Collagen in the ligaments holding teeth within the jaws is weak and the ligaments tend to break, leading to alveolar resorption. As the alveoli retreat, the gingivae may become infected and inflamed so that porosity develops on the adjacent bone.

Twenty-five distal femora from Isbister were found to have woven bone in various stages of remodelling on the anterior diaphyseal surface in the joint capsule area. This is suggestive of inflammation within the knee joint occurring widely within the population. This lesion was not recorded in any of the medieval or Norse collections at OM examined for comparative purposes.
most likely explanation, considering the other evidence within the Neolithic population, may be a reaction to scorbutic haemarthrosis but the case cannot be conclusively demonstrated.

_Cranial thickening_

Abnormally thickened cranial bone was observed in two adults: IS(2653) and IS(2642) (e.g. Figure 213 below).

_Figure 213. Thickened cranial vault and deep meningeal grooves. Endocranial view of IS(2653), localised bulging area circled. Thickening is particularly apparent in broken surface (arrowed); circle indicates endocranial lump._

It is difficult to tell whether the thickening arises in the diploë but the outer table is over 3mm thick itself and the border between the diploë and the inner table is generally diffuse. Neither macromorphologically nor radiographically does this fragment display the disorganised nature typical of Paget’s disease. One might speculate that this is the healed remodelled appearance of an earlier pathological condition such as seen in IS(7209) but it seems likely that this is a case of healed hyperplasia related to increased blood production or rachitic dysplasia. IS(2653) also exhibits an endocranial swelling in the right frontal,
which may be an unrelated healed lesion or lethargic neoplasm.

**Medullary Cavity Occlusion**

Several superficially normal femora appear thickened and porotic in cross-section, with occluded medullary cavities. These presented a range of expression that may relate to remodelling. There was no indication of infection nor are the bones noticeably heavy. Radiographic study of three such femora ruled out Paget’s disease. The most likely explanation is scorbutic haemorrhaging within the medullary cavity. Similar cases have been noted (Ortner *et al.* 2001) but Ortner elsewhere ascribes similar features to periostitis (Ortner 2003:213 figure 9-41).

![Figure 214. Porotic thickened cortical bone occluding the medullary cavity. Six different femora, apparently displaying different degrees of severity and healing.](image-url)
**Supratrochlear Woven Bone**

Supratrochlear woven bone on femora, confined to the anterior joint capsule area (Figure 215 below), was found with a high prevalence. It occurred significantly more frequently on the left than right. Since scurvy appears to be prevalent in this population, I hypothesise that this may be an inflammatory response to haemarthrosis.

![Figure 215. Examples of supratrochlear woven bone at different stages of remodelling.](image)

This was also noted on a femur from Knowe of Yarso.

![Figure 216. Femur ABDUA14966 from Knowe of Yarso, exhibiting supratrochlear woven bone (circled above) and remodelling associated with the attachment for M. gastrocnemius (arrow below). (Also exhibiting OA: a well defined pitted articular lesion.](image)
Records of these features are rare because of the difficulty of distinguishing them from normal features of bone growth in some cases and because of taphonomic masking. Only quite extreme manifestations are likely to be identified. The prevalence of non-degenerative pathological conditions involving woven bone is higher in sub-adults than in adults because they form bone more rapidly due to growth and they may have had less time for lesions to remodel prior to death.

The aetiology of these lesions is highly varied and individually they must be regarded as non-specific. Overall, the types of lesion described suggest metabolic problems associated with anaemias and avitaminoses.
Deficiency and metabolic diseases at Banks

Cribra orbitalia was recorded in four cases: BSR(135), BSR(134), BSR(146) and BSR(130) (Figures 217, 218).

Frontal BSR(1585) had a lateral orbit area 20mm x 20mm occupied by fine porosity (Figure 219). Examined under low magnification, it was apparent that there are areas within this region where superficial bone plaques were developing unrelated to the underlying foramina. These are most likely to result from the ossification of haemorrhagic tissue caused either by scurvy or by trauma. Reconstruction of much of the frontal for this individual showed the metopic suture to be patent and the anterior fontanelle clearly open, which
suggest an age at death under 2 years old. The estimated length of the frontal chord suggests an infant aged between birth and 6 months. Even if growth was retarded by malnutrition, as is not unlikely, this was nonetheless a very young individual. A child of this age would normally be expected to be relatively healthy because nursing should provide adequate nutrition and some protection against disease. It seems likely then that this infant was not being adequately breastfed.

Figure 219.
Superficial porous woven bone in the orbit of cranium BSR(1585).

Fig 220. BSR(1119)(left) and BSR(1026)(right): abnormal new bone formation.
BSR(1026) and BSR(1119) are (probably paired) left and right juvenile ischia from an individual aged about 5-12 years (possibly slightly older). They both exhibit porous woven bone deposited superiorly to the ischial tuberosity (Figure 220). These deposits are clearly superficial to the bone surface and are distinct from normal epiphyseal development. The condition here is probably an idiopathic inflammatory response of the periosteum. This is an unusual location for periostitis because it is deep below muscle tissue, which would be expected to provide protection. This is not, except in specific delimited areas, a site of muscle attachment, so torn muscles would seem to be an unlikely cause, although it is not impossible that they contributed. The most likely explanation is metabolic disorder, because the condition is bilateral and relatively diffuse.

![Figure 221. Extensive porosity of juvenile ilium BSR(1546).](image1)

![Figure 222. Anterior bone formation on mandible BSR(1375).](image2)

There is abnormal fine porosity on both surfaces of juvenile ilium BSR(1546) from an individual aged about 6-16 months at death (Figure 221). This is much more extensive than would be explained by normal growth and occupies most of both surfaces, with small geographic areas spared. This is indicative of some generalised inflammation and at sites protected from direct trauma by soft
tissue. A very similar case has been recognised at Quanterness (Rebecca Crozier pers. comm.). The most likely explanation is a metabolic condition.

There is an example of new bone deposition over the antero-inferior surfaces of a juvenile mandible BSR(1375) from an individual aged about 12-18 months at death (Figure 222). This is possibly from healing infection or trauma but is more likely to relate to inflammation or a healing scorbutic haemorrhage. It is possible that this and the preceding case

Figure 223. Cranium BSR(002) from a juvenile aged between seven and eleven years at death. It exhibits abnormal porosity of the anterior maxillary surface, indicating non-specific inflammation.

Figure 224. Cranium BSR(146), inferior aspect showing palatal pitting.

Pitting of palatals and anterior maxillae were recorded (Figures 223, 224) and woven bone deposits at the knee joint capsule (Figure 225), as at Isbister.
Figure 225. Left femur BSR(139), an adult left femur exhibiting striate woven bone formation limited to the area of the knee joint capsule.

Figure 226. Juvenile ulna BSR(1576), with excessive vascular porosity at muscle attachment sites.

Figure 227. Juvenile calcaneus BSR(189), with pathological pitting, slight lipping superiorly and an anomalous bone growth inferiorly (circled). The aetiology is uncertain but may be metabolic, traumatic or one of the arthritides.
Other Inflammatory or Infective Conditions at Isbister

Pitting of the anterior maxillae and frontal processes seems likely to indicate inflammation associated with the nasal orifice, laterally (above) and inferiorly (below); these may reflect some inflammatory condition, likely to have been chronic.

Table 174. Cases of Minor Pitting or Porosity of the Maxillae from Isbister

<table>
<thead>
<tr>
<th></th>
<th>J</th>
<th>M</th>
<th>?M</th>
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<th>?F</th>
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<tr>
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<td>2/16</td>
<td>0/3</td>
<td>1/9</td>
<td>0/4</td>
<td>1/7</td>
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</table>
IS(7341) is a first lumbar vertebra with minor signs of lipping around the superior articular facets. The neural spine is enlarged posteriorly to the left, forming buttressing down to the left inferior articular facet. The superior body surface has an anterior crescent-shaped area of destruction with associated lipping sometimes associated with brucellosis, similar to vertebral osteochondritis. Here it is associated with a spherical lytic lesion in the superior half of the anterior body (Figure 229). The void is 11mm in diameter and 9mm deep with a discontinuous ring of new bone along its inferior margin. Some of the exposed trabeculae appear thickened but not sufficiently to indicate reactive bone formation. It is likely that destruction of the superior cartilage and disc space indicated by the superior surface lesion was related to an infective process that created the anterior body lesion.

![Figure 229. Spherical lesion in lumbar vertebra body. IS(7341), anterior aspect.](image)

IS(6065) is a juvenile middle thoracic vertebra body (Figure 230). There is a well-defined crescent of lytic activity anterior on the inferior surface, reminiscent of Scheuermann’s disease. The superior surface has a lytic lesion 15mm across x6mm x 6mm anteriorly and another laterally, in which the exposed trabeculae have mostly remodelled. These may reflect intervertebral lesions, possibly exhibiting a mixture of infective and secondary traumatic conditions.
IS(6692) is a lower thoracic vertebra exhibiting an ovoid area of new bone on the anterior surface (Figure 231). This does not appear to be buttressing but may be associated with infection retained by the anterior spinous ligament.

A similar feature is apparent anterolaterally on lumbar vertebra IS(7346) (Figure 232).
Right side rib shaft fragment IS(7146) exhibits smooth surfaced new bone plaques on the visceral surface in the lateral part of the shaft (Figure 233).

Figure 233. Bone plaques on rib IS(7146).

IS(7147) is a fragment of right side rib 1, with two smooth surfaced new bone plaques on the inferior surface (Figure 234).

Figure 234. Bone plaques on rib IS(7147).

These two ribs are the only ones identified with new bone other than DJD. These indicate a non-specific inflammatory condition of the thorax, probably a pulmonary infection, perhaps pneumonia (Kelley et al. 1995).

Figure 235. IS(7208): endocranial bone formation in occipital.
Endocranial lesions might also be symptomatic of TB or other intrathoracic infection (Hershkovitz et al. 2002). This was observed in IS(7208) (Figure 235 above) but it is possible that it represents a healing phase of some other condition.

Three second cervical vertebrae (the axis) display signs of periostitis anteriorly (Figure 236). In none of these is there any indication of an underlying cause but it is not impossible that it is linked to the lower vertebral features.

Figure 236.
Axis with evidence of anterior periostitis.

The cases described here may have implications for major diseases. Periosteal reactions are the most likely explanations for most long bone diaphyseal lesions observed. These are non-specific and may relate to infective or traumatic processes; I have chosen to describe some cases above, under metabolic conditions. Apparently absent however are extensive lesions and any indication of osteomyelitis, which may indicate acute fatality of such major infections.
Examples from Banks

Figure 237. Basioccipital BSR(365), with extensive anterior pitting (circled).

The pitting in BSR(365) (Figure 237 above) has uncertain aetiology but is abnormal (possibly neoplastic or infection). It is likely to indicate a potentially significant pathological condition because of its proximity to the brain and pituitary gland.

Rousay Cases

The only case was infranasal pitting that was observed in a single adult from Knowe of Rowiegar (ABDUA12004).
Examples of Neoplastic Disease from Isbister

IS(1958) is a largely complete male cranium in good condition with a sound surface. This individual died as an adult but age at death cannot be more closely defined. There appear to be three small osteomata superiorly on the right parietal and one on the left. These are a common benign neoplastic condition and probably unrelated to other features of this cranium.

There is minor porosity inferior to the anterior nasal spine and widespread across the posterior ectocranium. There is a slight vermiculate appearance in the right orbit superiorly. These features are likely to be the result of non-specific infection and/or malnutritive conditions in which episodes of anaemia were implicated.
Both lesser wings of the sphenoid have porotic and vermiculate areas endocranially that are likely to be due to a non-specific infective or inflammatory agent.

This cranium displays two main groups of significant pathological features: oral
and neoplastic. Antemortem tooth loss was severe. Abscesses were present and there is generalised alveolar resorption. Palatal porosity and new bone suggest long standing periodontal infection and fine porosity present in the remaining tooth sockets suggests that this was still active at the time of death. These features are probably unrelated to other lytic lesions.

Small spherical lytic lesions are widespread endocranially and ectocranially, at least fifty being visible with further lesions in the diploë visible radiographically. With the exceptions of the temporal, malars and nasals, all the bones present are affected, most commonly the parietals, then the greater wings of the sphenoid, with fewer in the frontals and occipital; the orbits are involved. Some lesions in the maxillae, which appear to communicate with the antrim, could be
draining abscesses related to the dental pathology already described. There is no obvious pattern to the distribution, for example lesions are not related with the meningeal grooves. The lesions vary up to a maximum of 7mm in diameter and are most apparent endocranially; four perforate both tables. They do not have porotic margins and do not seem to coalesce. Some appear to have thickened trabeculae around them and this may imply lethargic growth or periods of remission. One sagittal endocranial depression is reminiscent of meningioma but meningioma, arising in the dura, is not usually metastatic. These lesions are probably a haematopoietic neoplastic condition such as multiple myeloma, leukemia or metastatic carcinoma.

Several carcinomas produce multifocal lytic metastases, most commonly lung cancer and gastric cancer. Those, such as prostate cancer producing proliferative lesions may be ruled out. Carcinomatous lytic foci are typically geographic but may be circular, in which case one dimension at least is ellipsoid (Rothschild et al. 1998). Such lesions typically vary greatly in size and would probably display aggressive characteristics including peripheral porosity, which are not visible in these lesions. Histiocytosis X is eliminated because it occurs predominantly in childhood (Ortner 2003:361-2). Lymphoma may be more likely (Ortner and Putschar 1981:264) but lesions would be larger and exhibit sclerosis. Leukemia produces multifocal lytic lesions but these are often superficial and usually smaller, only about 1-3mm diameter.

Multiple myeloma however, is a multifocal haematopoietic neoplastic disease that has spherical sharply defined lesions, usually of similar diameter under
about 10mm affecting the flat bones of the body. Woven bone metaplasia may be a symptom of haematopoietic diseases (Jónsdóttir et al. 2003:Table 4) but was not observed here.

Examination of other skeletal elements identified 11 with similar lytic lesions, which could all potentially come from the same individual (Figures 243-251). These elements are three os coxae fragments, 3 vertebrae and 6 rib fragments: all elements that would be likely to be implicated in a case of haematopoietic neoplastic disease.

Figure 243. Rib IS(7138) indicating lytic lesions.

Figure 244. Rib IS(7141), showing lytic lesions.

Figure 245. Rib IS(7144), showing lytic lesions.
Figure 246. Rib IS(7145), showing lytic lesions.

Figure 247. Lesions in ossa coxae: IS(3326) above and IS(3340) below.

Figure 248. Ilium IS(2918), showing lytic lesions.
These fragments are consistent with being from a single individual with multiple myeloma although there is possible discrepancy between ages inferred from the cranium and the ilium.
Multiple myeloma has been reported in several cases from the European Neolithic (Strouhal and Kritscher 1990). Modern Scottish prevalence rate is 5.1 per 100,000 person-years (ONS figures) but is related to age: most cases are identified in individuals over 50 years old. Multiple myeloma has an incidence related to abnormalities of chromosome 14, which may imply that this abnormality was common in the Neolithic founder population. The condition may be aggressive or lethargic in development: complications include kidney failure, bone fractures, fatigue and infection.

![Figure 252. Cranium IS(7353). Anterior aspect, showing tooth loss and dysplasia of the right maxilla.](image)

The anterior aspect of this cranium shows an inflated appearance of the right maxilla, with a raised floor of the right nasal cavity. This was caused by a space-occupying lesion of the right palatal, simultaneously causing the loss of the right anterior dentition. The remaining teeth exhibit the greatest dental attrition recorded in this population. The smooth circumference of the primary lesion shows that it was a slow growing benign neoplasm that permitted
The lesion has been identified as a dentigerous cyst (Chesterman 1983:124) but there is no evidence supporting a specific diagnosis and it should be considered a benign palatal cyst, possibly dentigerous. Soft tissue will have occluded the oral cavity, potentially affecting appearance, speech and eating. Similar cases were recognised in the Knowe of Rowiegar assemblage (see below), which may imply a common factor such as teratology, activity or heritability.

IS(1644) is the unfused distal epiphysis from a juvenile left femur (Figure 254).

This has occasional nodular areas of bone in the intercondylar fossa and the
attachment area for each cruciate ligament is porotic. The articular surface is distinguished by having seven smooth bordered hemispheric voids from 1mm to 4mm in diameter, two of which are confluent. These are distributed throughout the surface and are most likely to result from subchondral cysts.

Two calcanei exhibited large space-occupying lesions within the trabecular bone, visible to external examination (Figures 255 and 256 below). Calcaneus IS(7126) had a lesion visible due to modern damage that created a 11mm x 11mm hole in the cortex directly beneath the posterior talar articular surface. A spheroidal void approximately 20mm in diameter was visible, clearly defined by smoothly remodelled trabeculae forming a bone sheath; trabeculae remain apparent laterally but these are broad and flattened. The void occupies most of the volume inferior to the sustentaculum tali in the middle of the bone: the ‘neutral triangle’ of the calcaneus.

![Figure 255](image.png)

Calcaneus IS(7126). Plantar aspect showing space-occupying lesion.

The geographic shape, lateral expansion of the calcaneus and smoothly remodelled bone shell indicate that the lesion was slow growing and probably benign. Lack of periosteal involvement or destruction and absence of florid bone formation indicate that the lesion is unlikely to be infectious in origin. The location, entirely within the metaphysis, indicates that this is not for example
chondroblastoma. The likely alternatives to be present are the benign neoplasms: intraosseous lipoma, giant cell tumour, unicameral (solitary or single) bone cyst (UBC) and aneurismal bone cyst. Aneurismal bone cyst typically occurs at the metaphysis and is contraindicated by absence of its typically multilocal form; lipoma may be distinguished by ossification within the lesion, which is absent in this case; giant cell tumour does not produce the bone margins apparent here. None of these conditions - including a healing stage of haematogenous osteomyelitis - may be ruled out but the condition is most likely to be a unicameral bone cyst, which fits the observations exactly.

Left calcaneus IS(4688) had a lesion visible due to an existing 29mm x 18mm hole in the cortex of the plantar surface directly beneath the posterior talar articular surface. Part of the anterior edge appears rounded, suggesting that collapse of the cortex occurred during life. A void approximately 30mm long x 20mm wide x 20mm deep is sharply defined by smoothly remodelled trabeculae. There are three smaller lobes, one posterior and two medial around an essentially spherical void at the lateral plantar margin. The diagnostic features are essentially the same as IS(7126) except for the possible existence in this case of several coalescing lobes.

![Figure 256. Calcaneus IS(4688), lateral and infero-lateral aspects.](image)
Lipping and pitting suggest a degenerative condition of the calcaneal-talar joint (Figure 257 above), probably secondary osteoarthritis related to abnormal joint use following fracture of the inferolateral cortex around the calcaneal cyst.

Unicameral bone cyst (UBC) today is typically observed in juveniles between 5 and 15 years old, with males twice as frequently affected as females. The aetiology of UBC is unknown. The condition is usually asymptomatic except where it leads to fracture and causes pain as was probably the case in these instances. Both these individuals will have had pain, leading to mobility difficulties.

UBC is most commonly observed in the proximal humerus and proximal femur, these two locations accounting for about 90% of cases (i.e. over 9 times the numbers from all other locations, including calcanei) and is believed to resolve spontaneously. No femur or humerus from the Isbister collection has been recognised with UBC, despite the frequency of post-excavation fracture.
Neoplastic Lesions at Banks

Adult humerus, BSR(206) exhibits evidence of a space-occupying lesion affecting the distal diaphysis and olecranon fossa. This has invaded through the cortex superiorly and inferiorly and perforated the bone anteriorly, superficially mimicking a septal aperture. The capitulum has been mostly lost to a second lesion, leaving a smooth- bordered hemispheric cavity. This is associated with an eroded area and may possibly be taphonomic. There is a third possible space-occupying lesion in the proximal diaphysis. The perforation that allows this to be seen is associated with modern damage. It is not impossible that the perforation is a nail hole, although there is no indication of associated cracking or splintering. Radiography of this element showed absence of sclerosis. There is no peripheral porosity, nor any reactive bone formation. This appears to be a multifocal lytic condition but is difficult to diagnose. Despite the apparent absence of reactive bone, it may be a case of neoplastic disease, such as chondroblastoma, or infection. This could be any generalised infection but the focal points at either end of the metaphysis suggest that the condition may have involved the medullary cavity. There are two main forms of infection that could be implicated. Tuberculosis affects the joints and is known to attack the elbow without necessarily leading to secondary effects (Ortner 2003:243). Some fungal infections can produce similar lesions but these are not expected and may be unlikely to have this form (Ortner 2003:325ff).
Figure 258. Humerus BSR(206) showing lytic lesions (multiple views).

Figure 259. BSR(206): close-ups of distal lesion, note perforations (circles and arrowed).
Adult right ulna BSR(1394) also has a possible space-occupying lesion in the proximal diaphysis. Radiography shows an irregular large void without any sclerotic margins or obvious internal structure. The perforation that allows this to be seen is also associated with modern damage. It is not impossible that this is a modern nail hole but the void within the bone appears too large and there is no associated cracking or splintering.

Figure 260. Ulna BSR(1394), showing lytic lesion, with radiographic images.
Neoplastic Conditions from Knowe of Rowiegar

Two crania from Knowe of Rowiegar were observed to exhibit space-occupying lesions at the palatals.

ABDUA90035 is an adult male cranium with a healed depressed fracture anteriorly on the left frontal. It exhibits a large smooth-margined void in the right palatal, which appears to have been created by a lethargic benign growth expanding into the nasal orifice. The right maxillary process has also remodelled with a smooth irregular perforation into the maxillary antrim and irregular striate bone formation anteriorly. The maxillary antrim bears a bone lump of 6mm diameter. There is some indication of communication between the maxillary antrim and molar sockets. The left third molar was fully formed but unerupted. The surviving palatals exhibit pitting.

The similarity to IS(7353) seems remarkable.

Figure 261. Cranium ABDUA90035, from Knowe of Rowiegar, showing perforated palatal and dysplasia laterally. (Compare with Figures 252 and 253 above.)
ABDUA12017 is a partial viscerocranium from a young adult. There is a 14x7mm void in the left palatal, associated with the root of the left canine: trabeculae are exposed but smooth and concave in general appearance. The median palatine suture deviates to the right side. The floor of the nasal orifice is raised but there is no apparent reactive bone formation. These are consistent with pressure from soft tissue rather than infection. There is some palatal pitting but it seems to be associated with mild periodontal disease anteriorly. This lesion is probably from a lethargic benign tumour, possibly a dentigerous cyst.

Knaye of Rowiegar also produced a left adult calcaneus ABDUA16302 with a 10mm diameter space-occupying lesion surrounded by smoothly reorganised trabeculae inferior to the anterior talar facet.
Summary of Neoplastic Diseases

These collections appear to exhibit a high prevalence of neoplastic diseases, most of which will have affected appearance and caused some disability. There are no obvious teratological features to the Orkney environment but it is not impossible that activity or heredity were contributory factors, perhaps indicated by Neolithic cases of multiple myeloma recorded in Europe.

Summary of Macroscopic Analysis

The age and sex structure of the Isbister assemblage seem inconsistent with a random sample from a normal population: male adults outnumber females heavily; infants are underrepresented but children, especially aged 4-8, apparently rather common. These assemblages exhibit prevalences of pathological conditions higher than expected today or observed in 'normal' medieval cemetery populations. Many of the features will have had obvious symptoms during life, particularly involving deformity and disability. Trauma is also present with a high prevalence, especially on crania. Existing observations described briefly in chapter 1 above suggest that similar pathological features might have existed with high prevalence throughout Neolithic Britain.

These demographic and pathological features seem likely to have cultural implications, which are further examined in chapter 5.
4. ISOTOPIC ANALYSIS

Men are made of what is made,
The meat, the drink, the life, the corn,
Laid up by them, in them reborn.

Edwin Muir The Island

Stable light isotope analysis of bone collagen has become a standard archaeological tool for the investigation of diet and metabolism. Successive chemical reactions in metabolic processes are subtly affected by minor variations in atomic weight that affect reaction rates and equilibria (fractionation). The ratios $^{13}$C:$^{12}$C and $^{15}$N:$^{14}$N (conventionally expressed as $\delta^{A}X\%$ relative to international standards) have proven to be particularly useful in assessing the past intake of C4 versus C3 protein and examining trophic level effects (e.g. DeNiro and Epstein 1978, 1981). In prehistoric temperate Europe, which lacked native C4 crops, a C4-like signal reflects marine influence in diet as a result of long food chains and carbon exchange mechanisms in marine organisms and the ocean environment. Trophism, metabolic state and soil condition can affect nitrogen isotope ratios (e.g. Fuller et al. 2004; Fuller et al. 2005); environmental conditions can affect carbon isotope ratios (the 'canopy effect') (see Tables 175, 176 and Figure 266 pp408-9 below).

Differences in isotopic ratios between individuals or communities can reflect variations in subsistence, health (metabolic state) and social status exhibited via diet. From comparative studies, it is possible to infer details of resource exploitation and social structure. At Hambledon Hill in Dorset, for example, it
was suggested that there might have been variation in diet according to both sex and origin although the number of samples was too small for definitive conclusions to be drawn (Richards 2009).

4.1 Stable Light Isotope Analysis Methods

Limited destructive sampling of the OM Isbister collection was undertaken for stable isotope analysis. The intention was to examine changes in carbon and nitrogen isotopes that might relate to nutrition and metabolism. The Isbister assemblage was sufficiently large and informative that isotopic results could be tested against age, sex and pathology. This was expected to identify any major variations in metabolism or access to foods that might infer status and thresholds related to maturation or rites of passage.

Remains from Neolithic settlements indicate extensive exploitation of marine resources (Clarke 1976b; Nicholson 2007; Nicholson and Davis 2007) but this has been widely contradicted by chemical examination of human bone (e.g. Schulting 1998; Richards and Hedges 1999; Richards et al. 2003). A strontium trace-element study of human bone from four Orcadian sites was interpreted as indicating marine food exploitation (Antoine et al. 1988) but the $\delta^{13}C$ values in that study, quoted at around $-20.5\pm0.7\%o$, were consistent with solely terrestrial protein sources. The data were only presented as summary statistics and the range of results was greater than expected. The study was apparently subject to “serious analytical errors,” which made the nitrogen isotope results unreliable, although it is possible that the carbon isotope results were “acceptable” (Richards 2000:125). A more recent isotopic study has also suggested a small
marine protein component in human Neolithic diets in Orkney. This came from Holm of Papa Westray North, but the values quoted were nonetheless consistent with terrestrial origin by conventional standards, with $\delta^{13}C$ at -20.0 ±0.7‰ (Schulting and Richards 2009).

Samples from Orcadian prehistoric and medieval collections were assayed for stable light carbon and nitrogen ratios to investigate the questions of resource exploitation and lifetime variations.

A pilot study was undertaken first. The initial phase of analysis defined baseline values from animal bones found in Orkney. All faunal and human remains were sampled and processed in an identical manner, using a modified Longin method (Longin 1971), using the same equipment in the same laboratory (the Bradford Stable Light Isotope Laboratory). This ensured that the results were compatible.

Seaweeds were also examined. There has been discussion about the exploitation of seaweed and the subsequent effects on isotopic ratios in animal bone (e.g. Balasse and Tresset 2009). Very few values for UK macrophytes have been published and those may reflect particular local and seasonal conditions (Wiencke and Fischer 1990; Raven et al. 2002:appendix; Frederiksen 2003; Saraswathi et al. 2003; Finlay 2004). To address this problem of insufficient background data, a rocky shore was visited every month for eighteen months and macrophytes identified to species were collected. In retrospect, this was a naïve approach because conditions in such an environment are extremely variable and localised. Significant variations occur
on diurnal and seasonal scales and affect different areas according to exposure to sunlight, water flow, water depth etc. (Descolas-Gros and Fontugne 1990; Plafkin and Keller 2007; Schaal et al. 2010). To properly examine variability would require a major research project and therefore only an indicative series of samples were assayed to provide local groundtruthing for baseline data.

In the Isbister assemblage, the cranium was selected as the subject for bulk bone assay. Although sampling was potentially most obtrusive in this bone, it confers several major advantages in a commingled assemblage. It prevents duplication of individuals in the sample, whilst providing information on age, sex and pathology. Samples were taken only where modern fragmentation permitted removal without causing obtrusive destruction, avoiding anatomically significant parts. Many samples were small existing vault fragments that conjoining had positively identified as belonging to a specific cranium. Anatomical landmarks, parts used for ageing or sexing and areas with lesions were avoided. One cranium exhibiting pathology was intentionally sampled twice, to compare woven and cortical bone.

Samples were taken from other human bone assemblages in the Orkney Museum collections to permit comparisons between populations from different periods and sites. It was usually possible in these cases to select small broken femoral fragments for analysis without incurring extra damage.
Fine incremental Dentine Analysis

A pilot isotopic study was undertaken on the Isbister dentition. Since teeth develop incrementally and do not remodel significantly, incremental sampling should provide a time series of isotopic variation. This has been achieved with modern hair and fingernails (e.g. Fuller and Fuller et al. 2006; Huelsemann et al. 2009), with animal teeth (e.g. Balasse et al. 2001; Balasse et al. 2009) and, using coarse sampling intervals, with human teeth (Richards et al. 2002). The aim was to exploit the minimum practical sample sizes, in order to maximise resolution and examine changes with age.

Permission was given to sample loose teeth. A full photographic, drawn and text record was made of each sampled tooth. Pro forma sheets were used to record each sampled tooth and for each stage of processing and analysis. It was intended that if these techniques were demonstrated to provide useful information, then this should lead to the analysis of samples from the less damaged crania and more teeth. In the event, no further sampling was permitted and so the preliminary study provides the only isotopic information within the scope of this project.
This model of tooth development (Figure 264) is well-recognised and illustrates the potential for a time series of dentine samples (e.g. Avery 1992; Ten Cate 1998). In essence, teeth develop incrementally from the cusps towards the root tips; collagen is formed prior to mineralisation; and dentine begins to develop before enamel, forming identifiable nested irregular cones and frustums that appear sigmoid in section. The detail of understanding necessary for the calibration of stable isotope assay results against age is discussed further below (pp431ff).
Unworn tooth recorded and cleaned, then embedded

Longitudinally sectioned by machine

1mm thick section produced and enamel removed

Cross-sectioned at 1mm intervals following digestion, cutting with scalpel to avoid loss

Figure 265. Sampling Method Used for Incremental Study of Dentine
Table 175. Typical Isotopic Values (after Sponheimer and Lee-Thorp 1999, with additions).

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<th>$\delta^{15}$N‰</th>
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<tr>
<td>C3 plants</td>
<td>-26 (-24 to -36)</td>
<td>c3</td>
</tr>
<tr>
<td>C3 plant grazers (collagen)</td>
<td>-21</td>
<td>c6 (≈plants+4)</td>
</tr>
<tr>
<td>C3 region predators (collagen)</td>
<td>-19</td>
<td>c9 to 10 (≈plants+8)</td>
</tr>
<tr>
<td>Marine predators</td>
<td>-10 to -15</td>
<td>14 to 17</td>
</tr>
<tr>
<td>Air</td>
<td>-7</td>
<td>0</td>
</tr>
<tr>
<td>C4 plants</td>
<td>-12</td>
<td></td>
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<tr>
<td>C4 plant grazers (collagen)</td>
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<td></td>
</tr>
<tr>
<td>C4 region predators (collagen)</td>
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Figure 266. Trophic level carbon isotope fractionation model (after Lee-Thorp et al. 1989).
Neolithic farmers reportedly made little use of marine protein, even in coastal environments (e.g. Tauber 1981; Richards et al. 2003; Schulting 1998). This seems inherently unlikely in regions where agriculture is unreliable, such as Orkney and Shetland. Similar observations in these areas may then indicate a cultural imperative. Such results have occasionally been interpreted as freshwater, marsh or estuarine signals (e.g. Smits and Louwe Kooijmans 2006:101ff).

Radiocarbon Dating
The Isbister isotopic assay samples were also intended to provide subsamples for subsequent radiocarbon dating, so that diachronic variations could be examined.
4.2 Bulk Bone Collagen Results

Collagen yield was generally good (see Appendix), reaching 20% of dry weight in one case. The ratios of carbon to nitrogen varied from 3.1 and 3.8 (mean 3.24, standard deviation 0.07): all but one lay between 2.9 and 3.6, suggesting a lack of adverse diagenetic effects (deNiro 1985). There was no indication of instrumental drift, nor abnormalities of the mass spectrometer peak form during data collection. The measurement error estimated from replicated analyses was ±0.005‰ for δ¹⁵N and ±0.004‰ for δ¹³C (over 179 replicated measurements). All measurements of standards were within the quoted range except a single measurement on a laboratory standard sample, which produced a significant error for δ¹⁵N that was several orders of magnitude greater than any other. This was presumably due to operator error (most probably contamination) and was the major source of the quoted statistical error. It was noted that obviously degraded bone from particular sites – Crantit and Point of Cott – had low collagen content, showed evidence of diagenesis in C:N ratios and produced the greatest variation in measurement, suggesting that their measurement errors may be a diagenetic artefact.

Faunal values provide a baseline for comparing with human values but also infer domestic animal management practices. Differences between species are apparent in δ¹³C: cattle are most negative, pigs least negative and sheep intermediate. The differences are systematic and probably relate to physiological differences. The red deer are in the same general range but vary considerably – probably idiosyncrasies from living wild. Recently published figures for wild species from Greenland also indicate systematic variations

Figure 267. Domestic Animal Values (Appendix and published data as Table 177).

Table 177. Summary Isotopic Results from Different Groups of Fauna, δ\textsuperscript{13}C; δ\textsuperscript{15}N‰ (italics).

<table>
<thead>
<tr>
<th></th>
<th>Red Deer</th>
<th>Cattle</th>
<th>Sheep</th>
<th>Pig</th>
<th>Dog</th>
<th>Human</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neolithic</td>
<td>-21.4±0.57;</td>
<td>-21.5±0.54;</td>
<td>-21.0±0.25;</td>
<td>-20.3±0.57;</td>
<td>-20.0±0.27;</td>
<td>-20.7±0.48</td>
</tr>
<tr>
<td>English</td>
<td>4.6±1.14</td>
<td>5.1±0.40</td>
<td>4.8±0.51</td>
<td>5.1±0.66</td>
<td>8.2±0.51</td>
<td>9.2±0.82</td>
</tr>
<tr>
<td>Neolithic</td>
<td>-22.3±0.82</td>
<td>-21.6±0.24</td>
<td>-20.6±0.48</td>
<td>-19.7*</td>
<td>7.3</td>
<td>-20.6±0.51</td>
</tr>
<tr>
<td>Orkney</td>
<td>6.1±1.18</td>
<td>6.2±0.56</td>
<td>6.3±0.75</td>
<td>7.3</td>
<td>11.6±0.65</td>
<td></td>
</tr>
<tr>
<td>Medieval</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-19.1±1.44</td>
</tr>
<tr>
<td>Orkney</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12.3±1.68</td>
</tr>
</tbody>
</table>


The expected progression of values between species is displayed; there is a clear distinction between the Neolithic and medieval Orcadians, probably related to fish exploitation; the distinction between Neolithic Orcadians and Neolithic English is also apparent, in all species.

English Neolithic results show that herd species (except possibly red deer) have
δ¹⁵N values suggesting a local vegetation mean of about 2‰. The Orkney results suggest a significantly higher baseline in δ¹⁵N, although some individuals fall within the English range. As with the English animals, cattle are more negative in δ¹³C than sheep. The red deer are distinct from the main grouping but appear to have elevated δ¹⁵N in comparison with the English. The medieval Orcadian sheep have relatively elevated δ¹⁵N values. Notably, Orcadian grazers (here: deer, sheep, cattle, and including pigs) and humans are elevated in δ¹⁵N compared to the English examples.

Shetland sheep show similar values to Orkney, though more variable. Shetland cattle results form a long mixing line extending from the most negative δ¹³C
value among the English cattle, through the Orkney examples, up to a point among the dogs! The two lowest were from Neolithic Sumburgh (Keefe 2007); the higher ones from Iron Age Old Scatness. This suggests different forms of animal management. Seaweeds overlap with English grazers but exhibit much greater variation in $\delta^{13}\text{C}$, which may partly explain the differences (Balasse and Tresset 2009; Balasse et al. 2005; Balasse et al. 2006; Balasse et al. 2009).

The large number of Orcadian samples provides opportunities for investigation of systematic variations between groups.

![Figure 269. Human isotopic values from Orkney.](image)

(Newark Bay data from Barrett and Richards 2004, others from this project).

Samples from different sites clustered separately, probably indicating diachronic variation. Except where noted, isotopic data came from this project.

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**Pictish-Norse or medieval** (Mauve symbols)

**Newark Bay** (unpublished; data from Barrett and Richards 2004, with additions) exhibits a mixing line of marine and terrestrial protein signals with young juveniles elevated in $\delta^{15}$N due to nursing. Consistently low in $\delta^{15}$N relative to $\delta^{13}$C compared with the samples from this study, which could reflect interobserver error (e.g. differences in method).

**Bu of Cairston** (Stevens 2003; data from this project) has a similar distribution to Newark Bay but with higher $\delta^{15}$N / lower $\delta^{13}$C, which may indicate greater relative input from terrestrial animal protein.

**Westness** (Kaland 1993; data from Barrett and Richards 2004) has a bimodal distribution, which may reflect the distinct Pictish and Norse cultural groups.

**Buckquoy/Brough Road** (Ashmore 2003; data from Barrett *et al.* 2001 and this project) defines the most terrestrial part of the plot and the individuals exhibit relatively low $\delta^{15}$N values.

**Scar** (Owen and Dalland 1999; data from this project), **Skaill House** (James 1999; data from this project) etc. were small samples that fit within the same mixing line.

**Iron Age** (Green symbols)

**Howe** (Ballin Smith 1994; data from this project) and **Skaill Bay** (James 1999; Tucker 2011; data from this project) both exhibit terrestrial protein signals, with one individual from Howe suggesting a small marine influence.

**Bronze Age** (Blue symbols)

**Stenchme**, Lopness, Sanday was a cist burial exposed by coastal erosion (Rennie 2006; data from this project). This individual has results that suggest a mixed diet with marine protein input.
Neolithic (Red symbols)

Holm of Papa Westray North (Schulting and Richards 2010) and Point of Cott (Barber 1997; data from this project) overlap with Sumburgh cist (Keefe 2007 and forthcoming) (see Figure 268, not shown in Figure 269) but only at the lower end, signifying much less marine influence in the diet.

Pierowall Quarry (Sharples 1985a; data from this project) has a distribution comparable to Point of Cott (Barber 1997; data from this project) but with elevated δ¹⁵N, possibly indicating a higher proportion of dietary animal protein.

Isbister (Hedges 1983; data from this project) is the most terrestrial of the Neolithic groups but has a relatively high set of δ¹⁵N values. One outlier, with the highest δ¹³C value, lies close to the individual from Bronze Age Stenchme.

The Isbister Neolithic results indicate a well-defined distribution indicative of a terrestrial C₃ diet (Schoeninger and DeNiro 1983), consistent with existing data from other British Neolithic sites (Richards and Hedges 1999; Richards 2000; Richards 2009; Schulting and Richards 2009). This contrasts with the later Orcadians, which exhibit a spectrum from terrestrial to marine protein intake (Richards et al. 2006; Barrett et al. 2000; Barrett and Richards 2004).

Stable isotope evidence from Holm of Papa Westray North suggests a Neolithic human diet of predominantly terrestrial origin but data was only collected from the older interments. Results from HPWN suggested a seasonal seaweed component in the diet of sheep in the later Neolithic, that was thought to be probably linked to limited inland grazing (Schulting and Richards 2009). The animals for which there is evidence of seaweed fodder (Balasse and Tresset...
are dated later than the human remains from the same site. They may result from distinct practices so that a secondary signal deriving from such a route cannot necessarily be inferred from that data.

Sumburgh cist, a Neolithic tomb in Shetland (Hedges and Parry 1980) shows a distribution similar to the mixed diet of the medieval Orcadian groups but with lower δ¹⁵N and δ¹³C, nonetheless suggesting exploitation of mixed protein resources - which is supported by strontium and sulphur isotope results (Melton and Montgomery 2009) - with less marine influence than later people.

Table 178. Bulk Human Collagen Results from Neolithic or Orcadian Sites.

<table>
<thead>
<tr>
<th>SITE (n for this study)</th>
<th>δ¹³C ‰ Published Data</th>
<th>δ¹³C ‰ This Study</th>
<th>δ¹⁵N ‰ Published Data</th>
<th>δ¹⁵N ‰ This Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isbister (n=65)</td>
<td>20.7 ±0.6 a(n=30)</td>
<td>20.7 ±0.4</td>
<td>10.6 ±2.1 a(n=30)</td>
<td>11.8 ±0.5</td>
</tr>
<tr>
<td>Holm of Papa Westray</td>
<td>-20.4 ±1.2a(n=22)</td>
<td>-20.0 ±0.7e(n=5)</td>
<td>9.7 ±3.5a(n=22)</td>
<td>10.54 ±0.6e(n=5)</td>
</tr>
<tr>
<td>North</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point of Cott (n=2(/4))</td>
<td>-20.1 ±0.3a(n=10)</td>
<td>-20.1 ±0.2</td>
<td>9.0 ±3.9a(n=10)</td>
<td>10.6 ±0.3</td>
</tr>
<tr>
<td>Quanterness</td>
<td>-20.6 ±0.5a(n=45)</td>
<td></td>
<td>10.7 ±2.4a(n=55)</td>
<td></td>
</tr>
<tr>
<td>Pierowall Quarry (n=5)</td>
<td></td>
<td>-20.2 ±0.3</td>
<td></td>
<td>11.6 ±0.6</td>
</tr>
<tr>
<td>Crantit (n=1(/2))</td>
<td></td>
<td>-21.5</td>
<td></td>
<td>11.3</td>
</tr>
<tr>
<td>Hambledon Hill</td>
<td>-19.7 ±4.6c(n=56)</td>
<td></td>
<td>9.3 ±0.8c(n=56)</td>
<td></td>
</tr>
<tr>
<td>West Kennet</td>
<td>-20.5 ±0.6b(n=3)</td>
<td></td>
<td>8.3 ±0.2b(n=3)</td>
<td></td>
</tr>
<tr>
<td>Parc le Breos Cwm</td>
<td>-20.5 ±1.0b(n=8)</td>
<td></td>
<td>9.7 ±0.5b(n=8)</td>
<td></td>
</tr>
<tr>
<td>Hazleton North</td>
<td>-20.6 ±0.4b</td>
<td></td>
<td>7.9 ±0.4b</td>
<td></td>
</tr>
<tr>
<td>Bustatown (n=2)</td>
<td></td>
<td>-20.4 ±0.1</td>
<td></td>
<td>11.0 ±0.2</td>
</tr>
<tr>
<td>Howe (n=4)</td>
<td>-20.5 ±0.4</td>
<td></td>
<td></td>
<td>11.4 ±1.0</td>
</tr>
<tr>
<td>Buckquoy (n=4)</td>
<td></td>
<td>-21.0 ±0.2</td>
<td></td>
<td>10.8 ±0.3</td>
</tr>
<tr>
<td>Bu of Cairston (n=8)</td>
<td>-17.8 d(n=1)</td>
<td>-19.8 ±0.7</td>
<td>15.1 d(n=1)</td>
<td>13.1 ±0.6</td>
</tr>
<tr>
<td>Newark Bay (n=1)</td>
<td>-18.4 ±1.2 d(n=46)</td>
<td>-20.4</td>
<td>12.5 ±1.8 d(n=46)</td>
<td>11.0</td>
</tr>
<tr>
<td>Westness</td>
<td>-20.3 ±1.1 d(n=14)</td>
<td></td>
<td>11.8 ±1.5 d(n=14)</td>
<td></td>
</tr>
</tbody>
</table>

a Antoine et al. 1988(n=samples, not individuals); b Richards 2000; c Richards 2009; d Barrett and Richards 2004; e Schulting and Richards 2009.
The medieval Orcadians have a distribution consistent with a mixing line indicating varying amounts of marine vs. terrestrial foods. The variables are clearly correlated. This overlaps with Neolithic Orcadian females at the terrestrial end of the spectrum, leaving Neolithic males distinct. The Sumburgh cist sample overlaps with the medieval Orcadians more than other Neolithic groups do, possibly indicating a more similar mixed diet in these two groups, possibly because the Shetland environment was more demanding.

Sex Related Variation at Isbister

Table 179. Summary Values of Isotopic Results from Isbister Adults.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean δ¹⁵N‰</th>
<th>Standard Deviation</th>
<th>Mean δ¹³C‰</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males (n=14)</td>
<td>11.8</td>
<td>0.31</td>
<td>-20.7</td>
<td>0.43</td>
</tr>
<tr>
<td>M? (n=9)</td>
<td>11.9</td>
<td>0.38</td>
<td>-20.8</td>
<td>0.29</td>
</tr>
<tr>
<td>? (n=8)</td>
<td>11.9</td>
<td>0.62</td>
<td>-20.6</td>
<td>0.38</td>
</tr>
<tr>
<td>F? (n=5)</td>
<td>11.7 (11.5)</td>
<td>0.82 (0.64)</td>
<td>-20.1 (-20.4)</td>
<td>0.56 (0.24)</td>
</tr>
<tr>
<td>Females(n=7)</td>
<td>11.5</td>
<td>0.57</td>
<td>-20.4</td>
<td>0.44</td>
</tr>
<tr>
<td>All Males(n=23)</td>
<td>11.9</td>
<td>0.34</td>
<td>-20.9</td>
<td>0.37</td>
</tr>
<tr>
<td>All Females(n=12)</td>
<td>11.6 (11.5)</td>
<td>0.66 (0.31)</td>
<td>-20.3 (-20.4)</td>
<td>0.49 (0.36)</td>
</tr>
<tr>
<td>Overall Adults(n=43)</td>
<td>11.8 (11.8)</td>
<td>0.51 (0.52)</td>
<td>-20.6 (-20.6)</td>
<td>0.45 (0.39)</td>
</tr>
</tbody>
</table>

NB. Figures in brackets exclude significant outlier later dated to Bronze Age.

There are minor differences between the means for male and female isotope ratio values. Females have a slightly lower mean value for δ¹⁵N and a slightly higher mean value for δ¹³C. The females display a larger standard deviation for both carbon and nitrogen isotope ratios, especially for nitrogen and this
suggests greater variability in dietary or metabolic effects.

Both male and female Neolithic Orcadian humans have values of $\delta^{15}N$ that are consistent with the utilisation of $C_3$ animal protein, assuming a trophic shift of about $3\%$ above the domestic herbivores.

![Figure 270. Sex-related variation in adult isotopic values from Isbister.](image)

Outliers in the bone isotope distribution may come from separate populations. One was recovered from an outwork of the tomb and dated to the Bronze Age (solid triangle in Figure 270). Females have lower values than males in $\delta^{15}N$ but the appearance is influenced by $\delta^{13}C$: the females have a mean about $0.4\%$ lower and sd rather larger than males. The ranges of $\delta^{15}N$ values are similar but the differences are significant ($t=1.82$ with 30 degrees of freedom (2-tailed), $p<0.05$ but $t=3.41$ and $p<0.001$ omitting the Bronze Age outlier). This may indicate a tendency for males to get a higher proportion of their dietary protein from animal sources, especially if we assume a marine component in the females. In isolation, this $\delta^{15}N$ difference might indicate that females were
affected by chronic metabolic features from reproduction and nursing or had a low protein diet (Fuller et al. 2004) but the relationship with δ¹³C suggests otherwise. Because marine predators have very high values of both δ¹³C and δ¹⁵N, this may swamp other signals, so that it is likely, accepting these arguments, that much more of the female diet was vegetable based than the male. It is possible that much of any marine component will have derived from exploitation of low trophic level sources, such as seaweeds or limpets, which would be expected to increase δ¹³C values more than δ¹⁵N. The slight apparent difference in δ¹³C is also significant (t=3.75, p<0.001).

The males appear to cluster closely but randomly, which suggests normal variations of idiosyncratic origin in relative isotope ratios deriving from dietary and metabolic factors. This male cluster is totally distinct from the medieval Orcadian spectrum. The Isbister females however have a linear distribution in which the values for δ¹⁵N and δ¹³C are quite highly correlated (r=0.77). If this difference was the result of metabolic processes, then it might have been expected that the sexes would have shown similar distribution patterns with a shift along one or both axes. The males display what appears to be a normal distribution for each element. The females display a linear distribution, implying a proportional relationship between the variables. This suggests that protein δ¹³C intake is related to δ¹⁵N intake. The gradient is approximately unity, which is larger than expected from metabolic causes (Fuller et al. 2004; Fuller et al. 2005). In a prehistoric northern European context the only likely explanation is that the Isbister females had varying amounts of marine protein in their diets, which does not appear significant in males. Whatever is happening creates a
relationship between the variables in the females. This is not to imply that any single result suggests anything other than a C\textsubscript{3} diet, rather that the overall pattern of the distribution indicates a trend implying a marine component. This supports recently presented arguments for Neolithic marine protein utilisation in Orkney (Schulting and Richards 2009) but suggests sex-related factors, carrying implications for Neolithic social practices as well as subsistence.

It may be that all the females were deposited at a different time to the males, possibly after any taboo on marine foods had passed. If this was the case however, then it might be expected that a pattern more similar to that displayed by medieval people would be demonstrated than is apparent.

Newark Bay adults occupy a mixing line parallel to the Isbister females; the Isbister females seem equivalent to medieval infants but only over a limited
range (with low $\delta^{13}$C and $\delta^{15}$N). Medieval Orcadians had a clear marine protein signal (Barrett and Richards 2004) and the area of overlap with Neolithic samples may indicate environmentally determined and dietary similarities, while the restricted area of overlap illustrates extensive Norse marine exploitation.

**Age Differences at Isbister**

Dividing the samples into age groups also indicates systematic variations. There are distinct clusters for infants, young children (aged 1-4), children aged 4-8, older children (aged 8-12) and young adults. Most of these coincide with the distribution of adult male values but each occupies a different region.

![Figure 272. Isotopic values in different age ranges.](image)

(Areas of the adult male and female distributions are indicated by dashed ellipses for comparison.)

Infants occupy a distribution consistent with a trophic shift in $\delta^{15}$N from the adult female group, with higher $\delta^{15}$N than the adult females but only by about 2‰ –
the lower end of the expected range. This may exhibit a residual signal from gestation but could also reflect stress consistent with early death (e.g. Fuller et al. 2005). They have lower δ\textsuperscript{13}C than the 1-4 year old group.

Two different results came from infant IS(7209) that had superficial endocranial deposits of porous woven bone. The endocranial deposit was sampled separately from the apparently normal cranial bone. The normal bone result lies near to young children, higher in both dimensions than the other infant. The pathological bone forms a distinct outlier from the overall distribution: a dramatic shift downward in both δ\textsuperscript{15}N and δ\textsuperscript{13}C. Compared with the normal cortex, the woven bone will have formed over a short period and its values reflect the isotope reservoir in the body shortly before death. Since both carbon and nitrogen isotope signals were markedly affected, there is likely to have been dietary protein stress with associated metabolic abnormalities (Fuller et al. 2004; Fuller et al. 2005). Such a result might have been expected from this sample, since the most likely aetiology for the pathological bone deposits is ossification subsequent to scurbutic haemorrhages. Scurvy is said not to occur in breastfed infants during nursing (Carpenter 1988:245-6) but that would rely on the mother having sufficient ambient bodily vitamin C to secrete in her milk.

The young children (aged 1-4 years at death) all coincide with the upper part of the adult male distribution: this is most likely to be a trophic level effect from nursing by adult females. The δ\textsuperscript{15}N values only lie above the lower part of the adult female distribution, which may indicate that a limited number of females were actively rearing children and that these may be defined here by diet. The
upper part of the female distribution may therefore possibly then consist of women long enough past childbearing age to develop distinct features. Two infants (IS(7224) and IS(7209), both under two years old at death) actually have lower δ¹³C than any adult female and this could therefore relate to another factor. The young children’s values are intermediate between infants and older children. To ascribe the difference between infants and young children simply to weaning may be oversimplistic. It may be related to rapid growth and varying intakes of food other than breastmilk: these children are probably being nursed but might have additional foods and may be in the process of being weaned.

The intermediate (4-8 years old) and older children occupy the lower extreme of the distribution, indicating the least amount of dietary animal protein, possibly accentuated by metabolic effects of growth. Children aged over four cluster together in the lower part of the adult distribution and have presumably lost any significant nursing signal. Comparison with adult females and younger children suggests that children were probably weaned by about the age of 4 years and later collagen values reflect a childhood diet.

The older children (8-12 years at death) predominantly grouped lower in δ¹⁵N than the adult male mean and lower than younger children. The older children may be starting to exhibit sex-based variation in diet, since two are clearly in the adult female range although none of the other children are. This could indicate assumption of sex-related social roles between the ages of 8 and 12, early enough to cause the shift in bone collagen value. The number of individuals in this group is small so such an interpretation must be considered tentative.
There are two outliers, one of which (IS(1955)) is probably affected by diagenetic processes; the other (IS(1959)) groups with the young adults, which may imply an abnormally precocious diet for this individual.

There is a distinct shift between childhood and young adulthood. The young adults display relatively high $\delta^{15}$N values, at the upper part of the adult distribution. Where sex could be ascribed, they lie in appropriate adult sex-related clusters. This may indicate a high animal protein intake in this age group. It is likely to be significant that the young adult females have higher $\delta^{13}$C values than the males for similar $\delta^{15}$N, which may indicate that the female dietary protein of animal origin is more marine-derived.

No adult female values from this population occupy the region of the chart where a nursing mother would be expected to lie to produce the observed infant signal in bone collagen. The reason for this is likely to be the different timeframes represented in the samples from each age group. Bone turnover causes long-term averaging in the isotope signal ($c10$ years in adults). It is believed that temporary mass balance effects in pregnant women may also account for part of the difference (about 0.5‰ in $\delta^{15}$N) between expected and observed results (Kalhan 2000; Fuller et al. 2004). Another source of difference would exist if pregnant or nursing women had an abnormal diet: this would temporarily affect the ambient isotopic pool in the nurse/mother but would not be fully expressed in her skeletal tissues because of relative turnover half-lives.
Regional Variations in Isotope Results

Orcadian Neolithic humans have higher $\delta^{15}$N values than their English contemporaries. This has been attributed to the exploitation of domestic animals whose own $\delta^{15}$N values were high (Schulting and Richards 2009:71-2). Elsewhere in Europe, possibilities of exploiting freshwater protein sources have been debated (e.g. Bonsall et al. 1997; Borić et al. 2004; Lillie and Richards 2000; Smits and Louwe Kooijmans 2006). This seems implausible in Orkney because such resources were probably limited and there is no supporting faunal evidence for such an interpretation although similarity with Schipluiden could nonetheless be significant (Smits and Louwe Kooijmans 2006:102ff).

Interspecific differences between Orkney grazers show that the sheep have particularly elevated $\delta^{15}$N values. This has been attributed to the use of seaweed as a fodder (Balasse and Tresset 2009), although there is no obvious corresponding carbon isotope signal. Since Orcadian herbivorous domestic
animals exhibit elevated $\delta^{15}\text{N}$ values compared to English examples, the origin may lie in a high $\delta^{15}\text{N}$ in local vegetation. Absence of related $\delta^{13}\text{C}$ variation argues against any marine inputs. Nitrogen enters the food chain from bacterial fixation of atmospheric gas in plant roots, which should be approximately uniform across the British Isles. $\delta^{15}\text{N}$ enrichment is therefore most likely to have come about through the use of $^{15}\text{N}$ enriched fertilisers. The available Neolithic fertilisers were farmyard manure, seaweeds, household waste (including nightsoil) and vegetation. Plant-based fertilisers such as compost might be effective and extensive use of seaweed is recorded (Fenton 1978:274-9). Human 'nightsoil' manure might raise plant $\delta^{15}\text{N}$, but was probably not available in sufficiently large quantities. Excreted urea such as animal manure would be $^{15}\text{N}$ depleted compared with body tissues and use of fresh animal dung would be expected to result in a low $\delta^{15}\text{N}$ in soils and crops. If fresh dung were ploughed in to soil, then reactions would be slow and available nitrogen compounds would be taken up by plants as they were formed, this would result in a lower vegetational $\delta^{15}\text{N}$ signal; if urine were spread on fields without being stored, then it should be assimilated relatively quickly with little loss of the lighter fraction and again the $\delta^{15}\text{N}$ signal would be low. Historically, farmyard manure was managed inefficiently (Davy 1844; Fream 1892:63ff). Urea breaks down to form ammonia, producing heat and, in loose but not compact heaps, circulating air removes the ammonia as gas – particularly the isotopically light fraction. The simplest avenue for vegetational $^{15}\text{N}$ enrichment to occur is through the use of farmyard manure, managed in such a way that the more volatile part was lost as ammonia gas to the atmosphere (Bogaard et al. 2007). This may imply Neolithic use of loosely packed manure heaps for storing or
preparing fertiliser. It is most probable that manuring involved a combination of seaweeds, farmyard manure and nightsoil. There is supporting evidence, from thin-section analyses of Neolithic soils, land snails and isotopic analyses of sealed horizons, which have suggested the presence of ash, excrement and seaweed (e.g. Dockrill et al. 1994; Evans 2004; Guttmann et al. 2006; Dockrill 2007:386). The high δ¹⁵N values in domestic herbivores may then imply regular grazing on previously manured fields or extensive foddering with manured crops.

The corollary of this argument is that such a system was not used to the same degree in the other areas of the UK for which data is available. This is understandable in the case of seaweed use but less so for the other factors. The problem may be resolved through consideration of relative land areas available in Britain and Orkney. The larger land mass of Britain is likely to have had a lower population density than Orkney so that more land would have been available for exploitation. Shifting ‘swidden’ agriculture or transhumance would have been possible in Britain but impractical in Orkney. It has been argued from European ruderal remains that this practice was unlikely (Bogaard and Jones 2007) but differences might also occur from agriculture for different crops or combinations of crops (potentially including nitrogen fixers in European contexts). Longer-term soil development may have been more necessary in the Northern Isles, not only because of the limited extent and depths of cultivable soils but also the smaller land area suitable for inhabitation, which may have fixed occupation sites more greatly in comparison with England (leading to the development of deeply stratified sites such as Ness of Brodgar, Skara Brae and
Pool and apparent in the farm mounds - often still occupied - on Sanday and North Ronaldsay (Lamb 1982; Davidson et al. 1986)).

Another alternative, though not contradictory, explanation might be based on soil differences. Orkney’s soils are predominantly heavy, slightly acid clays but there are areas of calcareous sand around the coast (machair). Lighter coastal soils were predominantly farmed until the nineteenth century. Machair is light but highly aerated and drains rapidly, with little nutrient content: it will have required major inputs of manure or vegetable matter to provide nitrogen and water retention for crop growth, potentially increasing $\delta^{15}$N. If heavy inland soils had been utilised for agriculture, as increasing discoveries of inland Neolithic settlements in Orkney makes likely, then poor drainage and low pH will have affected nitrogenous gas loss and nitrification, also raising crop $\delta^{15}$N. There is considerable geological diversity in the Cotswold-Severn region: the Cotswolds are predominantly limestone with light well-drained soils; the Severn Valley has clays derived from New Red Sandstone and this might be expected to be reflected in local isotope results, which is not obviously (yet at least) the case.
4.3 INCREMENTAL TOOTH COLLAGEN ANALYSES

Bone collagen samples produce isotopic signals that are averaged over potentially long periods, due to continuous remodelling during life: this inhibits precise observation of age-related changes such as weaning (e.g. Mays et al. 2002; Choi et al. 2010; Pearson et al. 2010). Dental tissues by contrast are effectively unchanging in composition from their time of formation, which proceeds gradually in a known pattern, albeit with individual variation in duration (e.g. Anderson et al. 1976; Liversidge and Molleson 2004; AlQahtani et al. 2009 etc.).

Theoretically, in the absence of diagenetic effects, fine sampling of dentine along a transect from crown to root tip should permit an age-related time series of relative isotope values to be determined. This has previously been achieved in sampling dentine and enamel from animal teeth and in human keratinous tissues – hair and fingernails (e.g. O’Connell and Hedges 1999; Balasse et al. 2001; Balasse et al. 2005; Balasse et al. 2006; Fuller and Fuller et al. 2006). Previous investigations in human teeth (e.g. Richards et al. 2002) have been limited by the relatively large sample sizes needed for analysis but as instruments improve both for detection and for processing, smaller samples are becoming increasingly practical. This has clear benefits for resolution but brings associated problems of interpretation.
The graphical plots of results for $\delta^{15}$N and $\delta^{13}$C from incremental dentine samples may effectively be considered as time series with running averages. Because of the sampling method, any transient variations are likely to be smoothed on the graph: this is probably inevitable, since the body reservoir of amino acids might itself be expected to change gradually in isotopic constitution. Graphs below indicate the mean and standard deviation from the bone collagen analyses of this population for comparison; the estimated time of birth in relation to tooth development is shown for the second deciduous molar.
Assuming a steady rate of longitudinal development for the dentine, each successive increment from these teeth is likely to represent a period of about 3-4 months. Note that the increment number used as the x-axis in figures 1 and 2 identifies the equivalent sample for each individual. Comparing the two figures, there is a small offset apparent between the peaks and troughs of these distributions for the elements and this is probably due to the relative rapidity...
with which $\delta^{15}\text{N}$ is replaced in the body in comparison with $\delta^{13}\text{C}$.

Figure 276. The deciduous molar isotopic data as a time series, from increment 1 (in utero) to the latest increment, linked to indicate successive development. An early change is apparent following the extreme values of the first increments related to intrauterine development.

It was expected from the reported results of studies on keratinous tissues from living volunteers (e.g. Fuller et al. 2004) and from archaeological bone collagen reports (e.g. Mays et al. 2002; Richards et al. 2002), that the sections would show a relatively low initial value for $\delta^{15}\text{N}$, followed by a gradual increase as nursing created a trophic level effect until a steady state was reached through replacement of the maternal amino acid pool by a breastfeeding equilibrium, then diminution following weaning. Results were expected to illustrate nursing practices of the Neolithic population. This model has not been observed. The $\delta^{15}\text{N}$ value in each of the first increments is much higher than expected. They are about 2½ standard deviations above the bone collagen mean for Isbister. It exists at the same location in both these teeth. Experimental error is unlikely to be the cause because none of three permanent teeth that were subjected to
exactly the same methods at the same time exhibit this feature.

Interpretation of incremental samples of dentine requires consideration of the formation of the dental collagen during life. We need to know how much collagen is deposited over what age range and in which locations. This is problematic. As early as 1959, the accuracy of tables of development was criticised: the majority (including Schour and Massler 1937, 1941) were ultimately derived from Logan and Kronfeld’s flawed study (Garn et al. 1959). The age ranges quoted for development were claimed to be too narrow and the manner of development described inaccurately (Kraus 1959; Christensen and Kraus 1965; Garn et al. 1959:135; Coughlin and Christensen 1966). Radiography fails to accurately observe early mineralisation stages (Hess et al. 1932; Beynon et al. 1998; Scheuer and Black 2000; Grine et al. 2001) and the greater density of enamel effectively hides a significant part of the dentine. It is impossible to adequately observe the interior of concave structures, such as the cusps and the crowns. For deciduous teeth especially, there is little definitive published information because of the ethical and practical difficulties of in vivo study. Information comes mostly from post-mortem studies and in particular the work of Kraus, some 50 years ago (Kraus 1959; Kraus and Jordan 1965). Forensic and archaeological remains provide data but such remains rarely have a known age at death except (possibly inaccurately) in ‘nameplate’ samples recovered from post-medieval contexts (e.g. Molleson and Cox 1993): age is likely to be assigned based on development, which results in circular arguments. The other major source is autopsy results from perinatal and infantile deaths: for these, the age is known but the prenatal developmental
status may be abnormal (e.g. Levine et al. 1979). Although the study group used by Schour and Massler was affected by ill-health, the same will probably be true of most archaeologically recovered infants (Hillson 1996:146). Dental development is assessed at time of death but rates of development are not observed. Most studies, especially those using radiography, have concentrated on enamel and such data is not directly applicable to dentine. There are more (and more extensive) studies of permanent than of deciduous teeth (and of animals) but the results may not be transferable because of different growth rates and patterns. Broad trends of development are known but variation and possible age-related thresholds are less understood.

Deciduous teeth develop more rapidly than the permanent teeth and the earliest, intrauterine, development is faster than that occurring after birth. Initial mineralisation of the deciduous mandibular second molar occurs between 18 and 24 weeks in utero. Growth and mineralisation do not proceed at the same rate in all dimensions: buccolingual, mesiodistal and longitudinal rates have been observed to vary; even for individual cusps (e.g. Mahoney 2010) but dentine development is always in advance of enamel. An average daily rate of dentine apposition of 16μm has been calculated (e.g. Schour and Hoffman 1935; Massler 1946), with postnatal rates per odontoblast cell of 5.5μm at the cusps and 4μm at the mid-crown respectively (Schour and Massler 1937); Difficulties in interpreting incremental lines in dentine have been discussed (Hillson 1996:187ff) but are usually simply accepted as present; Schour’s definitions “have not stood the test of time” (Hillson 1996:126). A daily deposition of 4μm, with a superimposed 5-day cycle incrementally measuring
20μm has been suggested but without estimates of variation (Ten Cate 1998:128, 143); variation between 4μm and 8μm in crowns has been quoted elsewhere (Avery in Bhaskar 1976:114). There are additional problems from variations in terminology and development stages (Liversidge 2008).

Dental development has been summarised in atlases (e.g. van der Linden and Duterloo 1976) and used for attributing age at death by macroscopic examination. Systems of nomenclature related to that of Moorrees or Demirjian are used (Moorrees et al. 1963; Demirjian et al. 1973; AlQahtani et al. 2010) but definitions of developmental stages vary. Christensen and Kraus (1965:fig.1) considered development of dm2 at 36 weeks gestation to have the occlusal crown outline complete with a small unmineralised island; Turner (1963) implied that the cusps would still be separated at this age. Stack (1961) described the coalescence of cusps of dm2 before birth but noted that it was necessary to extract the cusps individually from mature foetuses, conceding that much of the study material may have suffered retarded development (Stack’s figure 1 however appears to show that cusps had coalesced). Tomes (1904:215) found that the full term foetus has a dm2 in which the cap dentine and root are 3mm in length. Little specific information is available on the mass or volume of dentine deposited. The proportion of enamel formed in utero for dm2 must be considered as a proxy. It varies according to cusp, with the greatest development being 76% of the protoconid but only 20% of the entoconid; the others are intermediate (Mahoney 2010).

Birth permits the direct observation of erupting tooth crowns and longitudinal
study of individuals. This biases studies towards enamel. Crown formation time has been assessed but increase in dentine volume remains obscure and there are reservations regarding definition (Beynon et al. 1998). Sources using different materials and methods suggest that mean crown formation time after birth may be between 0.75 years (0.6-0.9 years at 1sd – Moorrees et al. 1963) and 1.08 years (0.79-1.30 years at 1sd- Glister et al. 1964; 0.97-1.20 years at 1sd Mahoney 2011); Fanning and Brown (1971) suggested 0.77 years (0.51-1.01 years at 2sd) and Liversidge and Molleson (2004) gave 0.92 years (0.66-1.18 at 1sd). There is thus no simple precise figure for even this development stage.

For root development, radiography is more suitable because the root is not hidden by radio-opaque enamel. The root develops more rapidly lengthways than in cross-section, so dentine is still being deposited towards the pulp cavity relatively late (Liversidge and Molleson 2004). This has implications for cross-sectional incremental analysis because early in development the root will reflect more nearly a short developmental period but later there will be an increased signal from younger dentine, accentuated by sigmoid apposition. Relationships of mineralised root and tooth lengths to age are reasonably well understood but the premineralisation thickness of the dentine must also be considered. Liversidge and Molleson’s stage C has dentine visible below the occlusal surface and beginning to form sides of the molar; according to their table 2, this stage has been reached or passed by 0.39 ± 0.21 years of age. Although quoting median and range might be more appropriate, this implies that stage C could be reached before birth or later than 9 months of age.
Measurements of the thickness of mineralised tooth (not collagen formation) at each cusp in relationship to general stage of development have been published (Butler 1968, especially table 1) but dentine and enamel were not distinguished. If it is assumed that dentine develops earlier and is thicker than enamel, then on average, more than 1mm thickness of dentine will have formed at the cusps before birth.

<table>
<thead>
<tr>
<th>Cusp</th>
<th>Stage g</th>
<th>Stage h</th>
<th>Stage i</th>
<th>Stage j</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protoconid</td>
<td>1.10 (n=9)</td>
<td>1.71 (n=11)</td>
<td>2.06 (n=11)</td>
<td>3.11 (n=11)</td>
</tr>
<tr>
<td>Metaconid</td>
<td>0.29 (n=8)</td>
<td>1.03 (n=9)</td>
<td>1.63 (n=11)</td>
<td>2.51 (n=11)</td>
</tr>
<tr>
<td>Hypoconid</td>
<td>0.29 (n=9)</td>
<td>0.98 (n=11)</td>
<td>1.52 (n=10)</td>
<td>2.68 (n=9)</td>
</tr>
<tr>
<td>Entoconid</td>
<td>-</td>
<td>0.46 (n=9)</td>
<td>0.98 (n=9)</td>
<td>2.22 (n=8)</td>
</tr>
<tr>
<td>Approx Foetal Age</td>
<td>23.6</td>
<td>27.2</td>
<td>30.5</td>
<td>34.5</td>
</tr>
</tbody>
</table>

| Stage Description | Butler’s description claims that entoconid and hypoconid are uncalcified | All cusps present as separate calcified areas | Protoconid and metaconid have coalesced, sometimes hypoconid too | All coalesced except an area in talonid basin |

Dentine is laid down before enamel at each cusp location, organic matter developing prior to mineralisation, and by 27 weeks (estimated from crown-rump length), dentine extends to the base of the protoconid and beyond (Turner 1963:535ff). The dentine associated with all cusps in that study had coalesced by 40 weeks, although enamel was just starting to form over the hypoconid and entoconid. Unfortunately, the results were presented as a normative state of development for each crown-rump size group and there was no discussion of
variation, nor of the manner by which intermediately sized foetuses were assigned to a given size group. Although no table of measurements was published, Turner's figures appear to indicate a thickness of 1.5mm of mineralised tissue in the protoconid at 31-32 weeks (gestational, based on crown-rump length 255mm) (Turner 1963:fig.14), although some of this would probably be enamel. Tissue type clearly biases studies of dental development, with enamel better known than dentine and organic components least understood.

Crabb, though examining enamel mineralisation, gave illustrations of ground sections and microradiographs of ground sections of teeth from full term foetuses (Crabb 1959). One of these is the mesiobuccal cusp from a deciduous mandibular second molar, which appears to indicate a substantial thickness of dentine filling the cusp and extending both across and down the crown. This microradiograph is not accompanied by a transmitted light view, so that the presence of any neonatal line cannot be assessed. There is concern over the accuracy of age attribution for the foetuses studied in this paper, because fig 1a, supposedly of a “full-term foetus” appears to have a neonatal line midway up the dentine. In common with most enamel studies, the line drawings fail to indicate dentine.

One study has utilised serial microtomography to map volumes of dental tissue but was used on archaeologically recovered teeth (Avishai et al. 2004). Age of development therefore had to be inferred from development. The tooth studied was the deciduous mandibular second molar and the age distribution was
assessed as being from 7.5 months (gestational) through to 10 months postnatal. Refreshingly, dentine cusp height was measured. The authors grouped all their data together however, so they cannot be related to age: it seems to be assumed by the authors that this cusp height had formed by birth.

A 3-dimensional developmental atlas is under development, using serial histological sections and computer graphics to create tomographic images from 22 foetuses ranging from 18 to 270mm crown-rump length (Radlanski and Renz 2010). Material published so far concentrates on early development (19–117mm crown-rump length) however and has little utility here (Radlanski 2003). Others have used computerised tomography of radiographic data from living subjects, which limits usefulness of their atlas (Krarup et al. 2005).

It is also necessary to consider the time element for expression of isotopic changes in ingestion compared with changes in body tissues. For adults, an isotopic half-life of 300 days has been proposed but this is unlikely to apply to juveniles whose mass balance will be affected by growth rate. In adults, studies on hair and fingernails suggest that at least 4 weeks is required for a consistent change in diet to become apparent (Huelseman et al. 2009; Petzke and Lemke 2009).

<table>
<thead>
<tr>
<th>Cusp</th>
<th>Mean dentine cusp height (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protoconid</td>
<td>1.568 ± 0.156</td>
</tr>
<tr>
<td>Metaconid</td>
<td>1.990 ± 0.373</td>
</tr>
<tr>
<td>Hypoconid</td>
<td>1.649 ± 0.140</td>
</tr>
<tr>
<td>Entoconid</td>
<td>2.163 ± 0.255</td>
</tr>
<tr>
<td>Hypoconulid</td>
<td>1.798 ± 0.214</td>
</tr>
</tbody>
</table>

Table 182. Dentine Cusp Heights at Birth (reported by Avishai et al. 2004).
The result on this study of having so many unknowns is that it is properly necessary to consider different developmental models. The extreme models are that birth took place after one or more millimetres thickness of dentine had been deposited at the crown; and alternatively, that this thickness of dentine had not developed until sufficiently long after birth that no maternal signal may be observed; the intermediate position is that the initial increment(s) will contain a mixed prenatal and post-natal signal. One potential approach that might be used to partly overcome this would be to employ a parallel histological study to identify the neonatal line and thereby define the pre- and post-natal volumes.

There is less difficulty with tooth root increments. Although there may be a late dentine deposit present, each deciduous molar selected had an incomplete root and those roots were thin. It seems unlikely that the early development signal will have been much affected by root maturation or healing of lesions. The roots are likely to exhibit similar age-related time series. The time scale of observations still needs to be considered. Tooth length is closely related to age, so that the ages at death of each of these infants may be inferred (Stack 1967).

<table>
<thead>
<tr>
<th>Tooth</th>
<th>Development stage achieved</th>
<th>Age dentine formation begins</th>
<th>Age at death</th>
<th>Total development time</th>
<th>Period per increment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant 1</td>
<td>F</td>
<td>18-24 weeks</td>
<td>2.28 ± 0.51 yrs</td>
<td>16-40 months</td>
<td>2.3-5.7 months</td>
</tr>
<tr>
<td>Infant 2</td>
<td>F</td>
<td>18-24 weeks</td>
<td>2.28 ± 0.51 yrs</td>
<td>16-40 months</td>
<td>1.5-3.6 months</td>
</tr>
</tbody>
</table>

The small number of increments from infant 1 has a dramatic effect in
calculating the maximum development time and the lower figure seems more likely to be correct. For infant 2, the large number of increments reduces the lower estimate and an intermediate age at death is probable. Assuming stage G rather than F would have the effect of adding about 6 months to total development time (i.e. 23-45 months). This would effectively add 0.5 months to development for infant 2 (i.e. suggesting about 2-4 months development per increment) but would probably be inappropriate. There is a difficulty in assigning Demirjian stages here because the system was developed for permanent teeth and relies on proportions of crown to root for definition of stage.

<table>
<thead>
<tr>
<th>Tooth</th>
<th>Development stage achieved</th>
<th>Age dentine formation begins</th>
<th>Age of death (Ubelaker fig.77)</th>
<th>Total development time</th>
<th>Period per increment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant 1</td>
<td>R1/2</td>
<td>18-24 weeks</td>
<td>1.1 –2.1 yrs</td>
<td>14-26 months</td>
<td>2-3.7 months</td>
</tr>
<tr>
<td>Infant 2</td>
<td>R3/4</td>
<td>18-24 weeks</td>
<td>1.4 – 2.4 yrs</td>
<td>18-30 months</td>
<td>1.6-2.7 months</td>
</tr>
</tbody>
</table>

Mineralisation times estimated from atlases of dental development suggest that infant 1 died at 16-32 months (2.4-4.7 months per increment) and infant 2 died at 24-48 months (2.3-4.4 months per increment) (following Ubelaker 1999). These figures are highly consistent between the two teeth and suggest that assuming 3 months development per increment is appropriate.

Assuming that significant dentine formation only took place after birth makes interpretation highly problematic. Both infants have a very high initial δ¹⁵N value,
which is inconsistent with the gradual development that would be expected as a
trophic level effect from nursing. The early decreasing value with distance from
the occlusal surface would imply that nursing ceases or is reduced almost
immediately after the first increment has formed. Therefore weaning had begun
within 3 months in both individuals. Such an interpretation may be plausible for
infant 2, whose values for $\delta^{15}$N remain low, which is consistent with a
vegetable-based diet. In the case of infant 1, the subsequent rise in $\delta^{15}$N value
suggests either a resumption of breastfeeding at about one year of age, or
feeding with a high animal protein diet beginning at that time. Either of these
must be considered highly unlikely and the assumption of formation after birth
must be rejected. There may be further supporting evidence in an electron
micrograph of one tooth, which shows a demineralised layer that may reflect the
neonatal line: this occurs at about 1mm into the dentine.

Assuming that the earliest dentine increments were formed before birth
provides an alternative interpretation. The individual points effectively reflect the
body’s $\delta^{15}$N pool derived from dietary protein over successive three-month
(approximately) periods, beginning in the second gestational trimester (left of
chart) and ending at the probable age of about two or three years (far right of
chart). Birth will probably have occurred at about increment 2. During gestation,
a foetus is expected to have the same isotopic composition as its mother (e.g.
Fuller and Fuller et al. 2006). The cusp samples therefore reflect the mothers’
isotopic signals as well as the infants’. The high $\delta^{15}$N value is too early and
short-lived to be due to nursing. Such a high initial value might derive from
either a maternal diet with extremely high $\delta^{15}$N or from some condition resulting
in loss of low δ^{15}N protein. Pregnancy is likely to result in a diminished δ^{15}N value (Kalhan 2000; Fuller et al. 2004); nutritional stress is expected to cause an increase (Fuller et al. 2005). It is possible to suggest therefore, from the δ^{15}N values, either that pregnant women were receiving, or had received prior to pregnancy, a special diet, possibly very high in animal protein. It may be that the initial formation of the tooth in utero results in some metabolic feature that is not present elsewhere during tooth development but there is no apparent reason for this to be the case. The sharp decrease in δ^{15}N probably occurs around birth and may relate to maternal diet during pregnancy, perhaps a change introduced when pregnancy was recognised, allied to the mass balance effects from the growing foetus (Kahlan, 2000; Fuller et al. 2004). The increase in δ^{15}N after birth is most likely to be due to nursing, which gradually increases the value because the infant is being fed at a higher trophic level and thus the isotope ratios are affected by further fractionation. For infant 1, this rise stops abruptly, suggesting that there was no significant period without nursing before death. For infant 2 however, there is very little observable result of nursing: it is likely that this infant, with a uniformly low δ^{15}N value (close to the Isbister group minimum) was being fed predominantly vegetable foods, perhaps most likely to have been pap or gruel, with very little animal protein. Infant 2’s mother may have died in childbirth or been unable to produce milk, or the child may have been unable to suckle: any of these factors may have contributed to early death.

The chart of δ^{13}C against age corroborates these features and permits further interpretation. Again, both teeth appear to show a decrease at about the time of
birth. Infant 1 has a set of values that closely reflect the $\delta^{15}$N pattern and are likely to relate to breastfeeding; they are not however so extreme as the values for $\delta^{15}$N. It seems likely that the mother did not have a diet particularly high in marine protein because the $\delta^{13}$C value, though correlated strongly with $\delta^{15}$N, is clearly relatively too low. The first sample’s value is elevated well above the population mean but not to the degree apparent later, in what is likely to be the breastfeeding signal. Infant 2 has a low initial value from *in utero* formation, suggesting that the mother had little marine protein before or during pregnancy. Probably not breastfed after birth, this infant shows a gradual increase in $\delta^{13}$C over the period of tooth formation, rising from the population mean into the upper 15% for bone collagen results of the Isbister population. This increase may possibly reflect a marine component being used to supplement a predominantly terrestrial diet. In infant 1, the signals from each element are highly positively correlated following the initial drop in values ($r = 0.88$); in infant 2, there is a strong negative correlation ($r = -0.79$). The slight increase in $\delta^{13}$C in infant 2 is clearly not related to ingestion of marine foods from a high trophic level, because of the negative correlation with $\delta^{15}$N, but could be consistent with the use of seaweeds or marine grazers for example. This may then imply that particular food sources had particular dietary uses (i.e. for specific segments of society or at particular times).

Minor peaks and troughs in the distributions could reflect a seasonal variation in diet and this would be equally consistent with exploitation of particular foods as a seasonal activity or with the seasonal use of stored foods. The slight offset between the peaks and troughs for carbon and for nitrogen may reflect the
differences in turnover rates of the two elements (Huelsemann et al. 2009) Assuming a two-year spread of the data points, a five point periodicity would suggest seasonality for the appearance of the peaks and for the troughs in both δ^{15}N and δ^{13}C in infant 2, supporting the implication of intake of (seasonal) foods other than breast-milk, in contrast to infant 1. It may have been significant from a nutritional perspective, that infant 2 had a lower intrauterine δ^{13}C value than infant 1. Most significantly, there appears to be a systematic diminution in bone δ^{15}N values in this population at about the age of four years, which may indicate the age of weaning.

The possibility that one or both of these teeth was misidentified was considered. Morphologically, each tooth appeared to be a deciduous mandibular second molar. The spread of the roots, cervical “waist” and ratio of crown height to root length are correct but each crown is slightly larger than the largest dm2 still in its socket in this assemblage. There is no evidence to support the possibility that either of the two teeth considered here was a permanent molar.

The high intrauterine value for δ^{15}N in both infants remains to be satisfactorily explained. Although a dietary cause is most plausible, it may be that the early formation of the deciduous tooth results in some hitherto unrecognised physiological factor. Some suggestion that this might exist may be seen in a published high coronal δ^{15}N value for deciduous teeth (Richards et al. 2002) but this was probably a nursing signal.
Table 185. Alternative Interpretations of Deciduous Tooth Development (Infant 1).

<table>
<thead>
<tr>
<th>Infant 1 (R1/2)</th>
<th>Implications</th>
<th>Arguments For</th>
<th>Arguments Against</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dm2 with 1st increment formed in utero;</td>
<td>intrauterine – c2yrs: increments at 3-4 month intervals; died 13-24mths</td>
<td>Fits histological development model; Explains later increase in δ¹⁵N as breastfeeding</td>
<td>Unexpectedly high early δ¹⁵N; Crown size large; Early increment v v high δ¹⁵N</td>
</tr>
<tr>
<td>Dm2 with first increment formed after birth;</td>
<td>birth – c2yrs, increments at 3-4 month intervals; died 13-24mths</td>
<td>If early increments indicate breastfeeding then possibly delayed development</td>
<td>No indication of in utero signal; high δ¹⁵N early; no explanation for later increase in δ¹⁵N; crown size large</td>
</tr>
<tr>
<td>Misidentified M1</td>
<td>birth – c8yrs: increments at c9month intervals; died 4-6 years</td>
<td>Crown size large; early increments indicate breastfeeding and early weaning, young but possibly consistent with bone</td>
<td>Tooth form is dm2; roots relatively short; later rise in δ¹⁵N occurs much too young – inconsistent with bone</td>
</tr>
<tr>
<td>Misidentified M2</td>
<td>c3or4 - 9yrs: increments at c9 month intervals; died 7-12 years</td>
<td>Early high δ¹⁵N from late breastfeeding; later increase consistent with bone results</td>
<td>Crown large; early high δ¹⁵N should be lower due to other food inputs</td>
</tr>
</tbody>
</table>
Table 186. Alternative Interpretations of Deciduous Tooth Development (Infant 2).

<table>
<thead>
<tr>
<th>Infant 2 (R3/4)</th>
<th>Implications</th>
<th>Arguments For</th>
<th>Arguments Against</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dm2 with 1st increment formed in utero</td>
<td>intrauterine – c2yrs, increments at 3-4 month intervals; died c2yo (1.4-2.4)</td>
<td>Fits histological development model</td>
<td>Unexpectedly high early $\delta^{15}$N; crown size large</td>
</tr>
<tr>
<td>Dm2 with first increment formed after birth;</td>
<td>birth – c2yrs, increments at 3-4 month intervals; died c2yo (1.4-2.4)</td>
<td>Early increments may indicate breastfeeding if development delayed</td>
<td>No indication of in utero signal; early increments high $\delta^{15}$N; no explanation for later increase in $\delta^{15}$N; crown size large</td>
</tr>
<tr>
<td>Misidentified M1;</td>
<td>birth – c8yrs, increments at c9month intervals; died c5-9yo</td>
<td>Crown size consistent; explains $\delta^{15}$N values well - early increments indicate breastfeeding and early weaning, young but possibly consistent with bone</td>
<td>Tooth form is dm2; roots relatively short; exceptionally low $\delta^{13}$C in earliest increment</td>
</tr>
<tr>
<td>Misidentified M2</td>
<td>c3or4 -11yrs, increments at c9month intervals; died c9-13yo</td>
<td>Early high $\delta^{15}$N possibly from late breastfeeding</td>
<td>Crown large; early high $\delta^{15}$N should be lower due to other food inputs</td>
</tr>
</tbody>
</table>
Childhood: incremental analysis of the canine

This tooth develops between birth and about 11-15 years of age. Assuming uniform development, each increment represents approximately 9-12 months of life.

Table 187. Results from Incremental Isotopic Analysis of a permanent Canine.

<table>
<thead>
<tr>
<th>Increment from Coronal Tip (mm)</th>
<th>$\delta^{15}$N ‰</th>
<th>$\delta^{13}$C‰</th>
<th>Ratio C:N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.9</td>
<td>-21.1</td>
<td>3.2</td>
</tr>
<tr>
<td>2</td>
<td>11.7</td>
<td>-21.1</td>
<td>3.2</td>
</tr>
<tr>
<td>3</td>
<td>12.3</td>
<td>-21.0</td>
<td>3.2</td>
</tr>
<tr>
<td>4</td>
<td>12.3</td>
<td>-20.9</td>
<td>3.2</td>
</tr>
<tr>
<td>5</td>
<td>12.6</td>
<td>-20.8</td>
<td>3.2</td>
</tr>
<tr>
<td>6</td>
<td>12.4</td>
<td>-20.6</td>
<td>3.2</td>
</tr>
<tr>
<td>7</td>
<td>12.3</td>
<td>-20.6</td>
<td>3.2</td>
</tr>
<tr>
<td>8</td>
<td>12.2</td>
<td>-20.6</td>
<td>3.2</td>
</tr>
<tr>
<td>9</td>
<td>12.3</td>
<td>-20.6</td>
<td>3.2</td>
</tr>
<tr>
<td>10</td>
<td>12.4</td>
<td>-20.6</td>
<td>3.2</td>
</tr>
<tr>
<td>11</td>
<td>12.4</td>
<td>-20.6</td>
<td>3.2</td>
</tr>
<tr>
<td>12</td>
<td>12.3</td>
<td>-20.6</td>
<td>3.2</td>
</tr>
<tr>
<td>13</td>
<td>12.2</td>
<td>-20.6</td>
<td>3.3</td>
</tr>
<tr>
<td>14</td>
<td>12.2</td>
<td>-20.5</td>
<td>3.2</td>
</tr>
<tr>
<td>15</td>
<td>12.1</td>
<td>-20.5</td>
<td>3.2</td>
</tr>
<tr>
<td>16</td>
<td>12.2</td>
<td>-20.4</td>
<td>3.2</td>
</tr>
<tr>
<td>17</td>
<td>12.1</td>
<td>-20.5</td>
<td>3.2</td>
</tr>
<tr>
<td>18</td>
<td>12.6</td>
<td>-20.6</td>
<td>3.2</td>
</tr>
</tbody>
</table>
The canine has an initially low value for $\delta^{15}\text{N}$ that drops before rising sharply to a plateau. The initial decrease is small and may be mere random variation, a trophic level effect from nursing or a metabolic result from stress but it is possible that this reflects a much-reduced remnant of the signal from the high initial values noted in the deciduous molars. The $\delta^{15}\text{N}$ value peaks at increment...
5, which represents approximately 3-5 years of age. Although there is some fluctuation, there is a general trend of diminution in the signal from that point, suggesting a reduction in high $\delta^{15}$N protein and consistent with weaning onto what in this population is likely to be a predominantly cereal diet. The sudden jump in $\delta^{15}$N in the final increment (the 18th) is consistent with the age-related change noted in the bulk bone collagen, probably associated with the change from childhood to adulthood at puberty.

The $\delta^{13}$C values display a steady increase up to the 8th increment, followed by a plateau with a late peak before a relatively rapid diminution. The initial part of the distribution is consistent with the trophic level effect expected from breastfeeding. Although the changes in values seem high relative to those for $\delta^{15}$N, it may be that the nurse had an increase in marine protein in her diet that is being reflected. There is an offset in changes from the $\delta^{15}$N values, which may relate to slightly different isotope replacement rates leading to a time-lag in expression of intake in skeletal tissues. The peaks and central trough in the $\delta^{13}$C values are opposite to those for $\delta^{15}$N, which could indicate a negative correlation between the two during later childhood. This is clearly not a trophic level effect but there are two other likely possibilities: it may be that the child was under occasional stress, which led to a fall in the $\delta^{15}$N values; or it may be related to a need to use low trophic level marine protein, which would increase $\delta^{13}$C without necessarily affecting $\delta^{15}$N, if for example limpets or seaweed were replacing high $\delta^{15}$N cereals. The latest increments represent the very end of childhood (likely to be around puberty) and display a significant change: a rapid rise in $\delta^{15}$N associated with a diminution in $\delta^{13}$C. This is likely to represent an
increase in terrestrial animal protein in the diet and may be associated either with metabolic or social changes at this important time of life. It is unlikely to be caused by a growth spurt because in that case, a mass balance effect should lead to diminution in δ^{15}N (although one study suggested no such effect for well-fed animals (Ponsard and Averbuch 1999)). The variations are also apparent in the bone collagen at this age: a drop in δ^{15}N values after the age of four years and an increased value in young adults.

Figure 279. Canine isotopic values as a time series.
Adolescence and Early Adulthood: incremental analysis of third molars

The increments in adult 3rd molars relate to development periods of about 12 months, from about age 9, ending about the early twenties but this tooth is highly variable in its development.

The third molar incremental results, from two individuals, exhibit features that
are suggestive of sex variation. $\delta^{15}\text{N}$ values are similar to other samples, with a mean of 12.2‰ (range 11.7‰ – 12.6‰). The values for $\delta^{13}\text{C}$ however show considerable variation – from –20.6‰ to –18.1‰. These higher $\delta^{13}\text{C}$ values are not seen elsewhere in human results from the Orcadian Neolithic. The variation appears to be systematic, dominated by a periodic fluctuation in $\delta^{13}\text{C}$ associated with slight changes in $\delta^{15}\text{N}$ value. Adult 1’s earliest sample shows low $\delta^{15}\text{N}$, which then rises and falls and rises again with a possible 4 year cycle. This may illustrate the change from childhood to adulthood noted in the bone samples, followed by periodic variations. Adult 1 has a pattern of values in the ‘female’ region but with far higher values for $\delta^{13}\text{C}$ clearly indicative of periodic low trophic level marine protein. There is some association with a small variation in $\delta^{15}\text{N}$ that displays time lag. It is tempting to relate the apparent periodicity here to the suggested weaning age and potentially therefore to a childbearing cycle.

The values for adult 2 show little variation. The $\delta^{15}\text{N}$ values cluster around 12.0‰ (range 11.7‰ – 12.8‰) and $\delta^{13}\text{C}$ clusters around –20.6‰ (range -20.4‰ – –20.9‰). These are consistent with the bulk bone values from Isbister adult males. The values do not appear to be random but subtly systematic. There is a diminution in $\delta^{15}\text{N}$ followed by a rise that may be associated with a slight increase in $\delta^{13}\text{C}$, so that the series gives a U-shaped appearance on the chart. Each period of change is of about the same duration, with a minimum at about age 14-15. It is tempting to suggest that adulthood may have been achieved in the mid-teenage years, with the young adult high $\delta^{15}\text{N}$ diet developing from that age.
Table 188. Incremental Isotope Ratio Values of Third Molars from Isbister.

<table>
<thead>
<tr>
<th>Increment</th>
<th>Adult 1</th>
<th>Adult 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\delta^{15}\text{N}%$</td>
<td>$\delta^{13}\text{C}%$</td>
</tr>
<tr>
<td>1</td>
<td>11.6</td>
<td>-20.0</td>
</tr>
<tr>
<td>2</td>
<td>11.7</td>
<td>-19.3</td>
</tr>
<tr>
<td>3</td>
<td>12.1</td>
<td>-19.0</td>
</tr>
<tr>
<td>4</td>
<td>12.1</td>
<td>-18.7</td>
</tr>
<tr>
<td>5</td>
<td>12.5</td>
<td>-18.1</td>
</tr>
<tr>
<td>6</td>
<td>12.4</td>
<td>-19.3</td>
</tr>
<tr>
<td>7</td>
<td>12.1</td>
<td>-19.8</td>
</tr>
<tr>
<td>8</td>
<td>12.3</td>
<td>-20.3</td>
</tr>
<tr>
<td>9</td>
<td>12.0</td>
<td>-20.6</td>
</tr>
<tr>
<td>10</td>
<td>12.3</td>
<td>-20.2</td>
</tr>
<tr>
<td>11</td>
<td>12.4</td>
<td>-19.8</td>
</tr>
<tr>
<td>12</td>
<td>12.6</td>
<td>-19.2</td>
</tr>
<tr>
<td>13</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>14</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>15</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Figure 282. Third molar isotope values arranged as a time series. (Please note that the axes used in this figure have altered scales compared with others. This was necessary because otherwise the y-axis variation would be unidentifiable whereas the x-axis variation from adult 1 would be off the previous scale.)
4.4 **SUMMARY OF STABLE ISOTOPE STUDY**

The origin of dietary protein in Neolithic Orkney has been confirmed as predominantly terrestrial, based on intensive farming. Marine foods had a minor role, which may have been seasonal, as a famine food or related to particular circumstances of the reproductive cycle.

There is a question as to whether these results reflect diet or a combination of diet and catabolic processes. Malnourishment is a likely factor, in particular protein starvation, which may have led to elevated δ¹⁵N values (Katzenberg 2000:318). Young child IS(7210), aged 2-4 at death is likely to exhibit a nursing signal, giving a trophic shift relative to the mother or wet-nurse. The collagen values are consistent with this. A nursing trophic shift might be expected for the younger child IS(7223) but this individual is an outlier for collagen isotope values. Macroscopic study suggested that this child was stunted in growth and had probably suffered from scurvy. IS(1959), aged 5-6 at death, may have also had δ¹⁵N elevated by stress factors (Fuller *et al* 2005).

A fine sampling strategy for dentine allowed an approach to dietary and metabolic changes within single individuals over time. Time resolution in this method is likely to be limited by physiological factors of amino acid replacement. It is of a similar order to the isotopic half-life expected in a human adult and the delay following metabolic or dietary disturbance in changes becoming apparent in skeletal tissues is relatively significant on such a timescale. The fine detail of these results requires a conceptual leap from interpretations of bone collagen analyses. The number of teeth analysed was small but results were consistent
with observations from bone collagen. This approximates a partial life history for individuals, albeit at low resolution and led to some unexpected results. The variations demonstrated in the different data sets form a coherent pattern that can be interpreted in terms of diet. This is not to suggest that physiological factors are not present but rather that we need further longitudinal studies in order to investigate them before we can properly evaluate data of this sort.

One infant was shown to be breastfed and may have been influenced by the nurse’s intake of marine foods (pp430-447 above). Another infant appears not to have received significant quantities of human milk but had some other dietary input. This non-breastfed diet shows a degree of periodicity that is consistent with seasonal exploitation strategies involving minor quantities of marine protein. It is likely to be significant that the $\delta^{15}$N values from this infant signal are significantly below the population mean whereas the $\delta^{13}$C values are significantly high: whatever the source of marine protein, it was unlikely to have been fish, seal or any other high trophic level source.

The common practice in this population appears to have been one of weaning at the age of about four years old, although supplementary foods appear earlier in life (pp421ff above). This is a common age for weaning ethnomedically, and was for example reported in the USA in the nineteenth century (Dettwyler 1995). Adult female diet may have features linked to this periodicity (pp449-451 above). For the remainder of childhood – probably until puberty – individuals have a low animal protein diet that may reflect a low social status of children. This is unlikely to be due to a mass balance effect of growth because juveniles
in medieval Orkney are isotopically indistinguishable from adults after the age of about seven years (Figure 272 above).

Of particular significance are the relative distributions of adult females and young juveniles (Figure 272, pp442-445, pp449-451, pp543-454 above). The 0-4 years old at death age group form a nearly linear distribution elevated in $\delta^{15}N$ compared to the adult females. It is possible that some exhibit a relative decrease in $\delta^{15}N$ relative to $\delta^{13}C$ associated with the introduction of foods other than milk.

Thus far, each collection has been treated as a single population, despite the potentially long period represented. It is likely that there were diachronic variations but in commingled assemblages, the only way to investigate this is through radiocarbon dating. A radiocarbon dating project was therefore included within this project and is discussed in the following section.
4.5 Radiocarbon Dating of Human Bone from Isbister

“the poor world is almost six thousand years old”

As You Like It, Act IV, Scene 1

Typology of the Orcadian chambered tombs has been discussed briefly in Chapter 1. This was sufficient to indicate that there are several different schemes of development, none of which has been proven valid. Radiocarbon dating of chambered tombs is highly problematic. There are problems such as residuality of datable material, contamination, usually commingling and an absence of useful stratigraphy. Direct dating of individuals though is important.

Cranial bone samples from 64 individuals from Isbister were available for radiocarbon analysis. All had been subjected to stable isotope analysis, which indicated that four exhibit signs suggesting diagenesis and a further eight were considered to be poor prospects for radiocarbon work because they had low collagen yields. One sample was insufficiently large. This presented 51 potentially suitable samples but it was felt that this number was probably larger than needed to address the significant issues presented by macroscopic examination and stable isotope analysis. A sample was selected in such a manner as to represent the full range of results in numbers sufficiently large as to permit statistical tests. Individuals were selected that clearly demonstrate the presence/absence of major features (trauma, craniosynostosis and certain unusual pathologies); individuals were selected to represent the full age range and both sexes; individuals were selected to represent the full range of reliable isotopic results (including outliers and unexpected results). Differences in
location may possibly relate to period of deposition – if for example crania were systematically moved from the stalls to the chambers or if deposition began at one end and proceeded along the stalls: samples were selected to represent the range of depositional locations.

The sample size initially chosen was sufficiently large that diachronicity of each variable could be tested independently. Applications for 25 and then 38 radiocarbon dates were made (Lee-Thorp and Lawrence 2010 and 2011, application NF/2010/2/6). The panel decided that so many dates could not be justified but eight AMS dates were ultimately awarded. It was proposed by the awarding panel that there was a high probability that the duration of use of the site was brief (presumably following models presented by Whittle et al. 2007; Whittle et al. 2011), despite evidence to the contrary (Renfrew et al. 1983) and the award was made so that this hypothesis should be tested. The crania were therefore selected to include those individuals most likely to have been interred at extremes of site use.

The panel recommended that samples should be selected from the northern end of the tomb, specifying that two samples each should be selected from stalls 1 and 2, and side cells 1 and 2. This reasoning demonstrated a misunderstanding of the site’s excavation history. The northern end, excavated in 1958, has no spatial or stratigraphic information recorded for any of the material recovered: it would be impossible to select samples specific to each of the four areas named. The 1976 excavation was more controlled and areas of origin of finds were recorded, although stratigraphy was limited.
The previously identified variables were considered together in selecting the eight to address the main theme imposed by the panel, to derive extra value by exploiting samples that present particular significance. Accordingly, different areas of the monument are represented, including different stalls, a side chamber and an extramural sample. Representatives of the extremes of the stable isotope distribution were preferred, as were crania with exceptional features of preservation or pathology.

ST4 is represented by 2 samples, ST3 by 1, SC3 by 2, the northern area by 2 and the North horn by 1 (see Figure 284 below). There are at least 2 males and 2 females. The age range includes 2 young children (2-4 years old at death) and 6 adults, of which at least one is young (17-25 years old at death) and at least two are mature or older. Whilst it would have been desirable to investigate the pathology, isotopic data, age, sex and spatial distributions more fully, this was impractical given the number of assays available.
Figure 284. Numbers of radiocarbon dating samples from different parts of Isbister tomb.

Area excavated as one in 1958.

n Number of samples within area.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Location</th>
<th>C:N</th>
<th>%N</th>
<th>%Col.</th>
<th>δ¹³C‰</th>
<th>δ¹⁵N‰</th>
<th>Age</th>
<th>Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS(1958)</td>
<td>SC3</td>
<td>3.3</td>
<td>12.7</td>
<td>8</td>
<td>-20.8</td>
<td>12.3</td>
<td>A</td>
<td>M</td>
</tr>
</tbody>
</table>
| IS(1958) is a clear case of multiple myeloma. This is potentially the earliest case identified in the UK.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Location</th>
<th>C:N</th>
<th>%N</th>
<th>%Col.</th>
<th>δ¹³C‰</th>
<th>δ¹⁵N‰</th>
<th>Age</th>
<th>Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS(1972)</td>
<td>N. Horn 'cist'</td>
<td>3.2</td>
<td>14.9</td>
<td>12</td>
<td>-19.2</td>
<td>12.8</td>
<td>A</td>
<td>F</td>
</tr>
</tbody>
</table>
| IS(1972) has the highest δ¹³C value from the assemblage. It was recovered from an extramural area but exhibits skeletal features typical of the collection.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Location</th>
<th>C:N</th>
<th>%N</th>
<th>%Col.</th>
<th>δ¹³C‰</th>
<th>δ¹⁵N‰</th>
<th>Age</th>
<th>Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS(2642)</td>
<td>SC1-2/ST1-2</td>
<td>3.3</td>
<td>13.6</td>
<td>6</td>
<td>-20.2</td>
<td>13.0</td>
<td>A</td>
<td>?</td>
</tr>
</tbody>
</table>
| IS(2642) has a relatively high δ¹⁵N value and thickened diploë.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Location</th>
<th>C:N</th>
<th>%N</th>
<th>%Col.</th>
<th>δ¹³C‰</th>
<th>δ¹⁵N‰</th>
<th>Age</th>
<th>Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS(2783)</td>
<td>ST4</td>
<td>3.2</td>
<td>14.8</td>
<td>8</td>
<td>-19.7</td>
<td>11.9</td>
<td>A</td>
<td>M</td>
</tr>
</tbody>
</table>
| IS(2783) produced the highest δ¹³C value of any within the tomb.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Location</th>
<th>C:N</th>
<th>%N</th>
<th>%Col.</th>
<th>δ¹³C‰</th>
<th>δ¹⁵N‰</th>
<th>Age</th>
<th>Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS(7015)</td>
<td>ST4</td>
<td>3.3</td>
<td>14.4</td>
<td>6</td>
<td>-20.5</td>
<td>11.9</td>
<td>A</td>
<td>?</td>
</tr>
</tbody>
</table>
| IS(7015) had a large palatal cyst and is brachycephalic, a feature that might be considered to be typical of the Bronze Age rather than Neolithic.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Location</th>
<th>C:N</th>
<th>%N</th>
<th>%Col.</th>
<th>δ¹³C‰</th>
<th>δ¹⁵N‰</th>
<th>Age</th>
<th>Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS(7209)</td>
<td>SC3</td>
<td>3.3</td>
<td>12.5</td>
<td>6</td>
<td>-20.9</td>
<td>12.4</td>
<td>2YO</td>
<td>-</td>
</tr>
</tbody>
</table>
| IS(7209) is a young juvenile with unusual layering of the endocranium, likely to be due to scurvy.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Location</th>
<th>C:N</th>
<th>%N</th>
<th>%Col.</th>
<th>δ¹³C‰</th>
<th>δ¹⁵N‰</th>
<th>Age</th>
<th>Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS(7210)</td>
<td>ST3</td>
<td>3.3</td>
<td>14.7</td>
<td>20</td>
<td>-20.7</td>
<td>12.0</td>
<td>2-4</td>
<td>-</td>
</tr>
</tbody>
</table>
| IS(7210) has an exceptionally fresh appearance and remarkably high yield of collagen.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Location</th>
<th>C:N</th>
<th>%N</th>
<th>%Col.</th>
<th>δ¹³C‰</th>
<th>δ¹⁵N‰</th>
<th>Age</th>
<th>Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS(7284)</td>
<td>SC1-2/ST1-2</td>
<td>3.4</td>
<td>13.7</td>
<td>9</td>
<td>-21.1</td>
<td>11.2</td>
<td>YA</td>
<td>F</td>
</tr>
</tbody>
</table>
| IS(7284) had relatively low values for both δ¹³C and δ¹⁵N.
The range and distribution of radiocarbon dates from these samples closely resembles those previously published for the site although there is little indication of early third millennium individuals (Renfrew et al. 1983; see p107 above). In this project however each date was derived from a different individual for which age, sex, stable isotope and pathological data were available.

Two dates (IS(1972) and (2642)) appear significantly more recent than all of the others, which are essentially identical. Similarity of results need not reflect actual similarity of age: the assays coincide with a period of several centuries with a calibration curve plateau and are effectively indistinguishable without further information. All results are significant as spot-dates of individuals.
IS(1972) confirms the Bronze Age date from Hedges’ IS[110], which came from a humerus in the same deposit. This appears to have been an incompletely recovered extramural inhumation. It was the main isotopic outlier, so it is reasonable to suggest that Bronze Age diet was distinct from that in the Neolithic. IS(1972) also exhibited remarkably similar pathology to the Neolithic individuals from Orkney: perimortem blunt force trauma and cranial asymmetry (possible partial blindness). This may infer a continuity of practice in interring particular individuals at the cairn; individual inhumation may simply have been necessary because of the earlier infilling of the tomb rather than implying a distinct form of individual disposal from the Neolithic deposits.

The other outlier, IS(2642) is mid-late third millennium, similar to Hedges’ IS[105] and potentially consistent with IS[108]. This was recorded as coming from the North end of the chamber. This cranium has a thickened calvarium and is also an isotopic outlier, with the highest $\delta^{15}$N value. These stable isotope results are consistent with the bulk of Isbister results but for a dating outlier to possess the highest $\delta^{15}$N value could be more than coincidence and imply some diachronic factor. There was a virtually identical C14 date from a male femur from the southernmost part of the chamber and these dates appear to be consistent with those from Isbister’s eagle bones (Sheridan 2005). This raises questions of when (potentially why) the tomb was partly demolished and how late it remained possible to disturb the remains (prior to backfilling).

IS(1958), the cranium with multiple myeloma, is confirmed as Neolithic: the earliest case in the UK, although there are Neolithic and later prehistoric
examples from Europe and Egypt (Strouhal and Kritscher 1990; Strouhal 1991).

IS(7210), a juvenile cranium with 20% collagen surviving in the bone exhibits surprisingly good survival from the Neolithic. Reportedly from ST3, this cranium is unlikely to have enjoyed particular protection from decay processes, which supports hypotheses of localised variations within the tomb (Barber 1999).

IS(7015), the most brachycephalic individual is Neolithic, which confirms that dolichocephaly was not ubiquitous in the Orcadian Neolithic. This may support a Neolithic origin for the example from Banks.

The replication of determinations for IS(7210) permitted refinement of the radiocarbon date. Since each determination was made on the same bone, they may be considered independent estimates of the true value. Combination of the determinations (Figure 285 below) showed an interesting feature in that the considerable probability density later than c.3000BC in the later determination (labelled 7210b for convenience) was rendered negligible in the combined density plot (one might hypothesise that a similar feature could occur with IS(1958)). This has the property of increasing the probability density before 3200BC rather markedly, which is entirely consistent with most of the other new dates. This contradicts the late date distribution for Isbister suggested by a recent Bayesian study (Schulting, Sheridan et al. 2010) and illustrates some of the difficulties of imposing interpretive models. The increased precision in combining independent date estimates for a single entity can bring loss of accuracy for different entities where (sometimes implicit) assumptions exist
regarding relationships (e.g. Steier and Rom 2000; Bronk Ramsey 2000).

Figure 285. IS(7210) date probability densities before (above) and after (below) combination.
There is little evidence for systematic variations over time, possibly because sample size was too small. It is likely that the majority of individuals (males and females, adults and juveniles, those exhibiting pathology and otherwise) were interred over a period of potentially several centuries in the late fourth millennium (Figure 286). Perimortem trauma and cranial dysplasia are confirmed to exist in both Neolithic and later interments at Isbister. There is no evidence that patterns observed – congenital deformation, trauma, scurvy lesions, and age and sex-related differences - developed through the period of the monuments use, or occurred episodically, although they need not be entirely synchronous despite the similarity of features between individuals.

The broad distribution of dates from Isbister suggests that activity may not have
been completely transferred to Banks or Quarrel Geo. Some of the new dates may derive from individuals previously assayed and there may be interobserver errors (e.g. from laboratory techniques), so it may be improper to combine the two sets as if they were independent and distinct. Three original dates (human bone IS[100], IS[108] and deer IS[109], pp105-11) occupy a date range not observed with the new samples and are therefore probably distinct, indicating a denser late use-period than the new dates alone would suggest. It was felt that in the absence of additional information, Bayesian analysis would merely be an exercise in speculation. Modern computer power presents great potential for analysis, particularly when employed with statistical packages such as OxCal (Bronk Ramsey 2010). Statistical analyses require preliminary models to be constructed, reflecting assumptions made about the nature of the data. Imposing constraining dates and distribution patterns as Bayesian priors may seem reasonable (Bronk Ramsay 2009) but is not necessarily justifiable. Modelling based on such assumptions may run the risk of developing circular arguments or spurious precision based on tautology, and results may simply be artefacts of the assumptions themselves (see e.g. Christen 1994; Buck et al. 1996; Litton and Buck 1996; Buck 2004: Bayliss and Bronk Ramsay 2004; Whittle and Bayliss 2007; Whittle et al. 2011). The "uninformative" prior in fact makes strong assumptions and has considerable influence on the final results" (Scott 2000, commenting on Steier and Rom 2000).

Radiocarbon dating was the final research element of this project. The different strands will be considered together in the following section.
5. DISCUSSION

“The lack of contextual consideration of ritual has its greatest impact on the interpretation of the funerary record”

(Knüsel 2002:277)

The purpose of this project was to consider evidence drawn from studies of human remains in reconsidering Neolithic Orcadian society. This section examines the results in relationship with other evidence, following themes introduced earlier. Deposition, taphonomy, demographic features, palaeopathology, subsistence and representivity are considered. The environment - natural and man-made - within which Neolithic people lived is fundamental to our understanding and gives us a starting point for describing Neolithic Orcadian life (e.g. Pollard 2000:363). I begin with first-hand descriptions of nineteenth century Orcadian life in an attempt to avoid imposing too many subjective assumptions based on modern experience.

Figure 287. Archaeological interpretation by Calvin and Hobbes (Watterson 1995:130).
(This project attempts to make observations from which interpretations are developed without imposing undue preconceptions regarding the nature of Neolithic societies.)
5.1 Nineteenth Century Accounts

It is easy to imagine life in the past but more difficult to do so without projecting (sometimes anachronistic) preconceptions (e.g. Downes and Richards 2000:162-4). Few archaeologists are subsistence farmers living in unheated stone houses without ready access to mechanical aids, imported goods or transport; many Neolithic settlement features however are familiar from nineteenth century Orcadian cottages. Local stone was used to maximum advantage, houses were built to maximise exposure to the sun but minimise exposure to wind, they were predominantly single-storeyed, built on level ground where possible, or along the contours to minimise the gradient to be overcome. This resulted in a tendency for house construction on an east-west alignment and a rarity of west-facing doors or windows:

“the chosen site for the cottars house was the south side of a rising ground. The earth was dug away from where the house or rather hut was to stand, until a perpendicular face of earth was cut on the north side, equal in height to the north wall of the house. This natural embankment gave shelter, and also saved stones, as the north wall was built with what was called one-face; the natural ground forming at once the outer surface and support of the wall... The fire-place was in the middle of the floor. Parallel to, and about two feet from the horribly damp north wall, a row of flags was set up on edge, fixed to the earthen floor. The trough formed by the damp wall, for back, the damp earth covered with a little straw or heather for bottom, and having the cold flagstones for front, was the bed...” (Dennison 1884:51ff).
“… crazy outhouses are huddled together in front of these dismal dwellings, apparently for the purpose of breaking the force of the wintry blasts. … The doorway is generally so low-browed that every man of ordinary stature must make obeisance to the household gods as he enters and retires.” (Gorrie 1869:315). In one particular home, “the rays of light are only permitted to make their entrance, and the wreaths of smoke their exit, through one little circular hole which, being thus compelled to perform the double duty of enlightener and purifier, fails in both departments. The door is reached by a narrow passage, paved with dirty and slippery slate-slabs, …” and the doorway “has been apparently designed for the purpose of compelling stray visitors to bend their backs as well as bow their heads when seeking ingress, and, indeed, the easiest and most comfortable way of obtaining an entrance is by getting down on all fours,” (Gorrie 1869:319).

These are first-hand accounts of inhabited cottages in nineteenth century Orkney. Similarities with the Neolithic are inevitable because “the availability of building materials, the climatic conditions of the area, and the occupations of the inhabitants were the major determining elements until at least the mid nineteenth century,” (Carruthers and Frew 2003:90). Other features included: “A smooth flagstone, resting on upright stones … served the purpose of a dresser,” whilst “Food was stored in the ammery, a cupboard with stone shelves,” (Marwick 1991:96). Internal wall coatings might include a mixture of clay and dung. Seats might be benches, chairs or simple tussocks. ‘Neuk-beds’ are a feature of many older houses - hollows built into the thickness of the wall, with a narrow entrance from the living space.
A diary entry, dated March 1847, describes use of the ‘close wooden bed.' In a house 14 by 12 feet in size was a single box bed, itself 5’8" by 3’10.” On being asked how the family of eight coped at night: “The wife and I lie wi’ our heads at the head o’ the bed, the twa eldest lie wi’ their heads at the foot o’ the bed, the peerie t’ing – that is the baby – lies i’ his mither’s bosom, the ain next the peerie t’ing lies i’ mine, and the middle twa lie on a shelf at the foot o’ the bed, over the heads o’ the eldest twa. An’ trath I can tell you we are no’ cauld gin I close the bed doors.” (Dennison 1884).

Simple models relating floor area or number and size of beds to population might obviously be erronious. It is difficult to confidently interpret the manner in which even the familiar furnishings at Skara Brae would have been used.

Nineteenth century roofs were occasionally of thatch but often of large flagstones covered with turf and supported by the minimum number of rafters possible. Smoke was thick among the rafters, helping to preserve foods stored high over the hearth but potentially contributing to pulmonary disease. The form that Neolithic roofs took has been the subject of speculation because little evidence survives. Post-holes recorded at Tofts Ness, Knap of Howar and Braes of Ha’Breck suggest the use of upright timbers as supports in at least some cases (Dockrill 2007; Ritchie 1984; Thomas 2010). Fragments of wood and whalebone at Skara Brae were cited as possible rafters; roof decking was assumed to be some combination of brushwood, skins, straw and turf (Clarke and Sharples 1985:64). Recent excavation at Ness of Brodgar has demonstrated the presence of shaped stone flags collapsed within the buildings
in large numbers, that will have been eminently suited for use as a roofing material (Card 2010).

If the nineteenth century home was poor, then the diet was “not only meagre in quantity but in quality inferior.” The morning piece on waking was “half a bannock of bread made from bere ground on the quern (handmill), in which the seeds of all manner of weeds were carefully retained so as to increase the quantity of meal. His breakfast was porridge and milk, or dry porridge when the cow was dry. The porridge was made from the meal of the black native oats, in which there was a still larger quantity of wild seeds. His dinner was fish if possible, not often fresh, for he preferred it sour; sour fish having been the Orcadian’s marine venison. Failing fish, he had shell-fish or crustacea with which the shores abound. The dinner was in summer sometimes diversified by nettle broth, the nettles being boiled with a little meal. The water in which the dinner fish, or shell-fish, had been boiled was carefully preserved, and in it the cabbage for supper was boiled. … The only salt was salt water; with that the peasant’s wife seasoned all her food. … As a rule the cottar never tasted flesh except on holidays. … The above may be regarded as the normal bill of fare; but in years of scarcity the privations endured by the peasant were often extreme. And even in average years I have been told by old people that they never tasted bread made from grain for three months in the year, that is, from the time the old crop was finished and until the new was ready. If during this time the peasantry ate bread at all, it was what they called ‘reuthie breed’ – that is, bread made from the seed of wild mustard.” (Dennison 1884)
Dennison felt that to go into greater detail of the diet “could only pain and disgust the humane mind.” This situation was presented as an improvement over life up to the ‘fourth decade of the eighteenth century’ when “the condition … was miserable in the extreme” and the population “went on increasing in the face of terrible and long-continued privation.” Dennison suggested that “The only help that came to the wretchedly poor men and women was devastating epidemic in the shape of fever and smallpox, and their only refuge the churchyard.” As he pointed out, “the peasant of the past had no cheering cup of tea or soothing pipe” but the people of Neolithic Orkney also lacked the oats, potatoes and cabbage available in the nineteenth century. Food is fundamental to life but Orkney presents difficulties beyond cultivation and harvest. Orcadian storage of dried or salted foods is limited by a humid maritime climate. This means that goods not kept close to the fire (nor exposed to drying winds and out of mist and rain), are likely to become damp, promoting rot and mildew. The British Medical Journal published an exchange in which the soft, rotting dried fish served in Orkney was suggested as the cause of leprosy in the isles (Hutchinson 1906; Skae 1906). Elsewhere, leprosy was attributed to damp air (Cuthbert 2000:54). Some supposed cases of leprosy may have been misdiagnosed skin lesions (Browne 1975:487) e.g. from scurvy (which must have been seasonally prevalent because of a lack of reliable antiscorbutics) or syphilis. The major crops to contain vitamin C will have been the potato, turnips/swedes and kale; onions were present but do not appear to have been particularly significant. None of these was available in Neolithic Orkney.

Agriculture in Orkney remained primitive until well into the nineteenth century
and relied on the spade or the single-stilted plough without a mouldboard (Fenton 1965, 1978). This was hardly more than an ard and barely scratched the soil, which was often highly poached by animal hooves. Lighter coastal soils were predominantly farmed until the nineteenth century. The exploitation of calcareous sandy machair will have required major inputs of manure to provide nitrogen and soil retention for crop growth, which would have a multifactorial role in losses of nitrogenous gases, potentially increasing $\delta^{15}N$; if the heavy clay soils inland had been utilised for agriculture, as increasing discoveries of inland Neolithic settlements in Orkney makes likely (Richards and Jones 1995; Thomas 2011), then the poor drainage and low pH will have affected nitrogenous gas loss, leaching and nitrification, also raising crop $\delta^{15}N$.

Sowing and reaping, flailing and winnowing were all by hand, using simple tools (Fenton 1978:331-410). Immediately after reaping, barley would be bound and stood as ‘stooks’ to be threshed later. Threshing with a flail is relatively simple but is best performed on a sound clean floor, ideally with a cross-draught and in shelter. There is no evidence for these in Neolithic Orkney, except possibly Stonehall (Downes and Richards 2000). Alternatives are to beat the crop against stones (historically, walls might be constructed with protruding stones for this function (Fenton 1978:358)) or to draw the crop through a serrated blade (a suitable stone for which was discovered at Skara Brae (Childe 1930:Fig.24). Winnowing would be required to remove chaff. There is evidence of this practice from Tofts Ness (Dockrill 2007). Chaff itself may be used for stuffing furniture, making bedding or flooring, burned, used in animal fodder or deposited on manure heaps rather than simply being dumped; its absence in
British Neolithic deposits has been noted in comparison to European sites (Bogaard and Jones 2007:366). Straw might have additional uses as clothing, basketwork, bedding and rope (cf. Fenton 1978).

Grain must be dried if it is not to rot or sprout and it must be protected from vermin and fungal infestation. There is no evidence for the use of storage pits in Neolithic Orkney: it would have been impractical. Historically, drying kilns and granaries were widespread (Fenton 1978:374-387). Drying exposes the grain to potential combustion but if the grain retains too much moisture, it may germinate and could destroy the seed corn needed for the following year. Braes of Ha’Breck may provide evidence of storage and its attendant dangers in the large volume of carbonised grain recovered from one building (Thomas 2011). The large structures at Barnhouse and Ness of Brodgar could provide considerable storage space (Richards 2005; Card 2010, 2011). Stone querns (also found archaeologically) were used historically for grinding meal and malt but could leave dust and grit in the produce (Fenton 1978:388ff).

Nineteenth century farmers quickly recognised that the Orcadian climate and short growing season made large-scale agriculture an unreliable economic strategy and increasingly reared livestock (Gorrie 1869:310). It was not uncommon to keep a cow and her young in the cottage (Fenton 1978:113, 125). In winter and spring, the animals grazed any residue in the fields. Infield areas, used primarily for grain, potatoes and turnips, are only occasionally recorded as having enclosures except the ‘planticrues’ for sheltering growing vegetables (Fenton 1978:40-58, 100-105).
5.2 Mortuary Practices

“Corpses were offered to the goddess, who was embodied in birds of prey”

(Gimbutas 1987:342)

Much ethnological study on mortuary practices has been collated (e.g. Frazer 1910, 1933, 1951; Yarrow 1880; Bushnell 1920, 1927; Bendann 1930 etc.). Any society may have a suite of funerary forms that might apply under different conditions (e.g. Ucko 1969). This is seen historically for example among the Cheyennes (Hoebel 1978:93). Naive archaeological assumptions of normative practices have therefore been criticised (Leach 1977) but nonetheless continue to be employed.

It is broadly accepted in the archaeological literature that status during life may be reflected in burial details, especially elaboration or energy expenditure in disposal (Binford 1971). Archaeological explanations of chambered tombs and their deposits have usually adopted a model based on a single normative burial practice: it has been assumed that communal burial was typical, possibly secondary to excarnation (e.g. Darvill 2010:103ff). This has been contrasted with individual cist burial in the Bronze Age and interpreted as showing early egalitarian communities becoming more focussed on individualism: if burials were not normal, then such a model fails.

Tomb architecture may have included aspects of both pragmatism and ritual. There is sufficient variety and similarity to suggest that each one was built to some idiosyncratic local design within a regional tradition. This suggests that
communities shared core beliefs but were not entirely uniform. Size, decoration and elaboration may be interpreted from a number of perspectives, including community rivalry and varying religious significance between communities.

Inside intact tombs it will have been cool through insulation; there will have been little air movement because of the single small entrance and it will have been damp due to condensation in the maritime climate. The chemical environment will have been typified by the presence of cool, damp air and moist surfaces but will have altered when the tomb roof was removed and again when the chamber was filled in. Entrances were probably secured. Few land mammals were present in Neolithic Orkney: domestic animals, the Orkney vole and the field mouse were introduced during the Neolithic (Rowley-Conwy 2011); birds are perhaps unlikely to have entered roofed Neolithic structures. It is possible that the sites were occupied by certain animals, especially later (notably otters at Banks, eagles at Isbister, both at Point of Cott). Insects will have had access but may have found the chambers too cool for significant activity. The most important of these are the bluebottles and greenbottles, whose larvae often infest decaying bodies. Insect activity will have been moderated by temperature, so that maggots will certainly not have been present through much of the year. Green plants will have had little effect within the chamber. Fungi are likely to have contributed to decay through saprophytism.

At Midhowe, either “… bodies were whole when they were first brought into the tomb, but were displaced and became disarticulated as subsequent bodies were introduced.” (Scarre 2007:49) or “… bodies were left to rot outside on
mortuary platforms before being brought into the chamber itself.” (Cope 1998:411). Since the excavation report describes complete articulated skeletons (Callender and Grant 1934a), the former interpretation is correct. Cope’s description of the same site, though in a ‘fringe’ publication, is conventional and is an example of a problem that besets archaeological synthesis – misreporting by secondary authors. The continued application of Gresham’s speculative model for bone circulation displays increasing confidence (Gresham 1972; Richards 1988; Jones 2008) but has no convincing supporting evidence. Similar problems in synthesis arise from overinterpretation of value-laden phrases. For example “both longbones and skulls had been removed” at Hazleton (Thomas 2001:148) compared with “Some longbones and probably some skulls were removed” (Saville 1990:251, my emphasis), which it purports to quote, itself overconfident when even bones recovered were “disarticulated and fragmentary” and included “a mass of tiny fragments, crumbs and bone dust” (Rogers 1990:182). The assumption that the remains discovered are the intentional product of a single normative practice is rarely explicitly articulated. It has been claimed that claims that a common feature of long barrows is that “bones were often deposited in heaps” (Woodward 2000, my emphasis) although it is probably more accurate to say that bones were discovered in heaps during excavation. These two scenarios are quite distinct since deposition implies a specific action, probably a single (and possibly intentional) event whereas the presence of a heap of bones may result from casual subsequent activities. Properly, it must be recognised that the observed evidence is a palimpsest of potentially varied actions, many of which may have had no particular significance.
"Archaeological research has established that from early times, if not from the beginning, steps were normally taken to dispose of the dead"

(Polson and Marshall 1975:15)

Numbers of bone fragments identified from archaeological deposits reflect a combination of element robustness, size and ease of recognition. Archaeological recovery of particular elements is known to be poor (Waldron 1987; Cox and Bell 1999). In the context of a chambered tomb, bones are likely to have been exposed to damage from later activity and, if reorganised, will have had poor rates of recovery prior to secondary deposition, geometrically reducing numbers (see Beckett and Robb 2006 for implications from modelling). The larger, more robust and more readily identifiable elements are more likely to have been recovered. While the possibilities of both secondary burial and of systematic removal of the apparently missing elements may be admitted, there is no convincing argument for either having occurred (contra e.g. Brothwell and Blake 1966:62; Chesterman 1983; Baxter 1999; Reilly 2003). In attempting to maximise the amount of wet sieving undertaken, Banks’ excavation presented the opportunity to examine recovery rates of different elements from different areas in a manner that was not possible for Isbister. Comparing the numbers of bones recovered by hand (by experienced archaeologists taking particular care) with those from sieving demonstrates the bias that may occur in assemblages where sieving is not used extensively or is only used for limited samples (Table 191 below). This is not unexpected (Cox and Bell 1999; Waldron 1987) but if
unrecognised could lead to specious arguments, for example based on underrepresentation of bones of the extremities (see also Jonuks and Konsa 2007:figure 1, where only crania are clearly visible at an exposure site).

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<th>Table 191. Small Bones Recovered from Banks Tomb by Different Methods.</th>
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<td>Loose teeth</td>
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<td>Lateral cuneiform</td>
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<td>Navicular</td>
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<td>Patellae</td>
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<td>Epiphyses</td>
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Part of the argument for secondary inhumation practices in the Neolithic has centred on an apparent absence of particular bones. As Table 191 above demonstrates, recovery of the smaller and less obvious or identifiable elements is related to extensive sieving. This recovered the majority of the carpals,
phalanges, loose epiphyses, loose teeth and other small elements in the Banks assemblage. The younger age groups were disproportionately represented in the wet-sieved fraction. All three juvenile axis recovered at Banks came from wet sieving but both adult examples were hand recovered; seventeen of the forty-six juvenile thoracic vertebra elements (37%) came from sieving but only 9/50 (18%) from the adults. Age- and size-related bias is therefore likely in hand-collected assemblages even with experienced excavators.

Figure 288. Comparison of element recovery rates between a Roman inhumation cemetery (West Tenter Street, above (data from Waldron 1987)) and Isbister chambered tomb (below).

In comparing recovery rates between sites, it must be noted that inhumation cemeteries permit calculations based on number of identified graves but commingled chambered tomb remains require calculations based on the MNI.
figure calculated from the recovered fragments. The inhumation cemetery recovery rate therefore appear low and the chambered tomb rate may be high. The general patterns of recovery for skeletal elements however are similar.

Numerous bones from Banks and Isbister exhibited dry and early postmortem fracturing in antiquity. This was generally trivial and consistent with disturbance rather than intentional breakage. Although intent cannot be eliminated as a cause, post mortem fractures are neither uniform nor ubiquitous. Most of the fractures in both assemblages had occurred during or after excavation. One instance was identified at Isbister of conjoining fragments dispersed in antiquity: this was IS(6711) and IS(7066), which were recovered from ST5 and from the northern part of the tomb (SC1, ST2, ST1) respectively. Similarly, some fragments from different compartments at HPWN conjoined (Ritchie 2009:48). Some bones, especially from Banks, exhibit signs of fracture whilst containing significant organic material. This probably indicates damage occurring in the early years after death and deposition. The clearest example is BSR(115), an adult left femur that has a relatively clean v-shaped fracture rather than the rough transverse fractures that tend to occur in completely dry bone. This demonstrates that activity may have occurred damaging the bone at a short interval after death. Tibia BSR(1362) was fractured after greater collagen loss and therefore has a much rougher fracture surface, although the form is spiral. The issue is complicated by variable preservation: IS(7210) retained 20% collagen (wt./wt.) and was extremely tough despite dating to the 4th millennium BC but the collagen survival range in the tomb ran to below 1%. Overall, the Banks assemblage showed little breakage compared with either Quanterness or
Isbister. This may be because the main area excavated was a relatively sheltered side cell. At Quanterness, fragmentation occurred in antiquity but may have related to Iron Age as well as Neolithic activity on the site (Renfrew 1979).

One similarity between Neolithic human bone assemblages is a high degree of fragmentation. At Isbister, much of this was recent, whereas at Hambledon Hill and Giants' Hills 2 it often appeared to be caused by the burial environment and disturbance (McKinley 2009:493, 517; Harman and Evans 1991). Intentional disarticulation was inferred from cuts on bones at Haddenham, Hambledon Hill, Coldrum and Eyford (Lee 2006:153; McKinley 2009:497-503; Wysocki and Whittle 2000:595), where the cuts appeared to relate to particular muscle attachments, indicating defleshing. Cuts have also been noted in the Quanterness assemblage but there are few possible cases at Isbister or Banks. There is a V-shaped cut on the left frontal of IS(7115) but, though sharply defined, may be too broad for a flint blade; possible cuts on the right frontal appear finer but were difficult to identify since they are partly obscured by a taphonomic coating. If they are cuts, then there would appear to be some symmetry of location that suggests a strip of skin may have been removed from the crown of the head. The apparent absence of cut marks need not reflect mortuary practices. Sharp blades are unlikely to leave marks on bone unless they are serrated or used with pressure against bone; it is force or a sawing motion, possibly a blunt blade, that creates cut marks (Hamperl 1967:630ff).

In some communities, the cranium must be broken in order to free the individual's spirit/soul (e.g. the Hindu practice of kapāla kriyā: the cranium is
expected to break during cremation but otherwise, the eldest son has the responsibility of breaking it (Firth 1997:78, Beér 2004:252). There are several examples of perimortem fracture that might imply such a practice at Isbister. If this was a common practice, however, it might be expected that most of the crania would be damaged in antiquity and probably significantly so. In the Isbister assemblage, these fractures have a crude prevalence of about 20% and the damage is usually discrete – typically from a single blow. Of the examples demonstrating multiple blows, one individual may have peripheral cuts at one lesion, which suggest an attempt at surgical intervention and cannot therefore relate to this ritual practice. It is most likely, especially given the number of healed lesions present, that these fractures are due to accident or interpersonal violence rather than ritual activity.

The contexts excavated at Banks so far contain bones that were predominantly redeposited following skeletalisation. It may have been difficult to manoeuvre a cadaver into one of the side cells in a monument with such a narrow passage and central chamber but the possibility was demonstrated at Lanhill, where a crouched inhumation was discovered in a side cell and the practicality of inhumation via the entrance was tested (Keiller and Piggott 1939:128). Disarray of bones suggests disturbance but it is impossible to be confident that they were not intentionally placed. It cannot be demonstrated whether they been moved subsequent to secondary deposition because of the potential for repeated disturbance. Since a large quantity of otter spraint was recorded at Banks, as well as most of an otter skeleton, it is probable that the monument was used at some time as a holt and, therefore, during part of antiquity (before final infilling).
the tomb was probably dry (as was also noted at Point of Cott (Barber 1997)). This may have promoted the preservation of bone during the period of deposition but there will probably have been some surface dampness, from condensation for example, causing erosion where bones lay on surfaces. It is possible that the Banks tomb only began to flood recently, after the original mound was removed but evidence is lacking.

‘Weathering’/erosion is not necessarily an indicator for secondary burial (see Lyman and Fox 1997). This misinterpretation has been employed on numerous occasions, i.e. the presence of ‘weathering’ has been used to infer exposure of corpses and its absence has been used to infer the lack of exposure. The most sophisticated discussion was by Whittle and Wysocki, who despite acknowledging the variation in potential causes of ‘weathering’ signs nonetheless suggested that these indicated exposure practices in cases of bones interred at Parc le Breos Cwm (Whittle and Wysocki 1998). Variation in ‘weathering’ according to local conditions (microenvironments) has been suggested at Point of Cott (Barber 1997), where damage was interpreted as having developed entirely within the tomb. This reasonable idea has failed to attract general support but the variation in collagen preservation at Isbister (0-20%) supports such an interpretation.

Hambledon Hill produced no evidence of cremation, merely some burning affecting already dry bone (McKinley 2009:497). Charring was noted at Fussell’s Lodge (Brothwell and Blake 1966:40), West Kennet (Wells 1962:81), Hazleton North (Saville 1990:104, 183, 260), Haddenham (Lee 2006) and other
barrows/tombs (Kinnes 1992:101); not at Staines (Robertson MacKay 1987) or Etton (Armour-Chelu 1998). There was no evidence of burning at Banks; at Isbister it occurred after fragmentation (e.g. endocranially but not ectocranially). There is no evidence for cremation in Neolithic Orkney but fire was certainly used in tombs at some point, which may have been some late activity (pp98-9).

There are observable features of distribution in the apparent disorder of the bone deposits at Isbister. Crania and long-bones tend to occur near the walls, with a noticeable curvature to the distribution pattern that reflects orthostats jutting into chambers, curved walls and angles in the walling. This is likely to derive partly from simple trampling processes as bones are kicked around. Crania tend not to be trodden on but rather to be kicked and roll from a resting position (Shipman 1981). Long-bones will travel rather far (Beckett and Robb 2006) and tend to come to rest in a position where they are minimally exposed to disturbance, which, in a tomb, will inevitably tend to be at the foot of a wall, aligned with the structure. Smaller or flatter bones have less of a cross-section against potential disturbance and might be expected to suffer more direct trampling. Relatively fragile bones, regardless of form may tend to fracture, whether kicked or trampled. These principles might also be relevant in considering bone distributions at causewayed enclosures.

Sites cited as exhibiting structured deposition may be inappropriate (Sjögren 2010). Small bones do not necessarily decay faster than large but they are more difficult to see and some may be difficult to recognise. Their apparent absence cannot be used as the basis for any argument, especially from
antiquarian assemblages and interpretations relying on such evidence as indicators of formal practices (Shanks and Tilley 1982 etc.) may be false (Waldron 1987; Cox and Bell 1999). There is no evidence that agents of bone removal were culturally or genetically related to the dead. Such events could occur at any time until the tombs were backfilled or after (Beckett and Robb 2006). Meaning is difficult to ascribe to such possible processes, which may be neither structured nor normative but utterly idiosyncratic. The nature of chambered tombs and the historically poor quality of excavation and recording (pp8-27 above) preclude the recognition of such activity.

Windmill Hill had a relevant and widely cited Neolithic pit burial that may require reconsideration. Grave (707) contained a mostly articulated adult male skeleton that was radiocarbon dated to the middle of the fourth millennium BC (Whittle et al. 1999:79ff; Ambers and Housley 1999:119; Brothwell 1999:344-5). The skeleton was not disarticulated (Whittle et al. 1999:351) but disordered elements were interpreted as indicating that the body had been left exposed in the pit for some time after deposition, as part of a multi-stage exposure and curation disposal practice. The presence of numerous amphibian and rodent bones was cited in support (Brothwell 1999:344; Whittle et al. 1999:351-2); larger animal disturbance was considered possible but there was no evidence of gnaw marks (Brothwell 1999:344). A badger hole was recorded at this location in 1958 (Whittle et al. 1999:79), and badger burrowing better explains the observed features, especially the limitation of disturbance to right side elements. This has been proposed recently as an explanation for the associated small animal bones (Serjeantson 2011). This burial therefore is an example of a
disturbed flexed inhumation, not excarnation (which may nonetheless exist elsewhere on the site (Whittle et al. 1999:362)).

Archaeological samples may not satisfy statistical assumptions of sample size or independence. This affects interpretation as well as the appropriateness of statistic selection. Non-randomness of a distribution does not lead to the conclusion that the distribution occurred through human intent. Assemblage formation factors preclude simple location analyses of the poorly represented skeletal elements as indicative of symbolic significance. The dating evidence from Isbister suggests a major period of deposition followed by more sporadic inhumations. It cannot be assumed that all the inhumations used a single rite, nor that society, economy or population was stable during site use. Isbister failed to exhibit evidence for distinctions between skeletal elements or for demographic groupings manifested in find location (pp172-183 above). In examining the distributions of bones, it is immediately apparent that there is some set of non-random factors affecting the results; this is not however the result of prehistoric sorting (cf. Shanks and Tilley 1982) but has come about through loss of labels, and other systematic biases in the data.

It has been suggested that piles of bones occur at some sites because they were brought as bags full from a prior inhumation site (e.g. Ashbee 1966:37ff). That bones in chambered tombs may be found in piles or groups is clear. This seems to have little diagnostic value as an indicator for secondary interment though. If the pile contains a complete skeleton then there is no reason to assume that it was ever placed anywhere else. If the pile consists of fewer
bones then it may have been formed simply by pushing bones aside. It would be natural behaviour to place crania with mandibles or stacking long bones in a co-aligned fashion as seen in modern ossuary contexts. Extreme flexion of limb bones beyond normal anatomical limits has been suggested as indicating limbs held together by ligaments but not by sufficient soft tissue to inhibit flexion (Baxter 1999). This is a specious argument because once the soft tissue has been lost, the ligaments tend to dry out and become rigid, which would prevent relative movement of the bones. A simpler explanation in these cases would be pushing a skeletonised flexed inhumation sideways, which would have the effect of producing apparent hyperflexion, retaining anatomical position.

It has been suggested that an apparent absence of longbones and skulls indicates intentional manipulation as part of the accepted practices (e.g. Thomas 2001:136ff). These are exactly the bones that are most likely to be collected for other purposes at some later date, as curios or as raw materials: antiquaries and early archaeologists also particularly collected skulls and longbones (pp8-25 above). Modern cases have been recorded of graves and especially mausolea being raided for human remains, perhaps for magical purposes – usually skulls and longbones (Stern 1997:190-4). Such removal need not have been a cultural norm or have had ritualistic significance. We must not assume that once deposited a body would be allowed to rest in peace, nor that later activity was necessarily related to normative funerary rites. Isbister, in any case, contained appropriate relative numbers of skeletal elements and does not support any interpretation of removal: suggestions otherwise rest on inflated estimates for MNI (Chesterman 1983; Lawrence
Chambered tombs did not necessarily act as ossuaries following excarnation elsewhere (Henshall 2004; Barber 1988, 1997; Lawrence 2006). The argument that partial decay led to the loss of smaller and peripheral bones at some unknown site prior to deposition fails because there are different decay and recovery rates for different skeletal elements, under different excavation conditions and in different deposit types (Waldron 1987; Cox and Bell 1999). Neolithic tombs have been shown to contain articulated remains - perhaps most notably Midhowe (Callander and Grant 1934a) - and the presence of 'benches' as primary features indicates that such interment was intended in the initial design (Davidson and Henshall 1989:55) but these points rarely seem to be emphasised in archaeological syntheses.
5.4 Form and Function of Neolithic Tombs

"Ritual - All-purpose explanation used where nothing else comes to mind."

(Bahn 1989:62)

The designs of the tombs must reflect the expectations of the builders. Midhowe had numerous skeletons still articulated at the time of excavation but this is a very large tomb with a wide central space available; disposal of older remains appears to have been below the ‘shelves’ or ‘benches’ on which many skeletons lay (Callander and Grant 1934a). At Korkquoy in contrast, it was reported that skeletons lay upon each other (Davidson and Henshall 1989:141). A mother goddess symbolism has been suggested for the structures themselves (Gimbutas 2001:64ff; Biaggi de Blasys 1982) but remains unsupported. Side cells in the otherwise stalled cairns such as Isbister and Unstan could relate to ritual use but might equally well be ossuaries for the disarticulated remains of those that have decayed in the stalls. Using side cells as ossuaries would help to leave space for future interment or other activities. This may imply development from simpler forms, in recognition of decay processes and anticipation of future needs with prolonged use. Conversely, other tombs had articulated inhumations in side chambers (e.g. Keiller and Piggott 1938), so such a function cannot have been exclusive. The end stalls, often with low ceilings and sill stones, might better be considered as side cells from an architectural perspective. There is uncertainty regarding how closely sealed these tombs were in antiquity: were the entrances entirely filled to complete the overlying mound between use periods? Could dry or anaerobic conditions have developed, was air able to circulate and was there condensation?
The stalls, formed by pairs of opposing orthostats to create symmetry along the central chamber have been seen as ‘doorways’ with an associated duality between left and right derived from the entrance location (Richards 1988). With their concave side walls, stalls may best be viewed as conventional architecture adopted from Unstan Ware settlement buildings. Using Midhowe as a model, we can see that the orthostats help to protect lain out bodies from disturbance. A pragmatic origin could nonetheless become elaborated into a symbolic understanding and ritualisation through continued use (Rapoport 1969:52ff; Oliver 1987:153ff). Richards’ concept could still work within such a framework: once a cadaver has rotted away, awkward bones might be moved from a stall to make space. Placement at the ends or side cells, would mark the end of a progression through the tomb for at least some elements. At the same time, corners of the structure act in an informal manner to protect bones and there seems no a priori reason to impose symbolic significance. Left-right duality may possibly be inferred from the asymmetric distribution of male crania at Isbister but there is no other evidence apparent to support the idea.

Banks cranium BSR(140), appears to exhibit abrasive wear inferiorly, notably affecting the mastoid processes but not coplanar with the maxillae (which are more inferior). This may suggest movement of the cranium on an abrasive surface but the failure of the maxillae to be implicated shows that this was not even across the cranium and raises the possibility of the occipital having rested on a raised surface (cf. Barber 1992:24; Schulting 2007).

The side cells at both Isbister and Banks are roofed with large horizontally lain
flagstones but the nature of any potential roofing over the central chambers and Banks entrance passage is unknown. It is not impossible that entry in antiquity was effected from above (Piggott 1973) and that the supposed entrance served some other function (Lynch 1973). Hedges has suggested that similar ceiling flags at Isbister were intended to act as shelves (see also Barber 1992:24) but it is also possible that spaces above such flags were an architectural device limiting downward force. This is difficult to investigate because of the rarity of surviving roofs – entrance passages seem to survive better, perhaps because they were rarely targeted for later destruction. In the cases of the central chambers at Banks and Isbister, there is no evidence for superstructure; the entrance at Isbister survived in a roofed state but that at Banks did not; both sites have intact ceilings over their side cells. At Isbister, the concentration of fragmented pottery and post-depositional burning at ST3 suggest that this may indeed have served as the access point, as the entrance passage suggests. There seems to be no reason to accept the hypothesis (Lynch 1973) that the entrance passages were not the entrances.

Infilling of tombs was clearly often intentional, occurring in antiquity after the tombs had seen considerable use and deposition (Davidson and Henshall 1989:60ff). This might reflect widespread iconoclasm or upheaval. The presence of significant human skeletal elements in and above the superficial lain stone infill deposits at Banks raises questions of their origin: whether they were intentionally placed, redeposited as fill inclusions or inserted later. This could indicate curation and therefore special selection or possibly deposition in special areas high in the tomb (Barber 1992:24). Crania and ossa coxae, the
main bones recovered from the superficial deposits, share the properties of being flat bones with complex form, which may have been significant. One cranium was brachycephalic; at Belas Knap, a brachycephalic cranium found in a similarly superficial location was initially interpreted as Bronze Age but was shown by radiocarbon dating to be contemporary with the Neolithic remains at the site (Parsons 2002). Superficial deposition of a cranium above stone infilling was also observed at Holm of Papa Westray North (Ritchie 2009).

If it assumed that brachycephalic cranium (BSR(001)) from Banks’ eastern cell was deposited during a late, post-usage phase of site use, then this raises the question of where the remainder of this skeleton might be. The simplest solution to this would be that the deposition of this cranium was of a bone that had already become dissociated from its associated remains. This may imply redeposition from an inhumation on or around the mound at or later than the time of its infilling. Because the cranium sat above the rubble fill, it is likely to have been deposited after this rubble but was possibly a part of the same phase of deposition. It is also possible that the cranium had been curated and was deposited symbolically, reflecting some change in the community. This would be consistent with the absence of other skeletal elements since crania may have special status. It may simply reflect that crania were conspicuous and particularly easily recognised in excavated material as the tomb was filled.

Other Neolithic cadaver disposal forms are recorded. It remains possible that in Britain, causewayed enclosures, inhumation, caves or waterways may have played some role (e.g. Bradley and Gordon 1988; Chamberlain 1996; Pryor
1998; Evans and Hodder 2006; Schulting 2007; Mercer and Healy 2009; Schulting et al. 2010). Causewayed enclosures at (e.g. Windmill Hill, Etton, Haddenham and Hambledon Hill) have been shown to have disarticulated human remains within their ditches, especially near terminals and apparently following exposure, although some (especially infants) appear to have been buried entire (Pryor 1998:374-5; McKinley 2009:505; Whittle et al. 1999:361-2). It is therefore necessary to be wary of imposing simplistic models of normative practice and evolutionary change, especially as indicators of social change, or in imposing implicit assumptions regarding representation.

Radiocarbon dating suggests that individuals interred at Isbister, Quanterness, Point of Cott and Holm of Papa Westray North may have been contemporary with settlement at both Knap of Howar and Skara Brae. They all produced dates c.3500BC (Isbister slightly later) to c.2500BC (Figure 289 below), which is interesting since Isbister and Knap of Howar have Unstan Ware associations whereas Skara Brae and Quanterness are Grooved Ware sites (data from the Scottish Radiocarbon Database, Canmore, calibrated with OxCal 4.2). It has been noted that the Maes Howe type tomb Quanterness has produced dates from human bone that are consistent with earlier use than Isbister (Schulting, Sheridan et al. 2010). Knowe of Rowiegar has similar dates, while Quoyness, Blackhammer, Sandfield, Quanterness, Isbister and Point of Cott have produced human bone dates well into the third millennium, when relatively many radiocarbon dates from animal bones occur (from Isbister, Quanterness, Knowe of Ramsay, Cuween, Pierowall, Holm of Papa Westray North, Knowe of Rowiegar, Knowe of Yarso (Scottish Radiocarbon Database data, Canmore);
Ishbister, Taversoe Tuick, Sandfield and Cuween have also human bones after c.2000BC, suggesting three potentially overlapping deposition phases: first predominantly human remains deposition with some special animal material; then frequent animal bone depositions, many of which probably derive from faunal activity but are indistinguishable from some human bone dates; then occasional human remains deposition, possibly in discrete events.

![Image](image_url)

Figure 289. Indicative radiocarbon date ranges from Orcadian Neolithic sites, selected to suggest the periods of use of different sites. Different assays are distinguished by shade. (Data from Scottish Radiocarbon Database, via Canmore; also Schulting, Sheridan et al. 2010 for HPWN; this project for Isbister). Note the relatively late dates for animal remains at Point of Cott and Holm of Papa Westray North (HPWN) compared with human bone; and the overlapping date distributions for the settlements represented by Skara Brae and Knap of Howar. Stones of Stenness material was from basal layers in the ditch, suggesting earlier construction and use.
5.5 ANIMAL BONE

"The more such trophies and the larger the stone slab, the greater the chief."

(Lansing 1987:345)

Particular animal bones in Neolithic tombs seem likely to have been intentionally deposited (e.g. Lenneis 2007), including certain finds from Banks. Boar tusks are used for ornament in numerous tribal societies and appear to have had similar value in the Neolithic (Lenneis 2007). The presence of a red deer cranial fragment with antler, as at Banks, shows that the antler was neither shed nor a tool but must have come from a dead animal. Boar tusk and antler may symbolise masculinity, power or wealth. The limpet shells recorded at Knowe of Yarso were far from the sea, at an elevated location and must have been carried to the site intentionally, which is suggestive of some special significance.

If the juvenile sheep and cattle were deposited intentionally, they may indicate selection for age. Young animals may potentially symbolise wealth but perhaps more significantly in a funerary context, may be symbols of fertility or rebirth. An alternative explanation is that the tomb was open at some time and the sheep died there, although in such circumstances, some articulation of elements would have been expected. It seems likely that both intentional deposition in the tombs and incidental animal deaths will have occurred at different times. Animal remains in Orcadian Neolithic tombs often appear to be later than associated human bone (e.g. Ashmore 2009; Sheridan 2005), which supports such a hypothesis.
The presence of red deer in Neolithic Orkney is significant because it raises questions of management that are linked to social organisation. Red deer are difficult to control in a farming environment and must have presented a threat to crops but they were clearly thriving in Orkney because the presence of all skeletal elements and entire carcasses as well as antler demonstrates their live presence (Richards 1994; Sharples 2000). They cannot have been freely hunted because they would probably not have survived in the limited Orkney environment (the ‘Tragedy of the Commons’ (Hardin 1968)). There must have been a system of deer management, with recognised rights and sanctions, which implies that there was accepted authority enforcing limits on deer hunting.

Notwithstanding the question of symbolism in tomb plan or human bones, there are apparently significant elements in the Neolithic tombs in addition to simple functionality. The earlier animal bones, especially red deer and cattle, add to the impression given by monumentality, exotic stone artefacts, decoration and patterns in stonework to suggest some non-pragmatic (‘ritual’) influence that may be related to Neolithic beliefs.

The next issue is the people whose remains were deposited themselves: what were they like?
5.6 Body Proportions

“An appreciation must be made of the effect of time and climate in producing changes in the dimensions of the organs which have survived from the extinct race.”

(Pearson 1899:170)

Stature

Body proportions could not be fully examined because commingling prevented identification of elements as individuals and sample size is too small to define the population. A small number of observations may reasonably be discussed.

At Isbister, the shortest adult was probably a female and approximately 147cm (4'10") in height, the shortest male of about 163cm (5'4"). The tallest adult was probably a male and about 179cm (5'11") in height (tallest female about 166cm ≡ 5'5½"). The sex group averages from Isbister were 150cm (5') for females and 168cm (5'7") for males. The Banks sample, though too small for accurate statistical comparison, was consistent.

A small number of estimates were calculated for Quanterness, which, despite reservations regarding other aspects of the analysis, are likely to be accurate (Chesterman 1979). Regrettably, the actual measurements do not appear in the publication and the manner in which bones were associated is unclear. There was a male of 171cm (5'7", probably bones ZB4601, ZB4602, ZB4064 and ZB4606) – this appears to have been a pit inhumation and was thought to be late in the depositional sequence (Chesterman 1979:105); there was a female of 157cm (5'2", probably bones ZF 2342 and ZF2478), a right fibula and a left
tibia (apparently not used to calculate cnemic index) that gave estimates of 164cm (5'4½") and 162cm (5'4") if male (about 160cm (5'3") and 158cm (5'2") if female) respectively.

At Point of Cott, only three stature estimates were calculated and different elements were used for each (Lee 1997). An ulna, classed as female, gave stature 164cm (5'4½"); a radius classed as female gave 162cm (5'4"); and a combined tibia and fibula, classed as male gave 176cm (5'9"), using the formulae of Trotter and Gleser. Though few, these appear larger than expected.

The stature estimates for Hazleton North were calculated from combined measurements from different bones in some cases but these are in agreement with estimates from single bones (Rogers 1990). Four males had a mean stature of 172.6±3.37cm (5'8"); the sole female scored was estimated at 159.5cm (5'3").

The remains from Hambledon Hill came from different parts of the site (indeed from different monument types) and came from several distinct types of depositional activity. Stature was estimated for just four adult males, which produced a range from 163 – 172cm (5'4"-5'8", mean 168cm (5'6")) (McKinley 2009). This was similar to earlier results (Brothwell 1973).

The Fussell's Lodge long barrow report quotes summary statistics of bone measurements rather than individual cases (Brothwell and Blake 1966:56-8). Stature was estimated from the formulae of Trotter and Gleser 1958 for males
and of Trotter and Gleser 1952 for females, applying an age correction. The male stature range was estimated to be from 163.4–181.6cm (5'4½” - 5'11½”), with a mean of 170.1 (5'7”); for females the range was 148.5–162cm (4'10½”-5'4”), mean 157.5 (5'2”).

No measurements for any of the bones have been published for Ascott Under Wychwood, except a small number of juvenile long bones used to assess stature (Galer 2007). The results of just three stature estimates for adults were quoted, based on the Trotter formulae. One male was described as being between 155.9cm and 161.6cm tall (about 5’2½”) based on the right tibia; an

<table>
<thead>
<tr>
<th>Site</th>
<th>Male minimum</th>
<th>Male maximum</th>
<th>Male mean</th>
<th>Female minimum</th>
<th>Female maximum</th>
<th>Female mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isbister</td>
<td>163cm 5'4”</td>
<td>179cm 5'11”</td>
<td>168cm 5'7”</td>
<td>147cm 4'10”</td>
<td>166cm 5'5”</td>
<td>150cm 4'11”</td>
</tr>
<tr>
<td>Banks</td>
<td>160cm 5'3”</td>
<td>167cm 5'6”</td>
<td>164cm 5'4½”</td>
<td>148cm 4'10”</td>
<td>151cm 4'11½”</td>
<td>150cm 4'11”</td>
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<tr>
<td>Quanterness</td>
<td>171cm 5'7”</td>
<td>157cm 5'2”</td>
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<tr>
<td>Point of Cott</td>
<td>158cm 5’2”</td>
<td>179cm 5'11”</td>
<td>169cm 5'7”</td>
<td>147cm 4'10”</td>
<td>162cm 5'4”</td>
<td>159cm 5'3”</td>
</tr>
<tr>
<td>Hambledon Hill</td>
<td>163cm 5'5”</td>
<td>172cm 5'8”</td>
<td>168cm 5'6”</td>
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</tr>
<tr>
<td>Fussell’s Lodge</td>
<td>163cm 5'5”</td>
<td>182cm 6’</td>
<td>170cm 5'8”</td>
<td>149cm 4'10½”</td>
<td>162cm 5'4”</td>
<td>158cm 5'2”</td>
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<tr>
<td>Hazleton North</td>
<td>-</td>
<td>173cm 5'8”</td>
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<tr>
<td>Ascott-under-Wychwood</td>
<td>159cm 5'2½”</td>
<td>163cm 5'5”</td>
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<td>158cm</td>
<td>5'2”</td>
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NB Estimates have been rounded to nearest cm or ½”, ignoring errors.
adult male right femur gave an estimate of 165.2cm (5’5”); and a female was estimated as being 157.8cm tall (5’2”) from the right humerus.

There may have been regional variation in stature in Neolithic Europe. Brothwell noted that late Neolithic Danes appeared to have been much taller than other series, which tended to be below 170cm (Brothwell 1973:290). Stature may be considered as a general proxy for health and it might be assumed that greater height estimates would be the result of better nutrition and less stress in the population. It may be significant that there appear to be two older juveniles at Banks represented by many elements but that the dental development ages are older than diaphyseal length would lead us to expect. This may reflect stunted growth, if these elements came from the same individuals, which was also noted at Hazleton North (Rogers 1990:186). The Orcadian samples are similar to other British Neolithic groups and so despite the factors apparent from the marginal environment, the Orcadians may not have suffered sufficiently greater stress to affect stature.

Iron Age and later Orcadian populations provide comparative data. Five males at Brough Road, Birsay averaged 170±6cm (about 5’7”, Lunt and Young in Morris 1989); the mean stature for adult males of probable Norse descent at Westness (Sellevold 1999:12) and modern adult Orcadians from Westray was estimated as 173cm (5’8”, Brothwell et al. 1986). Simple comparisons of stature are not like-with-like however, since Lunt and Young used the formulae of Dupertuis and Haddon (1951); and Hooper and Sellevold used Trotter’s method. The stature calculated for the Iron Age male at Mine Howe suggested
a lifetime stature of about 167cm (5'6") (Lawrence 2008). Neolithic Orcadians seem to be shorter compared with the Norse and later Orcadians but were not necessarily different in stature from other populations. Danebury, for example, produced estimates of 164.5cm (5'5", Hooper 1991:426) and 166.5cm (5'½", Hooper 1984:465).

**Platymeria**

Platymeria is probably related to stresses on the bones caused by limb flexion (e.g. Buxton 1938). It has been known since the mid nineteenth century that Neolithic femora are typically platymeric. Brothwell demonstrated that this has no relationship with femoral length (Brothwell 1973:289). Platymeria was evident in all the femora that were assessed here. What initially seems surprising are the extreme values given by two right femora from Banks. Both of these may be from females, although this attribution is subject to slight doubt. It seems likely that two of the left femora with low values for platymeric index are also from females. This may then imply that females were more prone to such development than males. This could be due to the relative breadth of the hips in the sexes, which will result in different resolution of forces (Ruff 1987, 1994). In the Isbister sample, the right femora also produced a systematically lower meric index than the left side. The Isbister sample did not exhibit any obvious sex-related variation though. It is most likely then that there was some activity (or range of activities) undertaken by both sexes that related to handedness and this has affected the relative dimensions of the femora. This activity must be asymmetric and may therefore be unlikely to be simple squatting or climbing.
At Quanterness, adult left femora gave indices of 78.4 (ZB4602), 76.5 (ZF2342), 74.2 (ZB1299) and 72.2 (ZB15601); the sole right femur (ZB4601 – a pair with ZB4602 and presumably the individual that gave a stature estimate of 171cm) gave 78.4 (Chesterman 1979). The number of observations is low and there is only a single right femur for which the index is quoted but this shares the highest index in the sample.

At Point of Cott the sample was particularly small. Only two adult femora could be assessed. A right male femur gave 81.1 as the index; a left femur gave 71.5 (Lee 1997).

At Hambledon Hill, seven adult male femora were quoted, from five individuals. The range was 74.75 – 94, with a mean of 81.4. For one individual, the right femur had an index 11.05 greater than the left but no discussion of asymmetry was made and the figures were not quoted in detail (McKinley 2008:508).

The Fussell's Lodge males had a range from 68.1 to 82.3, with a mean of 73.1 from ten femora but no distinction was made for side (Brothwell and Blake 1966). The nine female femora had a range 61.2 to 71.7, with a mean 68.19.

Platymeria also seems to have been common in the Scottish Bronze Age (Bruce 1986:22), which may imply some behavioural similarities.

In his summary of European Neolithic samples, Brothwell found that the main samples had mean platymeric indices from 71 to 75 but did not distinguish left
from right. Bröste and Jørgensen (1956) observed increased platymeria with
time through the Danish Neolithic. They found that females were more
platymeric than males (except in their period C) without discriminating between
sides; of two period B (early Neolithic) male individuals, Stasevang had a right
index 69.7 and left 71.4 (i.e. nearly symmetrical) but the other (Døjringe 2) had
right 71.0 and left 66.7, which contradicts the Orcadian data but also suggests
behavioural differences. Bröste and Jørgensen’s attribution of dates and phases
cannot however be taken at face value because they were made without
radiocarbon dating and their use of stratigraphy for attributing termini ante quem
(e.g. Bröste and Jørgensen 1956 vol. 2 p52) is fallacious.

Platycnemia

The form of the tibia is also affected by activity, including lower limb flexion.
Brothwell found Neolithic tibiae from different samples to have platycnemic
index values ranging between 62 and 67. At Isbister, the left tibiae were
predominantly platycnemic whilst the right tibiae were mostly mesocnemic. The
lowest of the two Banks values is only on the boundary value for platycnemia.
The Banks examples, being both from the right side, are consistent with such
handedness (as was seen with the femora) but such a small sample may not be
representative.

Although few tibiae from Quanterness were described, again it is a right tibia,
ZF2717, that has the lowest index: 55.3. Two tibiae (ZB 4064 and ZB4606) are
quoted as being a pair with a cnemic index of 66.6, although this is a circular
argument (these are claimed to be from the same individual as femora with
platymeric indices of 78.4 for left and right). The only other tibia described was ZF2478 a left with an index of 70.3 (Chesterman 1979).

At Point of Cott, only two adult tibiae were assessed (Lee 1997). A left tibia had an index of 64.7 (platycnemic); a right male tibia gave 72.2 (eurycnemic).

The Hambledon Hill report only quotes the cnemic index from three male tibiae, although the side is not mentioned (McKinley 2008). These produced a range from 63.71 to 66.16, with a mean of 64.6. The other tibia therefore had an index of 63.93. It was noted that each tibia displayed ‘squatting facets’.

The Fussell’s Lodge data were only quoted in summary and without distinction by side. Four male tibiae had a range 57.7 to 64.5, mean 61.99; seven female tibiae scored 56.6 to 64.9, with a mean of 60.87 (Brothwell and Blake 1966).

The large number of Neolithic Danes examined by Bröste and Jørgensen only had the data presented as averages for the two sexes (Bröste and Jørgensen 1956). These implied that there was a tendency for males to be more platycnemic than females except in group E (latest Neolithic) and that platycnemia diminished over time (except group E females which were more platycnemic than their immediate forebears). Only one site had tibiae distinguished by side (Døjringe 2, early Neolithic) and these were symmetrical at 61.8. (The sided examples from Ølstykke cannot be properly evaluated because the right tibia is male and the left is female so that although the right is much more platycnemic (64.9 vs 72.4), the difference may be related to sex or
individual variation.)

Lower Limb Use

The lower limb longbones present evidence of asymmetric activities that suggest sexually determined roles. Comparison with other sites however is hampered by the lack of side and sex data as well as by inconsistent recording. Reporting of only summary statistics has limited usefulness of much published data.

The frequency with which squatting facets occur, platymeria and platycnemia, Poirier facets, and the development of the muscle attachment sites on the femora are all consistent with habitual flexion of the lower limb. This may relate to squatting for some purpose but could also relate to climbing (e.g. of cliffs) or perhaps agricultural or boat-using activities. Hazleton North individuals - from inland Gloucestershire - also exhibited high prevalence of vastus notch and tibial squatting facets (Rogers 1990), which may imply that climbing cliffs and using boats were not causal. It is significant that the lower limbs display sidedness in robusticity. This probably indicates a widely adopted asymmetric activity: one might expect for example some agricultural practices to result in such evidence (e.g. use of delling spades or caschroms, or possibly from ploughing (Fenton 1965 especially plate XLIX; Rees 1979 part i; Lysaght 1990 fig 8; Clarke 2006:23ff)).
Sex attributions were confident for Isbister but the Banks sample size was too small to permit similar definition of the population sex ratio. The most obvious feature of the Isbister sex distribution is that adult males appear to outnumber females. There may be biases or inaccuracies in sex attribution (e.g. Krogman and Íşcan 1986) but the consistency of morphological, metric and stable isotope results in this study support confidence in its findings. This inequality is generally reported from British Neolithic tomb sites (notably at the well-recorded Hambledon Hill and Hazleton North sites (McKinley 2009; Rogers 1990)) and may be a cultural artefact of Neolithic society (Brothwell 1973:284). Neolithic sex proportions overall have been calculated to be 1.6 males: 1 female (Smith and Brickley 2009). Although this was prior to some significant recent work, it seems clear that there was sex-related selection for tomb deposition, whilst the use of an 'indeterminate' sex category may actually have led to an underestimate of disproportionality (cf. Meindl et al. 1985). Similar features occur in examining age distribution.

In any pre-modern society, perinatal mortality is usually high, with a sharp decrease in early childhood. Those surviving would be expected to live well into adulthood. There is only a single individual represented in the Isbister assemblage that is likely to have died early in infancy (1/85 individuals). It is clear that infant death rarely led to interment in chambered tombs because the same feature is noted elsewhere. It is possible that infant bones are underrepresented because of their small size but this seems to be too
systematic for that to be the case and the assemblage cannot reflect population mortality. A second peak in mortality at weaning might be expected but the high proportion of young adults seems anomalous and may also reflect selection.

The presence of two children at Banks is consistent with observations made on the Isbister assemblage and may be related to the age of final weaning. This was inferred above to have occurred at about four years of age and may have affected health.

The youngest individual at Rowiegar was probably about 1.5 years old at death, with one child aged 3-5 and one 6-9, with 5 young adults and 8 older adults.

Holm of Papa Westray North (Ritchie 2009) had been largely damaged by antiquarian investigations and contained bones from about 9-10 individuals. The ages at death at HPWN were concentrated in young adulthood with particularly few young juveniles.

At Point of Cott, Lee noted the presence of 6 individuals aged 0-0.5 (i.e. “The infants were all under 6 months … tentatively aged 0-3 months”) from a MNI of 13 (Lee 1997:37-8). This is exceptional and may indicate that the people using Point of Cott applied distinct criteria to interment or that recovery was better than usual. There is difficulty in assessing these figures because the summary tables are not divided into the categories described in the text. The population of 17 included 3 adults, 2 young adults, 2 adolescents and 6 children.
The situation at Quanterness is difficult to interpret because of the age groups used in the published report and because of potential problems both in the way that numbers of individuals were calculated for that site (Rebecca Crozier pers. comm.; Lawrence 2006) and the use of various improperly applied ageing methods (Chesterman 1979:99). Chesterman describes the presence of 10 individuals aged 0-2 at death, 26 aged 2-12, 36 aged 13-19 and 85 aged over 20. He notes however that the youngest age at death attributed to any individual was 8 months: this is likely to have been derived from standard tables and therefore accurate. It seems likely that individuals in the youngest of Chesterman’s age groups would belong in the 1-2 years old category but that their number was lower than claimed. It is impossible to refine the numbers in the other age groups from information in the report but the figures published suggest higher mortality in mid childhood than in infancy.

At Hazleton North (Rogers 1990), there appears to have been a similar pattern of interment. The age attribution for adults was estimated from dental attrition for which more data was available than for the pubic symphysis (also the case at Isbister). Sex attribution was from four distinct methods, each of which gave slightly different results, although the numbers and proportions given by three are in reasonable agreement and it is likely that males outnumbered females by 4:1.

<table>
<thead>
<tr>
<th>Element</th>
<th>Male</th>
<th>Female</th>
<th>Uncertain</th>
<th>Sex Ratio M:F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pelvis</td>
<td>8</td>
<td>2</td>
<td></td>
<td>4:1</td>
</tr>
<tr>
<td>Skull</td>
<td>7</td>
<td>2</td>
<td></td>
<td>3.5:1</td>
</tr>
<tr>
<td>Femoral head</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1.3:1</td>
</tr>
<tr>
<td>Humeral head</td>
<td>8</td>
<td>2</td>
<td>1</td>
<td>4:1</td>
</tr>
</tbody>
</table>

Table 193. Adult Sex Distribution at Hazleton North (after Rogers 1990).
Infant bones were found in relatively large numbers in the Orkney-Cromarty tomb at Embo, Sutherland, although this may not necessarily have reflected large numbers of infants (Inkster in Henshall and Wallace 1963:29ff). Excluding the Bronze Age cists and the cremated bone deposits, there appear to have

<table>
<thead>
<tr>
<th>Age</th>
<th>HPWN</th>
<th>Isbister</th>
<th>Rowiegar</th>
<th>Point of Cott</th>
<th>Ascott-Under-Wychwood</th>
<th>Banks</th>
<th>Hazleton North</th>
<th>Fussell's Lodge</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>0</td>
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<td>2</td>
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<td></td>
<td></td>
<td></td>
</tr>
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<td>12-17</td>
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<td></td>
<td></td>
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<td>1</td>
</tr>
</tbody>
</table>

Note: Holm of Papa Westray North has two sets of figures: the first set is the number attributed by Harman (Harman 2009), the second, in brackets, is that of Lee (Lee 1985:32).

<table>
<thead>
<tr>
<th>MNI</th>
<th>9</th>
<th>83</th>
<th>16</th>
<th>13</th>
<th>21</th>
<th>15</th>
<th>41</th>
<th>53-57</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>3</td>
<td>28</td>
<td>4</td>
<td>2</td>
<td>8</td>
<td>4</td>
<td>8</td>
<td>14-15</td>
</tr>
<tr>
<td>F</td>
<td>2</td>
<td>15</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>15-16</td>
</tr>
<tr>
<td>J</td>
<td>30</td>
<td>3</td>
<td>8</td>
<td>4</td>
<td>9</td>
<td>19</td>
<td>22-24</td>
<td></td>
</tr>
</tbody>
</table>

Infant bones were found in relatively large numbers in the Orkney-Cromarty tomb at Embo, Sutherland, although this may not necessarily have reflected large numbers of infants (Inkster in Henshall and Wallace 1963:29ff). Excluding the Bronze Age cists and the cremated bone deposits, there appear to have
been four adults, three juveniles aged about 10, a child of about 4-5 and three very young or possibly neonatal infants. The numbers of individuals are difficult to ascertain because of later disturbance and the elements are not conveniently described. (Embo has further resonance with Banks in that the tomb was initially intended to be removed for a car-park but was left in the centre of the parking area instead because of its interest (ibid.:10).)

At Ascott-Under-Wychwood, Galer identified two juveniles aged about 7 and 8-14 respectively. There were 17 adults and, unusually, a near term foetus. The MNI figures for Ascott under Wychwood do not include all elements discovered in the original excavation since some appear to have been lost. The number of individuals interred may have been greater (Galer 2007:190). There is a possibility that some fragmentary elements from different areas of the tomb may actually belong together (e.g. F1 or F2 with others) so that MNI may be slightly lower than calculated.

Both Ascott under Wychwood and Hazleton North also held burned human bone, which was included in the MNI calculations. This may have represented distinct phases of use and so adding these figures may be inappropriate.

In general, male adults outnumber females in tombs and the numbers in age groups are disproportionate to expected mortality patterns. Particular age and sex groups were most likely to be interred in Neolithic tombs: the distributions are not random but seem systematic through the UK. It is possible that other elements within the skeletal evidence may explain this.
5.8 PALAEOPATHOLOGY

The Isbister assemblage exhibits numerous pathological lesions, often more commonly than might be expected in modern clinical practice (pp243-400).

**Craniostenosis and post-bregmatic depression**

Deformity has been observed across several sites, sometimes with a potentially high prevalence (this study and e.g. Low 1935; McKinley 2009), suggesting some systematic factor. Post bregma vault concavities were recognised in Neolithic crania in the mid nineteenth century (Thurnam 1865). A high level of post-bregmatic depression in the Isbister population was noted by Chesterman, who considered this feature to have resulted from the use of a band over the head to carry heavy burdens. Closer study of the affected crania suggests the presence of premature craniostenosis.

Craniostenosis may

- Be genetic in origin;
- be a consequence of intra-uterine developmental abnormalities; with multiparous births and cases where the foetus developed with the head lodged in one horn of the uterus, possibly artificially through constriction of the abdomen
- be caused by natal or post-natal trauma;
- result from intentional cranial deformation;
- be caused by hormonal abnormalities or poisoning;
- or develop as a side-effect of certain cultural practices such as sleeping
posture (see e.g. Cohen and MacLean 2000).

The estimated birth-prevalence for all craniosynostoses together is estimated at between 310 and 476 per million (Cohen 2000:113). For sagittal synostosis, birth prevalence has been estimated at 190 per million and to have a sex ratio of 3.5 male per female cases; for coronal synostosis 94 per million with 2 female per male cases; for metopic synostosis at 67 per million with 3.3 male per female cases. The genes for this condition are typically autosomal but can be either dominant or recessive; penetrance varies according to aetiology. The significantly higher rate at Isbister may indicate a small gene pool with limited exogamy. Because this feature has a strong genetic component, this could then relate to hereditary status. Alternatively, individuals may have been selected for interment based on appearance and/or behavioural criteria.

Abnormal growth of the cranium may cause neurological problems due to excessive intracranial pressure, leading to a syndrome of clinical manifestations. Syndromes especially appear to arise when sutures near the base of the cranium are involved (Cohen 2000). Epilepsy may occur, mental retardation and even death. Estimates of retardation prevalence indicate that it is rare (about 2.4 – 4.8%) when only a single suture is synostotic. Other secondary symptoms may result from the abnormal action of musculoskeletal forces or the limited volumes available for soft tissue, including eyes, tongue and cranial nerves. Diminished stature may be related, possibly due to pituitary disorders. Form and associated syndromes depend on location and severity of premature fusion, which requires compensatory growth elsewhere. Patterns of development are recognisable (Cohen and MacLean 2000, especially chapters
9 and 11): plagiocaphaly, trigonocephaly, scaphocephaly and brachycephaly were all identified at Isbister. There is also a high prevalence of bathocrany (the 'occipital bun')(pp245-251 above).

There is difficulty in diagnosing premature craniostenosis archaeologically. The behavioural, neurological, soft-tissue and superficial symptoms significant for diagnosis are not apparent in a skeletalised sample. Some syndromes affect other anatomical areas, such as the extremities but in a commingled, fragmented and incomplete assemblage this may not be apparent. Crania were not always sufficiently complete to permit observation of relevant sutures. Positive observations of dysplasia may be possible when negatives cannot be determined. Pressure on crania whilst buried can lead to distortion so that cranial form may not be diagnostic.

Though strongly hereditary, families do not always exhibit the same manifestations (Cohen 2000). There are usually variations in severity and there may be variation in the location of stenosis. In general, the juvenile crania from Isbister appear to exhibit more deformity than adults and this may indicate that the trait is inversely related to survival. Cases of asymmetrically developed orbits and of apparent torticollis (indicated by asymmetrically developed mastoid processes), failure of teeth to erupt and the occurrence of a narrow, pointed and high-arched maxillary dental arcade in other individuals may be inter-related and indicate the presence of a syndrome.

Similar traits have been noted in the skeletal assemblages from the Knowes of
Rowiegar and Yarso. Interestingly, the only pathology noted in the Embo (Caithness) assemblage was craniosynostosis (of the sagittal suture) in a child aged about 10 at death (Henshall and Wallace 1963). It may be that the cause of such malformation was widespread in Neolithic Orkney. This may have persisted in local populations: the clearly plagiocephalic IS(1972) has returned a Bronze Age radiocarbon date and similar traits have also recently been noted in an Iron Age cranium from the Bay of Skaill in Orkney (Tucker 2011).

One possible alternative cause is birth trauma at the neck. This can damage *m. sternocleidomastoideus* and lead to congenital wry-neck (torticollis). This can affect the cranium because the muscular forces acting through the mastoid process are asymmetric with the head habitually turned to one side. This could lead to asymmetry of the cranial vault. Breech birth significantly increases the prevalence of occipital bun (Hsieh *et al*. 2000; see p247 above).

**Post-bregmatic depression.**

Chesterman suggested that postbregmatic concavity occurred at Isbister (in six cases) because of particular activity patterns (Chesterman 1983:121-2). Sagittal synostosis was positively correlated with cranial deformation practised in a Mayan community (White 1996) and it is conceivable that activities simulating head binding might cause similar features. Since child crania in the Isbister population exhibit post-bregmatic depression, this is more likely a congenital condition. Conversely, there is occipital condyle DJD well developed in juvenile crania, which may support an activity-related aetiology or dysplasia (pp271-3).
Degenerative Joint Disease

Osteoarthritis is widespread in the Isbister assemblage. These lesions may be due to behavioural patterns but could include factors of heredity and diet. Osteoarthritis and DJD were distributed throughout skeletal elements but prevalences at particular joints and elements indicate behavioural factors in aetiology. This population appears to have died young, so that correlation with age is unlikely. It is impossible to compare most of the DJD results of this study directly with those of Roberts and Cox because they cite ‘number of joints affected’ or ‘number of individuals affected,’ (Roberts and Cox 2003:72-3). It seems that prevalence at Isbister is generally higher.

The human population provided labour during cultivation and needed to transport large volumes of fertilisers, crops and building materials, which could explain both the lower limb and spinal arthropathies as well as skeletal development associated with heavy musculature. Particular patterns of tool use or carrying might be implicated. OA has been observed to increase with the introduction of settled agriculture in North America, with patterning showing sexual dimorphism but the elbow was usually the second most commonly affected joint (Bridges 1992:71). Increases in traumatic injury associated with warfare might also be implicated (Bridges 1992:86). Posterior expansion and DJD of the occipital condyle may reflect use of a tump-line for carrying heavy burdens from an early age (ironically, this could have led to trauma, causing craniosynostosis and thus post-bregma concavity).

The prevalence figures for OA and DJD (pp264-304 above) show laterality in
the increased occurrence in the right wrist, left elbow and left first metatarso-
phalangeal joint over the opposite side in both severity categories; and
involvement of the left shoulder tends to be more severe than right. The left side
also has a high prevalence of septal apertures, at 9.3% compared with 1.6% for
the right side. Leaning on the overextended left arm may be related and Knüsel
has noted that overextension of the bow arm elbow is a common error among
inexpert archers (Knüsel 2000:109). Rogers did not find DJD in the elbow or
wrist in the Hazleton North population and no examples of severe osteoarthritis
in any major joint (Rogers 1990:193), unlike this study.

Patterning observed in the bones of the foot seems similar to that observed by
Merbs in the Sadlermiut although he found little laterality of the first metatarsal
(Merbs 1983:95ff). The high prevalence of osteoarthritis in the distal left first
metatarsal is striking. The only statistically significant laterality of tibial pathology
is the higher prevalence of left side proximal enthesophytes over the right. In
the femur, enthesopathy, supratrochlear woven bone and adaptation at the
medial head of m. gastrocnemius all have statistically significant higher
prevalence on the left side than the right (Table 144, pp284-5 above). It seems
probable that there is a particular behavioural pattern in the population that
causes these effects; this is consistent with the metrical observations.

There may be a genetic component present as a contributing factor in
degenerative disease of the temporomandibular joint. Many crania had
relatively shallow mandibular fossae. This might act as a predisposing factor in
permitting subluxation of the mandible anteriorly though this was not formally
assessed. Especially in a population likely to be performing non-masticatory tasks with the jaws, this could increase the prevalence of temporomandibular joint dysfunction. The most extreme case of TMJ dysfunction was in an individual that had survived an extensive series of traumas to the cranium in which it is possible that a trauma to the mandible occurred at the same time, causing the subluxation clearly present in this case. With 14 cranial examples of DJD at the TMJ, Isbister has an adult prevalence rate of about 32%. This is significantly higher than any population quoted by Roberts and Cox, where the overall prevalence rate was shown to be about 9% (Roberts and Cox 2003:72). Banks also appears to exhibit a high prevalence.

Both Davis and Rolleston noted in the late nineteenth century that ankylosis of the cervical vertebrae appeared to be common in various collections although Neolithic provenance was only suggested for one (Rolleston 1878:697ff; see p11 and p13 above). This could infer similar aetiology with the Banks case, where interpersonal violence was suggested.

The existence of psoriatic arthritis in the Isbister population is tentatively suggested from IS(7151). Psoriasis can be unsightly, uncomfortable and disabling. The aetiology is not fully determined but displays a strong hereditary component, with the initial onset apparently often triggered by streptococcal infection (especially of the throat) (Resnick and Niwayama 1988:1179ff). There is a link between pigmentation and prevalence, with psoriasis only occurring in pale-skinned populations; and the lesions may benefit from exposure to ultraviolet light. In caucasians today, psoriasis is reported to occur in about 1-
2% of the population: only 5-7% of sufferers develop psoriatic arthritis. Presence of this condition may imply a much greater prevalence of psoriasis in the Isbister population. Assuming a similar rate of skeletal involvement in the past, then potentially 20 times as many individuals in the community will have merely suffered from the skin complaint. In a small community, an adult with PA may have been a significant part of the reproductive population. It is possible that some other degenerative lesions relate to the spondylitis associated with PA and that they are not all biomechanical in origin.

The psoriatic arthritis sufferer develops pain and weakness associated with tendonitis as the major functional symptom but socially, the superficial appearance may lead to great distress. The unsightly nature of the skin leads many sufferers today to wear clothing that covers the lesions and misunderstanding of the nature of the disease may lead to stigmatisation and isolation from the community. This arthropathy is particularly expressed as erosion of the interphalangeal joints with ‘fluffy’ peripheral bone deposition, classically leading to a ‘pencil and cup’ joint and DIP ankylosis (Resnick and Niwayama 1981:1103ff). There is a tendency to develop spondylosis, similar in appearance to ankylosing spondylitis, and inflammation may affect any of the limb joints. Other symptoms include plantar spur, also found at Isbister and Banks and (possibly) retrocalcaneal bursitis.
Interpersonal Violence and Trauma

There are numerous examples of trauma affecting the Isbister population, with several indicators suggesting interpersonal violence: fractures, penetrating injuries and (rare) cuts. Many of these indicators possess likely alternative aetiologies, such as falls in the case of radius, clavicle and depressed cranial fractures or accident in the cases of cuts. Periodontal disease and non-masticatory use are implicated in cases of ante-mortem tooth loss. No trauma has so far been recorded from the Orcadian scapulae, humeri, femora, sterna or ossa coxae but evidence from most elements is limited by fragmentation and incompleteness, perhaps especially the viscerocranium, ribs, ossa coxae, scapulae and vertebrae and this may bias the observations.

The Isbister population has a high prevalence of fractures of the radius but none was apparent on any ulna (pp319-323 above). The most likely aetiology of traumatic lesions of the radius is injury caused by a fall broken by the outstretched hand. The well-healed appearance with little displacement in each case may support the hypothesis that the ulna may not have been implicated or that reduction and splinting were practised. Sudeck’s atrophy is a common complication of these injuries today and features tenderness, osteoporosis and restricted use of the fingers, hand and wrist (McRae 1994:178). There may have been a relatively high accident rate due to exploitation of cliff and shore resources. Fractures of the radius, clavicle and ulna in adult males from West Kennet long barrow (Wells 1962:81) however suggest that other factors existed.

Some cases are almost certain to derive from interpersonal violence. Fracture
of the fifth metacarpal, of which there were 3 cases from a total of 37 fifth metacarpals at Isbister (22 right side), is 95% likely to be from a technically poor blow delivered with the fist in modern populations (McRae 1994). All instances recorded at Isbister were from the right hand side, perhaps because of handedness within the population, although the asymmetric distribution may have been due to the larger number of right 5th metacarpals. This might be expected to derive from an almost casual form of violence, often associated today with excessive alcohol consumption. It may also offer one partial explanation for the high prevalence of ante-mortem anterior tooth loss.

Two (possibly 3) vertebrae were found to have angular insults penetrating deep into the body and exposing the trabeculae. There is some indication of healing but no indication of any spalling or surface bending that might suggest that the individuals were alive when the damage occurred. There is no indication in either case that trabeculae have been crushed and there is no sign of splintering, as typically occur with excavation damage. It is considered most likely that these injuries occurred perimortem but a taphonomic origin cannot yet be satisfactorily ruled out. If a traumatic cause is accepted then the original injury was most likely caused by an arrow wound, which must have penetrated the thorax, causing further injury. Such wounds are most readily observed where arrowheads are found embedded in bone and this has particularly been observed with vertebrae (e.g. Tulloch of Assery B (Lunt and Young 1967:63), Ascott-under-Wychwood (Knüsel 2007)). Another arrowhead was discovered embeded in a rib from Penywyrlod (Wysocki and Whittle 2000:600). These observations, along with high arrowhead densities at site entrances (Dixon
1988; Mercer 1988) have led to reinterpretations of arrowheads previously considered 'grave-goods' and their uses (e.g. Mercer 1999:149f).

Cervical vertebrae from Banks (Figure 184, pp334f above) echo observations of cervical trauma from other Neolithic sites (e.g. Ascott-under-Wychwood (Galer 2007:212-3)), which are most likely related to powerful blows to the back of the head that were survived. These cases are more likely to derive from violent assault than low ceilings (contra Thurnam 1869; see p11 and p13 above).

There is evidence of perimortem cranial trauma from about 20% of identifiable crania at Isbister; six individuals exhibited healed fractures. Both sexes and all ages were affected. There are three examples of adults (all older but of indeterminate sex) with circumferential 'ring' fractures. Prevalence rates are difficult to determine because the crania are largely fragmented and many are represented by relatively small amounts: since a positive diagnosis is more readily made than a negative and because rather a lot of cranial fragments appear to be missing, only a minimum crude estimate of about 20% is properly calculable although the true prevalence of cranial trauma may be much higher: about 40% of composite complete crania with adequately observable surfaces. The local population was obviously subjected to violence and yet this is an apparently remote island community that might be expected to be relatively secure. It is not impossible that prevalence reflects interment selection criteria.

This collection of lesions could derive from any of a number of practices, including warfare, raiding, feuding, domestic abuse, euthanasia, accident and
ritual combat. The disparity of the sexes and nutritional deficiencies in the assemblages may provide a clue regarding underlying causes (see Figure 291, p556 below). The high prevalence of pathology for example - including evidence that infants failed to thrive and may have suffered from neurological disorders - could indicate motives for euthanasia; if males had difficulty finding sexual partners/wives then competition might become violent (cf. Balikci 1970).

Cranial trauma is predominantly above the 'hatband' region and there is a higher prevalence of trauma to the anterior left cranium than to other areas, which suggests face-to-face violence. The variety of lesion form indicates the use of a variety of weapons, which seems unlikely to relate to ritual or sporting injuries. The most probable cause is interpersonal violence, which has been repeatedly demonstrated throughout Neolithic Europe (e.g. Schulting and Wysocki 2005; papers in Schulting and Fibiger 2012).

Warfare, or raiding, as inferred at Crickley Hill (Dixon 1988), Carn Brea (Mercer 1981) and Hambledon Hill (Mercer 2008) may have been endemic. It is likely that the monumental stone settlement boundary walls at Ness of Brodgar, stretching across the Brodgar peninsular between the lochs of Stenness and Harray had a defensive function and their very appearance may have acted as a deterrent: not been purely symbolic. Competition for resources - land, goods, adult females, - present motives for conflict. A high status settlement would be a profitable target for attack for conquest or booty but probably only by an organised force. Parallels for defensive structures exist at Carn Brea, Crickley Hill and Hambledon Hill (Mercer and Healy 2009; Dixon 1988; Mercer 1980,
1981, 1988, 1999), whilst palisaded sites (e.g. Tullahedy, perhaps especially so with its "peripheral" mound location (Cleary and Kelleher 2011)) and Neolithic 'crannogs' (e.g. Eilean Domhnuill (Armit 1992)) may also reflect need for defence. If interpersonal violence was significant then this presents a clear basis for the symbolism of the finely carved stone and antler maceheads and 'symbols of power' (Clarke et al. 1985; see also Simpson and Ransom 1992; Edmonds 1992).

Neoplastic Diseases
Neoplastic conditions appear to have been common (pp383-400 above). Both UBC (at Isbister) and palatal lesions (Isbister and Rowiegar) occur in multiple individuals; there was multiple myeloma (Isbister) and possibly long-bone tumours (Banks). These conditions seem to have been disfiguring or disabling and will have had no apparent cause. This may simply reflect selection for interment rather than a particular health problem in Neolithic Orkney.

Possible Pulmonary Disease
Several bones from Isbister exhibit lesions that are consistent with pulmonary disease. Two ribs have plaques of new bone on their visceral surfaces, which are likely to derive from a chronic inflammatory pulmonary disease. The most common recorded cause is TB but a substantial minority of other causes exist (Matos and Santos forthcoming) and the antiquity of evidence is debated (Manchester 1984; Roberts and Buikstra 2003:87-186. The lesions found in this
study are multifocal, healed and distributed generally along the visceral surface. In cases where pulmonary TB was cause of death, lesions are more common on the middle ribs and at the vertebral end of the ribs (Santos and Roberts 2006). Four cases were found of lesions on the anterior or lateral vertebral body surfaces, of which three had clear lytic manifestations. Endoccipital bone formation observed in IS(7208) and the lesions observed in thoracic vertebrae and ribs may all be symptomatic of TB, brucellosis or other intrathoracic infection (Hershkovitz et al. 2002).

Close proximity to livestock might lead to increased exposure to zoonoses (Roberts and Manchester 2005:184-5) but non-specific respiratory diseases might have been more common in smoky, dusty and probably dirty Neolithic homes (Roberts and Cox 2003:60-1). Pneumonia may be more consistent with rib periostitis (Kelley et al. 1994:127ff). This may be likely in a small population that might not support endemic TB. Hershkovitz et al. noted that adults with this condition only occurred in adults from modern (not old) collections, although children were more affected in the archaeological sample (Hershkovitz et al. 2002). Such features may have occurred because children were more susceptible to both epidural haemorrhage and respiratory infection; modern adults may have been affected because of high pollution and TB rates. High prevalence of TB in nineteenth century South Ronaldsay (Bowers 1983) probably reflected the close living quarters shared by humans and cattle, which seems unlikely for the low entrances of Neolithic houses. Contrarily, non-specific respiratory diseases might have been a common risk (Roberts and Cox 2003:60-1). Neolithic TB has been tentatively reported from Tulach an t-
Sionnaich, Caithness (Lunt and Young 1967:57). Respiratory disease might also have affected the prevalence of porosity as recorded on the anterior maxillae, through chronic inflammation around the air passages.

**Oral Conditions**

Brothwell found ante-mortem tooth loss to be the most common abnormality in British Neolithic populations (Brothwell 1973). Caries was restricted to the posterior dentition but ante mortem tooth loss and abscess formation afflicted the entire arcade and he considered this to indicate infection following severe attrition (Brothwell 1973:294). It could possibly indicate avulsion as a cultural practice. The distribution of lesions agrees with Hambledon Hill (McKinley 2009:508), Isbister and Banks but contrasts with Ascott Under Wychwood, where ante mortem tooth loss was reported to be primarily anterior (Galer 2007). Dental attrition was not a major factor at Isbister but gingival infection appears to have been common, which may reflect either non-masticatory jaw use or metabolic conditions (including scurvy). Calculus, though widespread, was apparently rarely severe, which could indicate limited protein intake, or coarse food, as well as limited attention to oral hygiene, all of which may affect its formation (e.g. Jin and Yip 2002). Supragingival calculus forms in plaque films under relatively high pH conditions, especially where large volumes of saliva maintain saturation in calcium phosphate and prevent acidity (that might otherwise result from sugars derived from starch in the diet); proteins are adsorbed onto the teeth, attracting plaque bacteria and forming a substrate for calculus formation; protein decay forms urea - available through stagnation and
saliva production - and then forms ammonia, which raises pH. Chewing coarse food (or some forms of non-alimentary mastication) has a mechanical effect to remove plaque and has consequent limiting effects on calculus formation, caries and periodontal disease (Stookey 2009). It may be significant that the oral environment required for calculus formation is opposite to that for dental caries, because caries was generally rare in these assemblages (Table 195 below; Roberts and Cox 2003:68-9). If both conditions are rare or of minor severity, then this may support the hypothesis that either food was abrasive or the population performed activities such as chewing hides. All periodontal disease at Hambledon Hill was accompanied by calculus deposits in the same dentition (McKinley 2009:509). Hambledon Hill seems unusual in having very even prevalence of the main pathological conditions, with exceptionally low figures for ante mortem loss (i.e. 1.6 or 1.7%), periodontal disease (12%) and calculus (12%) whereas the other large assemblages have significantly higher ante mortem loss rates especially: this may reflect the unusual nature of that assemblage, compared with tombs.
Table 195. Comparison of Dental Lesions (after \(^a\)Brothwell 1966, \(^c\)Rogers 1990, \(^d\)McKinley 2009, \(^e\)Galer 2007, \(^f\)Schulting 1998, \(^g\)Barclay and Halpin 1997, \(^i\)Brothwell and Cullen 1991).

<table>
<thead>
<tr>
<th>Site</th>
<th>Caries</th>
<th>Ante-mortem tooth loss</th>
<th>Abscesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fussell’s Lodge(^a)</td>
<td>7/179 teeth 3.9%</td>
<td>37/259 sockets 14.3%</td>
<td>5/259 sockets 1.9%</td>
</tr>
<tr>
<td>West Kennet(^b)</td>
<td>1/190 0.5%</td>
<td>27/336 8.0%</td>
<td>9/318 2.8%</td>
</tr>
<tr>
<td>Bowl’s Barrow(^a)</td>
<td>7/133 teeth 5.3%</td>
<td>13/200 sockets 6.5%</td>
<td>6/190 3.2%</td>
</tr>
<tr>
<td>Hazleton North(^c)</td>
<td>1/228 teeth 0.4% (5/393:1.3%)</td>
<td>115/507 sockets 22.7%</td>
<td>42/507 8.3% (45/659:6.8%)</td>
</tr>
<tr>
<td>Hambledon Hill(^d)</td>
<td>7/439 teeth 1.6%</td>
<td>9/538 sockets 1.7%</td>
<td>9/538 sockets 1.7%</td>
</tr>
<tr>
<td>Ascott under Wychwood(^e)</td>
<td>18/222 8.1%</td>
<td>18/223 sockets 8.1%</td>
<td>2/223 sockets 0.9%</td>
</tr>
<tr>
<td>Barrow Hills(^g)</td>
<td>2/160 1.3%</td>
<td>20/180 11.1%</td>
<td>5/180 2.8%</td>
</tr>
<tr>
<td>Wayland’s Smithy(^i)</td>
<td>10/205 4.9%</td>
<td>33/308 10.7%</td>
<td>17/310 5.5%</td>
</tr>
<tr>
<td>Isbister</td>
<td>3/857 teeth 0.4%</td>
<td>185/2150 sockets 8.6%</td>
<td>27/2150* sockets 1.3%</td>
</tr>
<tr>
<td>Banks</td>
<td>0/107 teeth</td>
<td>19/159 sockets 11.9%</td>
<td>5/159* sockets 3.1%</td>
</tr>
<tr>
<td>Previous Overall Neolithic(^f)</td>
<td>36/1510 3.1%</td>
<td>223/2058 10.8%</td>
<td>49/1870 2.6%</td>
</tr>
<tr>
<td>Previous Overall Neolithic(^f)</td>
<td>40/1565 2.56%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Including granuloma/cysts; † including juveniles over 1 year old at death.
Isbister showed high prevalence rates of periodontal disease, ante-mortem tooth loss and palatal pitting but a low degree of dental attrition or calculus deposition and low prevalence of caries (pp341ff). This may infer the presence of scurvy in the Isbister population to be the cause of much oral disease. The prevalence of enamel hypoplasia by contrast seems low at Isbister for the prevalence of other pathological conditions. The number of children and young adults in the skeletal sample may be significant in this regard. It seems possible that stressors would have been likely to result in early death rather than minor episodes of growth disruption, in keeping with ‘the osteological paradox’ (Wood et al. 1992). These features also appear at Hazleton North (Rogers 1990).

In general terms, pathology at Isbister would appear to be similar to Hazleton North, although there is not any obvious reason why this should be so. There was considerable periodontal disease at Ascott under Wychwood but also an unexpectedly high prevalence rate of dental caries for a Neolithic population – a feature only paralleled at Lanhill (Galer 2007; Piggott 1938). There is no evidence of dental caries from Banks and very little from the large number of teeth at Isbister. Periodontal disease is significant as an indicator for aspects of diet, activity or oral hygiene. There are several major possible causes of periodontal disease:

1) dental caries, which can lead to infection;

2) severe wear of the teeth, which can lead to infection if the pulp cavity is breached or if the occlusal surface is below the gum-line;

3) severe calculus, which can irritate the gums, causing them to become inflamed and recede;
4) non-masticatory use of the jaws, because the introduction of foreign matter can cause trauma leading to infection;
5) scurvy, which can lead to severe gum inflammation and tooth loosening with associated infection.

There is little caries in Orcadian assemblages and it is very rare in most Neolithic reports (Roberts and Cox 2003), so this is an unlikely cause. There is occasional severe dental attrition but this would not account for the level of periodontal disease and tooth loss observed. There is little calculus and this often occurs so low on the tooth that it suggests deposition after the gums have receded rather than being causative. There is no evidence of intermediate severity of such conditions leading to tooth loss. The suggestion that avulsion was practised in the Neolithic is contradicted by the varied locations of loss. There is a disparity between the jaws, with most ante mortem tooth loss occurring in the maxillae rather than the mandible. Trauma and scurvy are therefore the most likely causative factors for periodontal disease in the Neolithic.

**Scurvy**

“The diseases which were reckoned common were, the scurvy which I believe very few of the common people are free of, indeed there are few but are more or less tainted with this, which arises from the damp sea air and unhealthful colds of winter, which there is no such thing as guarding sufficiently against.”

The identification of scurvy in Neolithic assemblages is becoming more common – it has for example been observed at West Tump in England (Smith and Brickley 2009) – and it is highly significant both in terms of understanding health but also because of the implications for food access. Scurvy is difficult to identify skeletally because most lesions are individually non-diagnostic and in fragmented commingled assemblages patterns of lesions are difficult to identify. Scorbutic lesions could conceivably be explained by combinations of trauma and idiopathic inflammation in locations related to muscle attachments or in the palatals; or periostitis (e.g. the porous raised periosteal deposit on IS(6959) or occluded medullary cavities (Figures 211, 214)). Some lesions identified have however been described as "virtually pathognomic" for scurvy (bilateral pitting of the greater wing of sphenoid: Ortner and Ericksen 1997:214); "porous, hypertrophic lesions of the skull vault" have been emphasised as scorbutic symptoms (Ortner 2003:385-6) and notwithstanding the difficulty of demonstrating skeletal patterning, the Isbister collection presents examples of every skeletal lesion typically described as symptomatic of scurvy (Ortner et al. 1999; Ortner et al. 2001; Ortner 2003; Brickley and Ives 2008). Cranium IS(7209) presents a compelling case (pp359ff). Scurvy is not only the most likely explanation for a number of cranial lesions at Isbister but nutritional deficiency should also, in the absence of significant indicators for other common aetiologies, be considered the most likely cause of the periodontal disease observed.

It is apparent that the Neolithic Orcadian population periodically and chronically lacked vitamin C and probably other nutrients. Considering the climate and
vegetation of Orkney, this is perhaps not surprising. The consequences of scurvy would include weakness, tiredness, failure of injuries to heal, reduced resistance to disease, internal haemorrhaging, swollen gums and lost teeth with difficulty in eating, and ultimately death.

In infants and young children, the condition is very distressing. There is an abnormal appearance and immobility associated with pain, inevitably accompanied by crying, that causes additional distress to the immediate family (e.g. van Wersch 1954:71ff).

The potential diagnosis of scurvy as a widespread chronic condition within the South Ronaldsay population(s) is an important addition to our understanding of the Orcadian Neolithic because there are implications regarding both causes and effects, which relate to social and economic factors.

Scurvy arises when insufficient vitamin C is present in the body (avitaminosis C). Traditionally associated with long sea voyages in the days of sail, it occurred on land too ('land scurvy'), often seasonally in places and at times when insufficient vitamin C bearing foods were available (Hirsch 1883:vol.2:507-568). Humans cannot synthesise vitamin C and require a food source. Antiscorbutic foods were less available in the past. The modern western diet relies heavily on potatoes and citrus fruits as a vitamin C source, supported by other fresh fruit and vegetables, as well as liver and kidneys. A particularly important problem related to seasonality is that vitamin C is lost during storage or food preparation. The human body can store limited vitamin C so that from saturation, people can
manage for several weeks without ill effects. In the past, high tissue concentrations may not often have been achieved in temperate Europe.

A daily intake of 30mg vitamin C is recommended for a moderately active male and 50mg for a lactating female (WHO 1999); as little as 10mg per day is sufficient to prevent scurvy developing. Vitamin C is required for the body to manufacture collagen, our main connective tissue. In the absence of vitamin C, the collagen made by the body is unsound and weak, resulting in tearing of tissue. Individual vitamin C demand is increased by periods of injury and illness because it is used in the healing process.

Neolithic Orcadians did not have access to many modern foods, such as potatoes or the Brassicas. Most antiscorbutic foods will only have been available seasonally and many do not have high concentrations of vitamin C, including traditionally used herbs, requiring large volumes to be eaten at periods when other foods will have been available (see e.g. Hughes 1990). It is highly likely that most of the population had little intake of this essential vitamin except in summer and autumn, when foods such as berries and crab-apples will have been available – evidence of both was found at the Neolithic settlement of Barnhouse (Richards 2005:344) and crab apple is relatively common on Neolithic sites in England and Scotland, including six contexts at Balbridie, dated 5010±90 bp (Fairweather and Ralston 1993). Slaughter of domestic animals cannot have been extensive if husbandry was to be sustainable and a small island will have had limited access to hunting grounds, so access to fresh liver or kidney, even milk will have been extremely limited, possibly extending
only to the elite. On the Scottish mainland, the leaves of conifers may have been used as an infusion to stave off scurvy as was done by the North American Cree and Baltic sailors (Carpenter 1988:229) but few conifers probably grew in Neolithic Orkney. Angiosperm foliage has high vitamin C content (Jones and Hughes 1983; Jones and Hughes 1984) but would be seasonal and any trees or scrub may have been lost by the later fourth millennium. Food storage by drying, salting or pickling would have led to vitamin C loss, unlike the situation in the Arctic winter, where foods could be frozen.

Seaweeds may have been available all year, though some species are seasonal. Their vitamin C content varies seasonally (Chapman 1970:118) and a large volume would be needed as a winter antiscorbutic. Common seals come ashore in Orkney in the summer and grey seals in autumn (to breed) and so despite their antiscorbutic food value, may not have been available when needed. The Neolithic population of north-west Europe may however have failed to exploit the sea intensively for food (Richards and Hedges 1999).

Some individuals do not appear to have suffered from scorbutic symptoms, lacking even periodontal lesions. This may be because they had access to adequate food through the year. These individuals may then have had different dietary practices; they may have been an elite with access to the internal organs of slaughtered livestock; they may be a distinct population, either travellers or the remains may (given the dating uncertainties) simply come from different periods. The antiscorbutic foods for which evidence other than animal bone has been found in excavations in Orkney are rare (Richards 2005:344).
There is no indication from the isotopic study results that any significant marine protein was taken though this may not exhibit effects with occasional use. There may have been some unidentified use of marine fats and oils, which would be potentially significant for adult women, whose diets appear to have been limited.

This observation of restricted diet suggests that agricultural practice was well-developed and sufficient by itself to feed the population. The contrast with vitamin C sources among the Inuit (Figure 290 below) is marked. Individuals may not have needed to exploit the full range of available foods from the marine environment that might have otherwise helped to prevent dietary deficiencies developing (Tables 196 and particularly 197 below). Exploitation may therefore have been limited to particular individuals and special circumstances. The stable isotope evidence from this project supports periodic use in significant quantities by adult females but potentially greater variability and terrestrial animal protein among adult males. Such dietary differences may have had nutritional consequences and an improved diet might be appropriate at particular times of metabolic stress. Interestingly, a study of grave finds associated with inhumations in Neolithic flat cemeteries on the island of Gotland found that fish-hooks were especially associated with female burials, whilst male skeletons tended to be accompanied by hunting gear; child graves tended to include finds associated with fishing and bird hunting (Wallin 2010).
Figure 290. Vitamin C sources in the Inuit diet (data after Fediuk 2000).
Table 196. Vitamin C Content in Terrestrial Foods.

<table>
<thead>
<tr>
<th>Food</th>
<th>Vitamin C content (mg per 100g fresh)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal meat</td>
<td>0-2***</td>
<td>Probably seasonal: autumn</td>
</tr>
<tr>
<td>Animal liver/kidney</td>
<td>10-40***</td>
<td>Probably seasonal: autumn</td>
</tr>
<tr>
<td>Animal milk</td>
<td>1-2*** (cow) 3-5 (sheep and goat)</td>
<td>Availability relates to husbandry practices</td>
</tr>
<tr>
<td>Human milk</td>
<td>3-7***</td>
<td>Available to infants - if mother well nourished</td>
</tr>
<tr>
<td>Grain</td>
<td>0***</td>
<td>Staple, harvested autumn</td>
</tr>
<tr>
<td>Malt (sprouted grain)</td>
<td>10*** 8.8*** 30-100***</td>
<td>If fresh – probably available, Difficult to produce without diminishing seed stocks</td>
</tr>
<tr>
<td>Crab apples</td>
<td>10*</td>
<td>Seasonal, autumn, rare</td>
</tr>
<tr>
<td>Angiosperm leaves</td>
<td>496*</td>
<td>Seasonal, summer-autumn, rare</td>
</tr>
<tr>
<td>Berries, rosehips</td>
<td>300-1000***</td>
<td>Seasonal, autumn</td>
</tr>
<tr>
<td>Scurvy grass</td>
<td>63*, 200***</td>
<td>Seasonal spring-summer</td>
</tr>
<tr>
<td>Heather leaves</td>
<td>394*</td>
<td>Seasonal spring-summer</td>
</tr>
<tr>
<td>Stinging nettle</td>
<td>169*</td>
<td>Seasonal, spring-summer (later Neolithic only?)</td>
</tr>
<tr>
<td>Potatoes</td>
<td>28 (4 cooked)*</td>
<td>Not available in Neolithic Orkney</td>
</tr>
<tr>
<td>Cabbage</td>
<td>55 (11 cooked)*</td>
<td>Not available in Neolithic Orkney</td>
</tr>
</tbody>
</table>

* data from Hughes 2000:759, Hughes and Jones 1983, Hughes and Jones 1984
That scurvy should exist in young infants leads to speculation of ineffectiveness of weaning practices and poor nutritional status of pregnant women or nursing mothers. It seems likely that a re-examination of recorded cases of cribra orbitalia and of cases of rickets might identify more examples. One Neolithic example of rickets was based on endocranial ‘exostoses’ (Rolleston 1878:700) but the aetiology of the supposedly rachitic endocranial lesions does not seem to have been satisfactorily explained (see Brickley and Ives 2008:97ff and

<table>
<thead>
<tr>
<th>Table 197. Vitamin C Content in Marine Foods.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seal meat</td>
</tr>
<tr>
<td>Seal liver</td>
</tr>
<tr>
<td>Whale skin</td>
</tr>
<tr>
<td>Whale Blubber</td>
</tr>
<tr>
<td>Fish</td>
</tr>
<tr>
<td>Kelps: Laminaria spp.</td>
</tr>
<tr>
<td>Wracks: Fucus spp.</td>
</tr>
<tr>
<td>Ascophyllum nodosum</td>
</tr>
<tr>
<td>Dabberlocks: Alaria esculenta</td>
</tr>
<tr>
<td>Thongweed: Himanthalia</td>
</tr>
<tr>
<td>Laver: Porphyra spp.</td>
</tr>
<tr>
<td>Sea lettuce: Ulva lactuca</td>
</tr>
</tbody>
</table>

* data from Hughes 2000:759 **data from Chapman 1970:118
***data from WHO 1999:55-6
tables), they may derive from a dietary deficiency with a scorbutic (as well as rachitic) component. The origins of the deficiency diseases are complex and interlinked with comorbidity a common feature and the roles of trace elements are potentially significant, making them difficult to distinguish archaeologically.

Table 198. Clinical Manifestations of Scurvy. (After WHO 1999)

<table>
<thead>
<tr>
<th>Skin</th>
<th>Diffuse petechial haemorrhages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hyperkeratotic papules with spiral unerupted hairs</td>
</tr>
<tr>
<td>Mouth</td>
<td>Bleeding gums</td>
</tr>
<tr>
<td></td>
<td>Loosening teeth</td>
</tr>
<tr>
<td></td>
<td>Petechial haemorrhages</td>
</tr>
<tr>
<td>Eye</td>
<td>Intra-ocular haemorrhages</td>
</tr>
<tr>
<td>Blood</td>
<td>Anaemia</td>
</tr>
<tr>
<td>Bones</td>
<td>Irregular calcified cartilage in fibrous tissue</td>
</tr>
<tr>
<td></td>
<td>Marrow spaces fill with loose connective tissue</td>
</tr>
<tr>
<td></td>
<td>Bone shafts decrease in density</td>
</tr>
<tr>
<td>Generally</td>
<td>Lethargy</td>
</tr>
<tr>
<td></td>
<td>Reduced healing ability</td>
</tr>
<tr>
<td></td>
<td>Shortness of breath</td>
</tr>
<tr>
<td></td>
<td>Swollen joints</td>
</tr>
<tr>
<td></td>
<td>Stiffness</td>
</tr>
<tr>
<td>Symptoms in infants</td>
<td>Irritability</td>
</tr>
<tr>
<td></td>
<td>Tenderness of limbs</td>
</tr>
<tr>
<td></td>
<td>Pseudoparalysis of lower extremities</td>
</tr>
<tr>
<td></td>
<td>Costochondral junction effects</td>
</tr>
<tr>
<td></td>
<td>Haemorrhages around erupting teeth</td>
</tr>
<tr>
<td></td>
<td>Anaemia</td>
</tr>
<tr>
<td></td>
<td>Possible anorexia</td>
</tr>
<tr>
<td></td>
<td>Possible fever</td>
</tr>
<tr>
<td></td>
<td>Possible diarrhoea</td>
</tr>
<tr>
<td></td>
<td>Possible petechial haemorrhages</td>
</tr>
<tr>
<td></td>
<td>Heart attack may ensue</td>
</tr>
</tbody>
</table>
Skeletal lesions will not have formed in isolation: they are (possibly rare) manifestations within a broad suite of symptoms with others that are likely to have afflicted individuals before the archaeologically visible signs appeared (Steinbock 1976:246; Živanović 1982:77; Ortner 2003:109-118; Roberts and Manchester 2005:12ff; see Table 198 above).

Scurvy has a synergistic effect with iron deficiency anaemia in that scorbutic haemorrhage increases the body’s need to produce blood. Both conditions therefore are likely to result in increased vascularity. At the same time, scurvy reduces the body’s ability to metabolise iron (Ryan 1997:30). Lack of vitamin C and/or iron affect the body’s ability to respond adequately to disease or trauma but disease is also a causative factor in the development of anaemia, possibly as a defence mechanism (Ryan 1997:50ff). Coupled with frequent gingival disease, lack of disease resistance may help explain why the age at death profile of the Isbister collection includes so many young individuals.
Iron Deficiency Anaemia

“Following the frontal, more exclusively osteoporotic manifestations developed on the posterior portion of each parietal, between the temporal crest and the sagittal suture, and on the occipital above the crest.”


Palaeopathologically, the symptoms of iron deficiency anaemia (and other anaemias) most particularly include the expansion of blood producing areas within bone. This results in enlargement of the diploë, which then impinge on the outer table of the cranium to give a porotic appearance and thickening, although aetiology is complex (see Brickley and Ives 2008). The external appearance of the resultant lesions has become widely known as porotic hyperostosis, with the related lesions observed in the orbit (cribra orbitalia). The pattern of calvarial porosity is that described by Hrdlička (quoted above). It has been observed that cribra orbitalia occurs mostly in sub-adults and it has been suggested that most recognised porotic hyperostosis lesions result from a condition occurring during childhood or adolescence, which, when found in adults, has not yet fully remodelled.

In the Isbister assemblage, cribra orbitalia or similar lesions were recorded in 44 individuals, mostly juveniles. Calvarial lesions were recognised in 22 individuals, mostly adults. The calvarial lesions were found in a spectrum of states of formation and healing from clear, well-defined pores likely to be from an active lesion at death, to a smoothly stippled ‘orange peel’ appearance that probably represents advanced healing. These were limited to the area superior to the
nuchal crest, which may be significant (see Hrdlička 1914, quoted p542 above). A frequent observation in the same crania was of a vermiculate appearance on the surface of the superior orbital margins. This may be a related condition, probably in a state of remodelling. At Banks, four cases of cribra orbitalia were recognised; Point of Cott had one individual with cribra orbitalia and one had dental enamel hypoplasia.

Microscopic features of anaemia were present in 43.5% of cases in a study of 85 individuals with cribra orbitalia from Nubian Sudan (Wapler et al. 2004). Osteitis or hypervascularisation was present in a further 25.9% but only taphonomic erosion was observed in 20%. The study is difficult to evaluate because insufficient description is given of the criteria for identifying cribra orbitalia or whether there were visible differences between the microscopically identified groups (Sullivan 2005).

Iron metabolism is of profound importance in maintaining human health. An appropriate level of metabolic iron is necessary both for an efficient immune system and for respiration. In its absence, lethargy and a failure of disease resistance result. Iron is of significance in the behavioural and neurological development of infants, chronically anaemic children showing difficulty in language acquisition and motor skills that may affect the individual into later childhood (Ryan 1997:47ff)

Of the anaemias, iron deficiency has perhaps the most complex aetiology. Stuart-Macadam (1995:55) notes the variables affecting metabolism of iron.
Particularly noteworthy are that phytates (from cereals in the diet) and calcium (from milk or cheese) act as inhibiting factors on iron absorption; vitamin C enhances iron absorption. Barley and dairy products are likely to have been Neolithic staples: evidence for processing has been recorded at Barnhouse for example (Jones et al. 2005). Blood loss is another potential causative factor and results from several possible conditions: e.g. menstruation, childbirth, trauma, scorbutic haemorrhage, heavy gastrointestinal parasite load, use of salicylic acid as a painkiller (available as an infusion from willow bark or meadowsweet). The situation is further complicated because the body may react to infection by reducing blood iron to levels that inhibit the invasive organism (Ortner 2003:369-370).

The Isbister evidence indicates that scurvy was widespread in the population, so vitamin C will have often been present only at low levels. This will have reduced iron absorption and also have caused a reduced disease resistance that might itself have led to a defensive reduction in iron levels. Neolithic subsistence patterns seem to be based on a cereal and livestock economy. Meat, a major source of dietary iron may have been a seasonal luxury because its production requires slaughter of stock; fish, another potentially rich source may have been culturally limited in exploitation (Richards and Hedges 1999).

It is likely that the deficiency diseases were present in a spectrum of severity, with variations of comorbidity that make diagnosis difficult. The nature of many suggested archaeological diagnoses has been criticised as oversimplistic and failing to recognise the non-specific nature of some lesions (Brickley and Ives
There is nonetheless little compelling evidence for any differences between English and Orcadian populations.

Eighteen of the known British large Neolithic human bone assemblages came from Gloucestershire, Wiltshire and Oxfordshire. It might be expected on environmental grounds that they would provide a contrast with the Orcadian material. The Hambledon Hill, Fussell’s Lodge, West Kennett and Hazleton North assemblages have features in common with Isbister but direct comparisons are confounded by differing methodologies, preservation and quality of reporting. The Parc le Breos Cwm population had robust lower limbs in which femoral and tibial Harris lines were noted, suggesting periods of reduced childhood growth due to stress factors (Wysocki in Whittle and Wysocki 1998:147ff). The Hazleton North human skeletal assemblage (Saville 1990) included a high prevalence of ante-mortem tooth loss and mandibular abscesses but low caries; frequent periodontal disease and approximately 30% prevalence of cribra orbitalia. Brothwell and Blake (1966) observed cribra orbitalia, cranial porosity and abnormal vault thickening in large parts of the population at Fussell’s Lodge.

With such similarities between Orkney and England, it is likely that the underlying causes were widespread and not specific to communities in the agriculturally marginal Orcadian environment at the edge of the Neolithic European world.
<table>
<thead>
<tr>
<th>Condition</th>
<th>Hambledon Hill Cases (McKinley 2009)</th>
<th>Fussell’s Lodge (after Brothwell and Blake 1966)</th>
<th>Isbister</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premature Cranial suture closure</td>
<td>2</td>
<td></td>
<td>(e50%)</td>
</tr>
<tr>
<td>Occipital bun</td>
<td>2</td>
<td>16/35 adults (46%)</td>
<td></td>
</tr>
<tr>
<td>Wormian bones</td>
<td>3 (11%)</td>
<td>4 (36%)</td>
<td>18 (38%)</td>
</tr>
<tr>
<td>Metopism</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Double facetting</td>
<td>2/7</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Cribra orbitalia</td>
<td>14 (27% of orbits, mostly immature)</td>
<td>10 (20%) adults, 6/7 (85%) juveniles</td>
<td>15 (44%) (75% of juveniles)</td>
</tr>
<tr>
<td>Endocranial new bone</td>
<td>3 (2 juveniles, on sphenoid; 1 adult, on frontal)</td>
<td>2 cases</td>
<td></td>
</tr>
<tr>
<td>Cranial thickening</td>
<td>2/13 adults</td>
<td>2/39 adults</td>
<td></td>
</tr>
<tr>
<td>Cranial porosity</td>
<td>1/13 (7.7%) adults, 1/2 (50%) juveniles</td>
<td>29/52 (56%) none in juveniles</td>
<td></td>
</tr>
<tr>
<td>Ante-mortem tooth loss</td>
<td>5 (1.7% teeth)</td>
<td>14.3% teeth</td>
<td>15 cases (12.3% teeth)</td>
</tr>
<tr>
<td>Periodontal disease</td>
<td>9 (always with calculus)</td>
<td>6/20 (30%) adults</td>
<td>33 cases (e60%)</td>
</tr>
<tr>
<td>Dental abscesses</td>
<td>7 (1.7% sockets)</td>
<td>5 (1.9% sockets)</td>
<td>14/27 cases</td>
</tr>
<tr>
<td>Temporo-mandibular DJD</td>
<td>1</td>
<td></td>
<td>27/55 (49%)</td>
</tr>
<tr>
<td>Dental caries</td>
<td>5 (1.6% teeth, mostly slight)</td>
<td>7 (3.9% teeth)</td>
<td>3 (0.3% teeth)</td>
</tr>
</tbody>
</table>
Interrelatedness of Palaeopathological Features

Sample sizes were very small in testing some features against groups and there may be effects from the numbers of imprecisely attributed individuals. DJD of the TMJ was expected to be associated with age and this is the case. The association of cribra orbitalia with juveniles was also expected but ectocranial pitting shows an association with adulthood, which may indicate that it has a distinct aetiology.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Age relatedness</th>
<th>Sex relatedness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post bregma depression</td>
<td>Appears to develop with age</td>
<td>More common in males than females</td>
</tr>
<tr>
<td>Bathocrany (occipital boss)</td>
<td>No obvious relationship</td>
<td>More common in males than females</td>
</tr>
<tr>
<td>Occipital condyle DJD</td>
<td>No obvious relationship</td>
<td>No obvious relationship</td>
</tr>
<tr>
<td>TMJ disorder</td>
<td>Much more common in adults</td>
<td>No obvious relationship</td>
</tr>
<tr>
<td>Cribra orbitalia</td>
<td>Much more common in juveniles</td>
<td>No obvious relationship</td>
</tr>
<tr>
<td>’Orange peel’ hyperostosis</td>
<td>Much more common in adults</td>
<td>No obvious relationship</td>
</tr>
<tr>
<td>Porosity of greater wing of sphenoid</td>
<td>No obvious relationship</td>
<td>Possibly more common in females than males</td>
</tr>
<tr>
<td>Suprameatal porosity</td>
<td>More common in adults</td>
<td>No obvious relationship</td>
</tr>
<tr>
<td>Supraorbital porosity</td>
<td>Much more common in adults</td>
<td>More common in males than females</td>
</tr>
<tr>
<td>Palatal pitting</td>
<td>No obvious relationship</td>
<td>No obvious relationship</td>
</tr>
<tr>
<td>Cranial Trauma</td>
<td>No obvious relationship</td>
<td>No obvious relationship</td>
</tr>
</tbody>
</table>

There are several conditions that exhibit significant relationships with sex. Some may have inter-related aetiologies. Both bathocrany and post-bregma concavity

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are more prevalent in males than females, which may indicate either a sex-linked genetic component or a sex-related activity that affected cranial form. The only feature more prevalent in females than males was porosity of the greater wing of sphenoid: this feature has been linked to scurvy (Ortner and Ericksen 1997:214) and may indicate that the sexes enjoyed different access to antiscorbutic foods. Porosity of the frontals and posterior vault however are both more prevalent in males; since the posterior vault examples are not prevalent in juveniles, they may reflect some particular activity or exposure rather than any metabolic condition but could indicate differences in response from size or metabolism. There is no clear relationship between age or sex and cranial trauma based on overall lesions.

The presence of craniostenosis introduces additional problems into study of the Isbister assemblage. In these commingled assemblages, other bones cannot be related to any cranium and the crania can only be aged according to their own attributes. Cranial suture closure is one of the major methods used to assess age at death from the cranium. If this is occurring prematurely in this population for some reason, then that method is inappropriate.
Summary of Palaeopathology

"I became so ill that death was very near. It was then that I began to shamanize"  
(Shaman quoted in Holmberg 1927:497)

Pathology of individuals from Orcadian and English tombs indicates examples of disability that would have been readily apparent. Gait, speech, appearance and limb mobility were all affected. These features may have affected the way in which the individuals were perceived by others in the community, leading to differences in behaviour and status and possibly affected community morale and relationships. It is striking that perimortem skeletal trauma (pp307-340 above) suggests frequent violent death (cf. Keeley 1996:88-93). Overall, the existence of so many pathological conditions and congenital abnormalities in an assemblage of this size may indicate that, rather than disease and trauma being common, the individuals interred in the tomb were selected for a reason related to those conditions. Whilst the presence of such pathological individuals may suggest some form of ‘uncleanliness’ (cf. Barber 2000), it seems unlikely that the highly visible, elaborate, laboriously constructed chambered tombs would have been especially used for such individuals. Possibly the most likely explanation is that these individuals were seen as possessing or being especially subject to supernatural powers, evidenced by their disability. This may then relate to the apparent selection by age and sex, since vulnerability to these conditions may have varied. This may also relate to the function of chambered tombs, since later access to such supernatural powers may have been necessary, preventing permanent burial. The size and thickness (even elaboration) of mounds may then have provided protection from those forces.
5.9 WHO WAS INTERRED IN THE TOMBS?

“The same people reporting data which show evidence for high mortality also describe the relatively peaceful and disease-free nature of the people and their lives… the people appear fit and healthy, their diet is reported to be good… Wars are often claimed to be ritualistic and not to take a heavy toll, and the people care for each other’s welfare.”

(Weiss 1973:78)

This section examines the commonly expressed ideas that chambered tombs represent normative burial practices, exemplifying models of egalitarian social organisation. Alternative hypotheses are developed.

The large quantity of human remains recovered from the excavation at Isbister inspired Hedges to attempt demographic analysis (Hedges 1982, 1983, 1984). This was groundbreaking for the British Neolithic but was heavily criticised (Kinnes 1984). The criticism was perhaps deserved but might have been avoided had assumptions underlying the analysis been made explicit. These are well-known (e.g. Weiss 1973; Moore et al. 1975):

a) that there was a single population;

b) that the population was stable; and

c) that the sample was representative of the population.

Even accepting these assumptions though, Hedges’ study was nonetheless flawed because the figures used for numbers of individuals at different ages
were inflated and erroneously precise (Chesterman 1983; Hedges 1982, 1983, 1984; Lawrence 2006).

Ethnographic study suggests that, in living and historical populations, without the advantages of high-quality modern medical care or nutrition, infant mortality is expected to be very high, mortality in young childhood (between the ages of 1 and 5 years) still high but lower, decreasing further in late childhood (5-10 years old) and mortality between 10 and 15 years lowest of all age groups. Weiss (1973) quotes a series of infant mortality values that vary from 17% to 60% (perhaps typically 20%) and a range of survival into adulthood values from as low as 25% up to 80% (typically about 60%).

The corollary of mortality is fecundity. In a stable population, numbers of dead must be replaced by births. Birth-rates in a community are controlled by the number of procreative females and their fertility. The number of lifetime successful pregnancies in populations not practicing modern contraceptive measures varies according to nutrition (affecting body fat content, age of menarche and menopause) and social factors (including marriage, length of nursing, sexual abstinence etc.). Among the Dobe !Kung, menarche averages at 17, menopause at 37 and women bear an average of 4.6 children, each nursed for about 4 years (Howell 1979).

It has been recognised that the seemingly large number of Neolithic tombs in the British Isles cannot contain more than a small proportion of the Neolithic population (Piggott 1954:368, quoting Crawford 1925). Three explanatory
models have been proposed (Barber 2000). Burial in chambered cairns may represent:

a) communal burials, i.e. all burials of a small local community;

b) sequential burials of high prestige individuals from local communities;

c) the unacceptable dead (e.g. murder victims, accident victims, other tribes).

The size of the assemblage of human remains from Isbister presented an opportunity to address this question.

At Isbister, of 85 individuals only two are aged 0-1, with an additional 26 other juveniles aged below 11 but only 2 adolescents (12-16); there are 13 young adults (17-25) and 26 older adults. Among the adults, males outnumber females by almost 2:1 (28:15). In the case of Isbister, the number of females of procreative age is estimated at about 20 (approximately 1/3 of the adults), many of whom died in young adulthood. Notwithstanding suggestions made for English Neolithic tombs (Whittle et al. 2007), radiocarbon dates from Isbister could suggest a deposition period of several centuries. This large assemblage is not a whole population unless each female present was procreative serially for the maximum possible period. It is apparent that the Isbister sample does not represent a natural population.

The demographic profile formed from the human skeletal remains at Isbister suggests that there were proportionally very few very young juveniles dying over the period of use. The small number of young infants is anomalous and
probably indicates that the bodies of dead infants were disposed of in a manner other than being interred in the chambered tomb. This may not be significant in itself since the very young may have their bodies disposed of relatively casually but it may imply that the tomb was not primarily a dynastic sepulchre. If alternative disposal was the normal fate for the remains of infants, then there may have been some distinctive aspect to those interred. The presence of two individuals in this age-group might therefore be particularly informative if they display some unusual feature that could suggest selection criteria.

The other immediately apparent demographic feature is the disparity between the sexes, which has also been observed in other Neolithic tombs (Smith and Brickley 2006; Piggott 1954). This could be explained by female infanticide but otherwise must be most likely to be due to biased selection. In itself, this may imply that there is a matter of status that selects against females. for example if there was a male elite, then it might be expected that males would be selected over females and this might also be related to female infanticide, as among the Yanomamő (Chagnon 1992; Neel 1977), or in cases of stress or demographic necessity as among the Inuit (Balikci 1967; Shrire and Steiger 1974; Smith and Smith 1994). Just possibly then, sex disparity in the assemblage may reflect the adult population.

There are essentially just two possibilities regarding the relationship of this skeletal assemblage with the population of Neolithic Orkney: either the assemblage is representative of the population or it is not. The assumptions and implications of each possibility need to be explored.
The Representative Population Model

If the assemblage is representative of the local population (except those individuals dying very young), then a model can be constructed that explains the observed features (Figure 291 below).

The absence of young children may imply that infants were not considered to be significant members of society.

Significant disparity of the sexes is unlikely to occur naturally. If the 2:1 sex ratio reflects the adult population, then it suggests that female infanticide may have been practised more frequently than male infanticide. It may have been necessary to maintain a stable population, because males were more valued but females were expensive to raise, or because it was desirable (for example for purposes of inheritance or exogamy) to have a son as first-born. It is likely that the Neolithic Orcadian diet was periodically nutritionally deficient and that there were also periods of famine due to crop failure: one response might be infanticide. This would be likely to produce subsequent effects on group and individual interactions, as was historically the case among the Yanomamō and the Inuit (Chagnon 1992; Balikci 1967). Killing of the weakest individuals might be expected. A disproportionate number of males over females has implications for marriage and sexual activity: it suggests that either females were shared, that females were a source of particular competition, that wives might be sought for outside the community, that wife-taking was an elite act, or that a high proportion of males were celibate.
Competition for resources - land, food, adult females, other goods - may have led to conflict and interpersonal violence (Otterbein 1994b). Violence may have been more or less organised for raiding, conquest or even annihilation. This would be consistent with a warrior ethos existing or monumental commemoration of those killed violently. Some special status may have been conferred upon individuals that had suffered death by violence (as for example among the Dani: Gardner and Heider 1974:89) and so include juveniles and female adults. This would explain the presence of the small number of infants in the Isbister assemblage since those present display features of perimortem trauma. This might be consistent with the location of the tombs on prominent locations overlooking the presumed homes and farmland of the local community – guardians literally and figuratively watching over the people. Visibility would then either advertise martial prowess or act as a memorial of some significant event(s). This would also be consistent with some form of veneration. Such possibilities reflect the intersection of different social and economic factors and would result in a bias through non-random interment but not necessarily indicate intentional selection of a particular group within the community.

Competition, political and economic factors would not be necessary to produce violence in society. Feuding between groups could arise through idiosyncratic causes and become institutionalised. In a limited study, feuding was found to have positive relationships with patrilocality and polygyny but that they were not significant factors in societies with centralised political systems (Otterbein 1994). The relative frequencies with which interpersonal violence occurred within and between communities remain undetermined.
Figure 291. Neolithic Orkney environmental and social drivers model.

- Short growing season
- Summer storms
- Periodic failure of harvest
- Reliance on domestic animals and crops
- Need to store food and seed over winter
- Presence of portable commodities
- Raiding, annihilation and conquest of other groups
- Competition for Limited Resources
- Decreasing usable land area due to rising relative sea level
- Small founder population
- Isolated population
- Congenital dysplasias etc
- Reduced genetic variation
- Failure of infants to thrive
- Euthanasia
- Low birth rates
- Few females
- Male competition for sexual partners
- Interpersonal violence common
- Status achieved through success in combat
- Interpersonal violence common
- Selective Female Infanticide
- Males (warriors) preferred as group members
- Status achieved through success in combat

“Models are undeniably beautiful, and a man may justifiably be proud to be seen in their company … But they may have their hidden vices. The question is, after all, not only whether they are good to look at, but whether we can live happily with them.” (Kaplan 1964:288).
The evidence of pathology from the assemblages is significant. There are excessively high prevalences of dysplasias normally expected to be rare (although these may not be independent). It is possible that those individuals weakened by disease or disability would have been singled out or more easily killed by an assailant, so this might explain the apparently high prevalence of cranial trauma. It is not impossible that the population, living in a small, potentially isolated, community possessed some inherited gene that led to a high prevalence rate of some of these conditions. Coxa vara and UBC may both derive from a single syndrome but too many probably unrelated pathological features seem to be exhibited for this to provide a single explanation.

There is no likely simple explanation for the presence of all the features observed at Isbister if we assume that the assemblage is representative of the community. Whilst it is a possibility, the hypothesis requires many suppositions in support and so Occam’s razor would suggest that selection of particular individuals for interment was more likely.

The Selected Group Model

Status may be reflected in the details of corpse disposal employed for particular individuals (Binford 1971). Great effort in construction and elaborate form of many chambered tombs suggest high prestige but the precise nature of such status may be less obvious (e.g. Bloch 1968, 1981). Selection of particular individuals contradicts collective status of the dead and would therefore undermine an interpretation of Neolithic tombs as evidence for an ancestor cult.
The acknowledgement of kinship might still exist. Either model might fit with the exclusion of young infants but the presence of a very small number might fit better with selection for a feature that they exhibit.

The fundamental difficulty in interpreting the selection model for interment lies in deciding whether individuals were selected or excluded. Is interment the preferred disposal method or was it for disposal of the unclean? It may have been neither: interment may not have been high or low status, sacred or profane but simply for some segment of society not distinguished by a simplistic model.

A high prevalence of degenerative joint disease including osteoarthritis has been repeatedly observed in British Neolithic populations (Brothwell 1973). At Isbister and Banks DJD and activity-related pathologies indicate strenuous activity, even in childhood. It is very likely that the individuals interred at Isbister endured heavy labour and this may suggest that these are not an elite ruling group.

The skeletal assemblages exhibit pathological traits that will have had readily apparent effects, including deformity and disability. One older adult male had suffered multiple myeloma. This is a form of neoplastic disease in which soft tissue lesions replace bone. Mechanical weakness of the bone results and diagnosis often follows catastrophic fracture of a femur or vertebra, when the victim stands and the weakened bone breaks under the weight. Complications include anaemia and bone necrosis. This unfortunate individual had also
suffered periodontal disease and ante mortem tooth loss, probably associated with scurvy. Long before death, this person will have had difficulty in eating, muscular pain, lassitude and foetid breath. The modern prevalence of multiple myeloma is 5.8/100 000 in the North of Scotland (NHS Scotland average over the last 28 years: www.isdscotland.org accessed 18/11/2010).

Craniosynostosis has been recorded with a high prevalence in Neolithic assemblages. A wide range of expression is present, and it is likely that at least one victim from Isbister died from high intracranial pressure. Several cases are present where one orbit is at a markedly different level and of a different shape or size than the other, possibly even of blindness in one eye. In modern populations, craniosynostosis occurs with a clinical prevalence of 3-5/1000 (Cohen 2000): at Isbister, it occurs in about 50% of all individuals whose crania were sufficiently complete for examination (although many may not have exhibited clinical symptoms). It seems clear that craniosynostosis resulted in obvious cranial deformation in an excessively high proportion of Neolithic crania from tombs. Whilst possibly caused by genetic or cultural factors, it is unlikely that the deformations identified were intentional because they are often asymmetric and because their form (of deformity) varies, clearly not uniform.

The crania from Isbister notably includes a group that exhibit a combination of male and female sex attributes (pp204ff). Although these are distinguished from other crania by their relatively high cranial index, such individuals might possibly have been abnormal within the population.
The cases of palatal growths at Isbister and Rowiegar (pp390-1 and 398-9 above) will have partly occluded the mouth and possibly affected the nasal passage; the example from Knowe of Rowiegar will certainly have presented as visibly abnormal. This will also have affected speech and mastication. Similar symptoms may have attended cases of scurvy.

A neonatal infant from Isbister was represented by a few long bones, a single pubis and some cranial fragments. The only frontal from this individual exhibited a large blastic ectocranial lesion indicative of Barlow’s disease. Another particularly young infant had evidence of severe intracranial haemorrhages, intraorbital haemorrhages and cribra orbitalia. In a prehistoric northerly context, the endocranial exostosis accompanied by orbital bone deposits and cribra orbitalia in infancy are most likely to have been caused by comorbidity of scurvy and iron deficiency anaemia (although it is not impossible that rickets is present, no longbones were observed to display specific lesions). Another infant, probably aged 2-4 years at death, also had orbital features indicative of scurvy and had a frontal chord length expected of a 1-year old. Scurvy is often associated with stunted growth and it seems that this child had failed to thrive in addition to probably exhibiting general scorbutic symptoms. Perhaps significantly, this child had a perimortem traumatic lesion to the frontal. With scurvy, these children will probably have cried incessantly, had obvious signs of haemorrhaging and adopted the ‘frog position’ to minimise pain: they will have been obviously distressed and diseased.

Porosity of the palatals is common at Isbister (36 cases), sometimes with woven
bone deposits, as are periodontal disease (40-90% of sockets, according to position) and ante mortem tooth loss (6-16% according to tooth). Dental caries and extensive calculus formations are rare in the collections so these may be discounted as significant causative factors. Other oral problems are extremely common in this sample. These consist of severe periodontal disease and ante mortem tooth loss, frequently associated with palatal pitting and new bone deposits. These are probably the result of scurvy. The gums will have been swollen during an attack to the point where eating would be difficult, breath would have been rank; they would have been struck by lassitude and pain, with haemorrhages in the joints and petechial haemorrhages elsewhere; they will have been anaemic. Approximately 50% of individuals show symptoms of this disease. The presence of scurvy was probably widespread in an age where few vitamin C containing foods were available in spring and winter but it may be significant that such metabolic conditions do not have an aetiology that is readily apparent. It may have seemed mysterious in the Neolithic.

Dysfunction at the temporomandibular joint is common in Neolithic assemblages, including both Isbister and Banks, where there are several severe examples (pp264ff above). Mandibular dysfunction is also indicated by the hypoplastic pterygoid process from Banks (p259 above). In several cases, there will therefore have been difficulty in chewing and probably in speaking.

Crippling upper limb pathology was identified in a humerus among the Banks assemblage and was also noted in a humerus at West Kennet (Piggott 1962), gross deformity of the elbow at Lanhill (Keiller and Piggott 1938). The fused and
arthritic phalanges from Isbister may be part of a more widespread condition crippling individuals

Some cases of pathology at Isbister will have affected gait. Two examples of unicameral bone cyst in calcanei led to fracture and secondary osteoarthritis, probably with abnormal postures adopted to reduce pain (pp392-394 above). There is an example of a healed abscess laterally on one calcaneus (pp328-9 above). An unusual ossified lesion on another calcaneus will have interrupted the flexors of the ankle and foot (p327 above). These traumatic lesions and certainly the second will have affected the gait of the victim. A fractured tibia (pp326-7 above) will have given the victim a limp. There is an abnormal talus, possibly caused by fracture or congenitally abnormal tarsals (pp288-9 above) and this is also likely to have caused an abnormal gait. There are four identified cases at Isbister of coxa vara (p258 above): one result of which is that the lateral muscles of the hip and thigh are at a mechanical disadvantage, causing the gait to become a stagger or, if the condition is bilateral a waddle. In modern populations, coxa vara occurs in 1/25000 people and 1/3 of these have the condition bilaterally. To have four such femora at Isbister is unlikely to be a random event, even if they come from just two individuals. Gait will also have been affected in the case of at least one individual from Point of Cott, whose grossly dysplastic tarsals were recently identified among the site’s animal bone assemblage (Chris Walmsley pers. comm.). Similarly, club foot has been identified at Nether Swell, genu valgum at Kings Play Down (Smith and Brickley 2009:132).
Healed fractures are present in the Isbister assemblage (pp307ff above) and it is clear that injury was common: a fractured tibia, fractured metacarpals, fractured radii. More severe is the cervical crush fracture from Banks that will have caused the sufferer to carry the head bowed anteriorly with subsequent disability (some similar problem may have been associated with the angular occipital condyles from Isbister).

Perimortem and healed cranial trauma are very common at Isbister (pp307ff above), with an estimated 40% of individuals affected. Lesions vary in form and location, with sharp-edged, blunt and pointed weapons all implicated and all superior parts of the neurocranium affected. There is a slight tendency for the target area to have been the left frontal, but this is not statistically significant. The wide variety of the lesions and the fact that several are healed indicates that this is neither the result of ritualised execution nor some funerary practice but rather interpersonal violence with high prevalence (cf. Keeley 1996:90). There are examples of cranial trauma at Banks but these are relatively minor, healed examples. Cranial trauma seems common in Neolithic assemblages: it is readily apparent at Knowe of Rowiegar and has been reported throughout the UK (Schulting and Wysocki 2005; Smith and Brickley 2009; Schulting 2012).

Congenital malformation has been estimated to have an overall prevalence in newborns of about 12%, including minor expressions and soft tissues (Kurczynski 1992:375). Any assemblage will be expected to exhibit an array of pathological lesions but there may have been a founder effect with high prevalences decreasing later through natural selection, so that the Isbister
remains might possibly be representative of population health but this seems unlikely. The hypothesis of 'warrior status' interment seems unlikely. If it is therefore assumed that all or most of the features described above are present in abnormally large numbers rather than reflecting population prevalences, then they may relate to the criteria of selection for interment. The people interred seem to have suffered from conditions that were often visibly apparent: diseased, crippled, limping, half blind, abnormally formed, with difficulty in eating or speaking. This is perhaps an impurity, most likely to be associated with Barber’s “unacceptable deaths” (e.g. Schepet-Hughes 1992:375).

The question then arises of whether elaborate chambered tombs would be built and remodelled and be the location for ritual if they specifically housed "unacceptable" individuals. It seems unlikely. Isbister tomb itself is no simple construction. It shows maturity of design and complexity of internal and external features, including the chambers and outer 'hornwork.' If it is assumed that stalled cairns at least were all constructed for a similar purpose, then the prominent locations, decorative masonry and enormous size of sites such as Midhowe also require explanation. These were not trivial places to be forgotten or ignored but significant monuments highly visible and prominent in the lives of local communities. These seem unlikely places for the ‘unacceptable’ dead.

One possibility is that the tomb was a laying out place used to ensure that potentially contagious people actually were dead before disposing of their bodies. This would not explain the size, location and complexity of the tomb, nor that bodies were left there once death was demonstrated by decomposition. It
may rather be that the visibly abnormal, the crippled and the strange had some liminal status. Such people may for example have been considered touched by obscure, possibly supernatural forces and therefore be potential intermediaries with the spirit world (Eliade 1964:15ff, 343 etc.; Hutton 1993:18-19; Campbell 1987:254ff). In this case, it might seem particularly appropriate to place their remains in an accessible artificial cave between the world of the living and the world of the spirits (Campbell 1987:254-5) or in some location where supernatural forces could be contained (e.g. Vitebsky 1995:95). Such beliefs have been widespread and linked to shamanistic practices leading to the development of recognised priests with prestige and political authority (Frazer 1913:14ff; Campbell 1987) (use of the term ‘shamanistic’ here is intended to avoid any technical definition or implication of relationships with particular cultural phenomena, whilst introducing an apt and familiar analogy (Hultkrantz 1979:85-6; Hutton 1993:15ff)). The elaboration and decoration of some tombs may then have had magical, or at least supernatural, intent, which would be consistent with evidence for ritual at such sites.

Such an interpretation may help to explain clusters of Neolithic tombs at particular locations, such as exist around the Brodgar peninsula. They may indicate places of power or the replacement of failed tombs. This may support the interpretation of standing stones, stone circles and henges as essentially religious monuments, sometimes associated with tombs.

This hypothesis does not completely explain the locations of most other Orcadian tombs, which seem in some respects to be pragmatic solutions for
construction. Positions at the expected margin of agricultural land may however have been liminal, at the border between the tamed and the wild. Elevated positions presumably kept the tombs isolated from settlement sites but may have been a reminder that powerful spirits were watching, advertising widely the supernatural forces controlled by the local community.

There is no evidence for settlement in close proximity to the Orkney tombs, except possibly at Ness of Brodgar - Rinyo for example is 300m from the nearest tomb, Wideford about 750m. This may indicate a desire to keep the dead in the chambered tomb at a safe distance but cannot be extended to a general attitude of fear of the dead since human remains are recovered from settlement sites (Ness of Brodgar (Lawrence 2007), Tofts Ness (Dockrill 2007), Skara Brae (Childe 1931a)). Few settlements have been identified however and any normative funerary practice is unknown.

Cranial trauma and other significant pathology appear to have been widespread in those individuals from the British Neolithic whose remains have been recorded (e.g. Roberts and Cox 2003; Schulting and Wysocki 2005). Postcranial perimortem trauma is recorded with some frequency, perhaps especially associated with flint arrowheads that explicitly demonstrate interpersonal violence (e.g. Knüsel in Benson and Whittle 2007). We might assume that the individuals interred at Isbister had additional soft-tissue lesions that cannot be observed, in which case the mortality from violence could be greater than any group noted by Keeley (1996:90). Violence may simply have been endemic and some individuals particularly vulnerable. If however the individuals in the tombs
had been perceived as having supernatural powers, then they may have been especially feared and targeted for attack, whether from within or outside their immediate community.

It seems inherently unlikely, under selection models, that these tomb-interred individuals will have been considered particularly appropriate for veneration as ‘ancestors’ by their contemporaries, especially if others were being deposited or exposed at settlements (e.g. the inhumations at Skara Brae and Ness of Brodgar). Selection itself contradicts such a principle except exclusion of infants (Hardacre 1995), although later development of such a practice seems possible. It is perhaps more likely that contact with some otherworld or spirit might have been facilitated by their presence. This would explain the apparent elaboration of some ‘forecourt’ areas as ritual or ceremonial sites and could provide a motive for later destruction of the tombs.

Lynch (1973:147) suggested that the passages in megalithic tombs might be best viewed as “means of communication rather than access,” because of their intentional blocking, which was not typically of a form suited for repeated access but probably constituted formal closure. The apparent repeated movement of a quartz block (perhaps originally two blocks - O’Kelly 1973:142) in the so-called ‘light-box’ at Newgrange and the apparent blockage of its main entrance were suggested to indicate a function other than successive interment, focussed on the slot (Lynch 1973). Deposition of offerings was discounted because of an apparent absence of any appropriate material. Oracular use through contact with the dead was suggested (Lynch 1973:152). Such behaviour is explicit in
both classical and Norse mythology (Seyffert 1894:435; MacCulloch 1930:311) and reminiscent of the consultation of Sibyls in caves or clefts in rock (e.g. Cumae and Delphi: Seyffert 1891:175-6, 583).

Such interpretations may explain the great variation in numbers interred in tombs. It might have been a cultural imperative to be able to visit the spirits at such a monument but there may not in any particular community have been individuals considered suitable for interment. Conversely, some communities may have had particularly large numbers of deformed because of inbreeding or even misfortune. It could be significant that several of the pathologies noted here may have a hereditary component (Chapter 3 above). Danger or exploitation of supernatural powers could explain removal or destruction of bones and provide a motive for demolition, burning and infilling of the tombs equally as well as would 'ancestors.' Ethnographic parallels have previously been drawn upon to support ancestor veneration in Neolithic contexts (e.g. Barrett 1988; Parker Pearson 2000) but this is not necessarily the same as descent-based territoriality (Renfrew 1976; Chapman 1981) and may falter as an explanation for Orcadian megalithic tombs under the selection hypothesis, which seems to provide slightly different inferences.

We cannot with certainty decide whether the tomb assemblages are representative of their local populations or not. Each alternative is possible but the selection hypothesis may require fewer assumptions (and these seem more likely) in explaining demographic features and palaeopathological lesions and is therefore preferred.
It seems likely that selection for interment rather than underlying high prevalence in the population resulted in the high prevalence of pathological skeletal features in the tomb assemblages studied. It has been suggested that the change from multiple to single inhumation that appears in the late Neolithic/early Bronze Age marks some change in beliefs (e.g. Renfrew 1976; Barrett 1988). It could simply be a practical response to the widespread infilling of chambered tombs without rebuilding, especially since the same sites often seem to have been used. Similarities in pathology between the individuals recorded from prehistoric mounds may imply some continuity of selection. It is possible that there have been environmental or genetic factors in Orkney that could have produced such effects but these would not explain similarities with results from England.

A major question remains: where are the other human bones and what was the normal Neolithic disposal practice? There are insufficient Neolithic human remains to represent the dead of antiquity - even from Neolithic Orkney and regardless of models of tomb-use periods. Where are the missing?

There is some evidence of burned human bone in Neolithic Orkney but not on the scale that would be expected if cremation was the normal practice (unlike Ireland). None was recorded at Banks and the effects of burning on human bone at Isbister appears to be very limited: burning is most apparent on
endocranial surfaces, potentially from a single cranium. It seems certain that this burning occurred post depositionally at Isbister. There is no evidence to suggest that cremation was used as a major funerary form in Neolithic Orkney but fire may have been related to destruction of the tomb.

Neolithic use of caves as inhumation sites has been noted (Chamberlain 1996; Schulting 2000, 2007; Leach 2008; Schulting et al. 2010). This seems appropriate in parts of the highland zone but has not yet been demonstrated to be so common as to have been a major depositional form. It will have been impractical in many areas where no caves exist, except through the creation of artificial analogues such as burials, barrows or tombs. No known Neolithic caves survive in Orkney, with one possible exception on Hoy where a polished "egg-shaped" stone was discovered (Bremner 1997; Lee 2009). Most Orcadian caves today are in sea-cliffs and it is not impossible that evidence has been lost to erosion, sea-level change and collapse.

Commitment of bodies to water is a possible disposal method that would have resulted in general loss to archaeology. Skulls found in the Thames (Garson 1891; Bradley and Gordon 1988) may indicate such a practice but it might be expected that more remains would have been recovered from waterfront sites, lakes and peat bogs if that were the case. Dated Neolithic examples are rare and may result from redeposition (Knüsel and Carr 1995). There is in any case no evidence for any such practice in Orkney.
It is possible that cadavers were disposed of by excarnation but this must have resulted in destruction and not the later collection of bones for interment that has generally been proposed. Use of causewayed enclosures (e.g. Mercer 1980; Healy 2004:23-4), or mortuary enclosures for disposal is unlikely in Orkney because none is recorded. There is some evidence that human remains were associated with settlements, such as the two interments at Skara Brae (Childe 1931). Cranial fragments have been identified at Tofts Ness, Knap of Howar and Ness of Brodgar (Dockrill 2007; Platt in Traill and Kirkness 1937; Lawrence 2007). These are not so common or complete as to indicate intentional curation but may indicate nearby exposure sites or token collection. An articulated neonatal infant inhumation at Ness of Brodgar (Lawrence 2007) and one at Hambledon Hill (Mercer 2009) may be evidence for distinct disposal of the very young, or special circumstances but their rarity might argue against normative practice. No alternative disposal sites have been identified in Orkney although it is not impossible that the stone circles had this function. The single human phalanx recovered at Stones of Stenness is insufficient to base such an argument on; the Ring of Brodgar has not produced human remains but has not been adequately explored. The apparent concentration of funerary monuments around the stone circles may indicate mortuary significance.

Human remains from Neolithic settlement sites and enclosures may represent the residue from the majority of the dead, whose remains are relatively rare because of attrition through exposure rather than protection through burial. It may be an irony of archaeology that Neolithic tombs appear to have contained complete bodies, even though they have frequently been interpreted otherwise,
and yet consideration of the tomb contents leads to the conclusion that some form of exposure practice was utilised for the wider population.

There is a complication in that the time dimension is not well defined. Changes in use are possible and there may have been some increase in centralisation of functions over time. The functions originally met by several structures or sites scattered across the landscape may have later accrued to a single monument. This might help explain why there are sometimes many tombs in close proximity, some tombs being increasingly elaborated or rebuilt, others remaining small and simple; some with many bones, others with few.

We should perhaps not attempt to rigidly impose any uniform interpretation on all these monuments. Dating remains problematic and rarely addresses the monuments rather than their contents. There could very easily have been idiosyncratic variables affecting the manner in which any community addressed issues relating to these tombs and the disposal of the remains of particular segments of society, perhaps unidentifiable reasons for tomb replacement.

It would appear that chambered tombs are not (fundamentally at least) for an ancestor cult, nor for common use but must have some other purpose. If the tombs were typically for supernaturally endowed people, then perhaps it makes great sense that so many of these tombs were later broken open and then filled in. This could be more than grave robbing, curiosity or even denying claims to ancestral lands. It could be the laying of ghosts and the denial of supernatural access to the living, as well as a clear demonstration of temporal and religious
power, perhaps of authority. This then suggests a dichotomy in Neolithic belief exhibited through distinctions between tombs and possibly contemporary henges / stone circles. Both types of monument seem likely to have ritual functions but their essential forms are completely distinct; stone circles in particular seem to persist although tombs suffer destruction. The relative rarity of stone circles / henges in Orkney and their concentration at the Ness of Brodgar in contrast with the common, widely dispersed chambered tombs may imply a more centralised religious function for them, which apparently remains important despite social changes that affect tomb use.
Vogon Captain: ...Tell me how good you thought my poem was.

Arthur Dent: I liked it.

VC: Good...

AD: Oh...Oh yes, I thought some of the metaphysical imagery was particularly effective.

VC: Yes...

AD: Oh... and um... interesting rhythmic devices too, which seemed to counterpoint the er...

Ford Prefect: Counterpoint the surrealism of the underlying metaphor of the um...

AD: The humanity of the er...

FP: Vogonity.

AD: What?

FP: Vogonity.

AD: Oh. Oh, vogonity, sorry, of the poet's compassionate soul, which contrives, through the medium of the verse structure, to summarise this, transcend that and come to terms with the fundamental dichotomies of the other; and one is left with a profound and vivid insight into er...

FP: Into whatever it was (with AD): the poem was about.

FP: Well done, Arthur. That was very good.

VC: So what you're saying is that I write poetry because underneath my mean, callous, heartless exterior, I really just want to be loved. Is that right?

AD: Oh... well... I mean... yes.

FP: Yes. Don't we all, deep down, you know.

VC: No. No, you're completely wrong. I just write poetry to throw my mean, callous, heartless exterior into sharp focus!
6. CONCLUSIONS

There is a view that “one of the major problems of Scottish archaeology is the disproportionately large amount of resources spent on excavating, researching and arguing about Orkney,” (Sharples 1992:322), creating “an imbalance in the Scottish and British Neolithic” (Noble 2006:1). However “the results of this effort and the quality of the surviving archaeology enable an exploration of problems which are seldom even visible in other areas,” (Sharples 1992). The significance of Orcadian remains to our understanding of the Neolithic is profound and seems likely to increase. Notwithstanding past work, this project has produced evidence of previously unsuspected features. I have failed to bring the dead to life, which is probably just as well; I have however found that considerable life persists in the study of the remains of the dead.

The introduction (Chapter 1 above) described the historical failure of archaeologists to fully exploit information from human remains in constructing models of prehistoric societies. The large number of prehistoric burials to have been excavated with little recording and with poor curation of skeletal material was shown to have left a legacy of standing monuments and museum artefacts on which later interpretations have often been typologically based “…archaeologists engaged in the endless comparison of structural features between one monument and another. To what end?” (Barrett 1994:50).

Many observations made in this study are consistent with those made on other Neolithic assemblages but the sample size and quality from the South Ronaldsay remains permitted unique examination of relationships between
variables. The identifications of sex-based variation in access to foods and selection of individuals for interment for example are particularly significant.

Neolithic life in Orkney required hard, even severe, physical labour that we can begin to examine in close detail: use of the left arm in extension, hyperextension at the neck, asymmetric lower limb use, interpersonal violence (using both weapons and fists). Society was nuanced with distinctions between the sexes that affected access to foods. Female food access may also have varied according to the procreative cycle and possibly underlying humoral beliefs. Some individuals were probably perceived as being endowed with supernatural capacities, even after death. Tombs had a special function and were not normal sites for interment. Neolithic society was definitely not egalitarian but had clear sex distinctions and although the individuals in the tombs may have been venerated, they were not necessarily generic ancestors.

The ante mortem tooth loss that has been reported in numerous cases from the Neolithic and for which ritual avulsion was occasionally suggested as a cause has now been linked to scurvy – a condition difficult to diagnose in skeletal material but one that should have been expected to be endemic had preconceptions of a sound diet not existed (see Brothwell 1971:85).

This research produced the earliest evidence of multiple myeloma in the British Isles and demonstrates the antiquity of neoplastic diseases. The presence of craniosynostosis had been recognised widely in the UK before (e.g. pp10ff,)
though not on the scale that it occurs at Isbister, nor had the cases elsewhere in Britain previously been linked to the issue of selection for tomb interment.

It seems clear that the individuals interred in these tombs would be unsatisfactory as generic ancestors. They may have been particularly vulnerable to or singled out for interpersonal violence, which was observed with a prevalence potentially as high as any tribe noted by Keeley (1996:90). They were probably not the ‘big men’ of the community but neither were they a random sample from Neolithic society. The people whose remains were studied appear to have some special status, possibly related to their pathological features, that required a special form of interment. The most likely overall explanation is that they had been touched by supernatural forces; their remains required physical (possibly ceremonial, symbolic and magical) containment. Decorative use of masonry and continued elaboration of structure may have had some supernatural effect, perhaps appeasing, controlling or confusing supernatural powers, or to accentuate their tomb’s importance. This suggestion may be extended to other Neolithic sites, such as Skara Brae and Ness of Brodgar. It could provide an explanation for the opening of tombs and use of fire inside, since these may indicate iconoclasm or possibly destruction and purification of the contained forces, which may occur at settlements (Thomas 2011) but not stone circles. None of these features has any necessary underlying concept of ‘ancestors’ although such veneration could develop.

Selection for interment undermines widespread suggestions that megalithic architecture was specifically related primarily to death. There is no reason to
impose a living / dead dichotomy on the landscape (contra Parker Pearson 2000). There is also no reason to infer an egalitarian society through symbolic deposition and intermingling of bones: this only occurs for a special group and not the majority. There is then no reason to posit any diachronic change in emphasis from the community to the individual into the Bronze Age. Reuse of sites suggests some continuity of practice (though destruction prevented proper use of tomb chambers). The Bronze Age individual interred at Isbister for example exhibits skeletal features highly reminiscent of the Neolithic remains, as does the inhumation at Skaill Bay, which may indicate persistent selection criteria for individuals.

The possibility that the tombs related to territorial divisions and acted in some degree as markers survives this reassessment and may even be strengthened. Identification of a large monumental tomb in a prominent position with some local community seems likely. It may advertise control over supernatural powers, consolidating claims of ownership with display. Perhaps here we have an explanation for new tomb construction as at Banks, which shares a terrestrial viewshed with Isbister but enjoys greater visibility across the Pentland Firth. Relationships of megalithic tombs with possible roads have been noted in Neolithic Europe (e.g. Bakker 1976, 1991; Criado Boado et al. 1994; Criado Boado and Vázquez 2000; Baldia 1995); in Orkney, communications routes would probably especially be maritime. Altering site location may relate to changing needs for display to different groups: the local community, neighbouring communities or travellers. This may echo changes in Neolithic society that are exhibited in alterations in architecture and the development of
new pottery forms (i.e. Unstan Ware vs. Grooved Ware, with associations). Dichotomies of form, use and history between stone circles and tombs suggest complexity of beliefs, perhaps of distinct aspects.

There is little evidence for any normative disposal form for the dead in the Neolithic British Isles. Although it is possible that burials have been misinterpreted, the numbers of inhumations and other evidence seem insufficient to suggest a large proportion of the Neolithic dead. It is most likely that the dead were given to the sea, cremated or exposed in some manner that has left little trace. It is paradoxical that Isbister has for so long been held up as demonstrating 'excarnation' but actually shows no direct evidence for this; and yet the results infer that some form of funerary exposure must have been practised. Suitable sites need to be located and may contain 'normal' people.

What was planned as a simple test to investigate exploitation of marine protein and life passage events through stable isotope analyses developed into an investigation of status and child-rearing. A distinction has been demonstrated between the sexes in access to foods, particularly animal products. This is highly significant to understanding Neolithic society, where it has previously been said that “these contemporary categories [of male and female] may not have been recognised at all” (Thomas 2001:149). We now need no longer discuss male and female adults but may justifiably attribute gender from sex. Speaking of men and women rather than males and females, we can begin to address social structures that permit differences in access to foods.
The systematic difference between male and female collagen isotope ratios must have a source. The cause seems unlikely to be metabolic in nature because the female distribution is linear whereas the male distribution is random. If the difference were metabolic, then the female values would be expected to display a distribution similar in form to that of the males but offset in one or both dimensions. Metabolic features such as pregnancy or dietary stress would be expected to affect $\delta^{15}\text{N}$ values but apparently not $\delta^{13}\text{C}$ (Fuller et al. 2004; Fuller et al. 2005). The linear form of the female distribution indicates a direct relationship between the sources of $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ that must derive from either a marine or C4 protein origin. The variations demonstrated between the sexes at Isbister can thus be interpreted in simple terms of diet. This is not to suggest that physiological factors are not present but rather that we would need further longitudinal studies in order to investigate them. The male distribution seems likely to indicate an idiosyncratic variation in expression of intake of predominantly terrestrial foods. The female distribution seems to indicate a more restricted diet, perhaps predominantly derived from two major sources. A varying combination of well-manured cereal crops and limited marine protein would be likely to produce the pattern observed. Further work is needed before a more definitive interpretation is possible.

Common practice in this population appears to have been one of weaning at the age of about four years, although supplementary foods probably appear earlier in life (cf. Fuller et al. 2006). This is a common age for weaning ethnologically (Stuart-Macadam 1995:84) and may relate to the period separating successive pregnancies. Adult female diet may have features linked to this periodicity, as
among some coastal tribes (Price 1938:257), possibly because of associated symbolism, taboos or superstitions (Fieldhouse 1986:52-3).

Figure 292. Towards lifetime variations in stable isotope analysis.
Composite plots of $\delta^{15}$N and $\delta^{13}$C from the five teeth discussed above, using distance along the tooth adjusted according to expected age range and duration of development as a proxy for age. It should be noted that the deciduous molars (infants 1 and 2) must develop more rapidly than the other teeth but the permanent canine and third molars illustrated are quite variable, so that the charts reflect a series of best guesses for age in years. It may be significant that both infants died in infancy whereas the other individuals survived childhood. It is also of some interest that some fluctuations appear almost regular.
The origin of dietary protein in Neolithic Orkney was, it seems, predominantly terrestrial and based on intensive farming. Marine foods had a minor role, which may have been seasonal and related to particular circumstances of the reproductive cycle, such as being used by nursing mothers, or as a famine food. It was not uncommon in some cultures to provide or restrict foods according to status, especially sex or particular stages in life. Childbearing is one particularly frequently observed period for diet change. It may be that this obvious difference between male and female was grounded in understanding of diet related to Neolithic beliefs. The results from detailed incremental study on adult teeth may be significant in this regard. It was found that the isotope signal varied over time in a manner that was consistent with the likely periodicity of childbirth and weaning. This variation appeared to be primarily related to an intake of high $\delta^{13}C$ protein that could only have derived from a marine source. This variation only had a small, related effect on $\delta^{15}N$ values. Although there may have been some inhibition in expression caused by metabolic stress, it seems possible that the source was not necessarily marine predators such as fish or marine mammals but rather low trophic level marine foods.

This sex difference in relative isotopic values leads to further hypotheses regarding Neolithic society. Since the males and females may not be eating the same foods, it is likely that some foods were prepared separately, possibly in different vessels. Vessel use may be determined from adsorbed lipid analysis of pottery fabrics and a gender-based attribution may possibly be discovered. It may also be that the sexes did not eat together. If they did not eat together, then there is a high probability, based on analogy with ethnological
observations, that they did not sleep together either (Broude 2003:197-8) and this may support suggested interpretations of the difference in bed size on either side of the houses at Skara Brae (Childe 1931; Richards 1998).

Observation of different isotopic value clusters for the sexes may present a useful tool for assessing sex in morphologically indeterminate cases but the degree of overlap between the groups remains undefined. Any such method is probabilistic and may be site-specific. This observation may therefore be inapplicable to other populations and care would need to be exercised in order to avoid circular arguments. If a similar social structure is assumed, then in cases where there is a large sample of sexually indeterminate individuals, such a method may prove useful.

The relatively higher $\delta^{15}$N signal in Orcadians compared with English Neolithic populations is not apparently related to an increased ‘marine’ protein component but may rather result from intensive manuring. Use of seaweeds as animal fodder, is unlikely to be the main cause because the $\delta^{13}$C signal is not generally affected. Manure and compost fertilisers initially appear an unlikely origin for this $\delta^{15}$N signal because they should theoretically be relatively $\delta^{15}$N depleted. This paradox may be resolved if methods employed for storage and treatment caused or facilitated fractionation. Stable light isotope assay of archaeological grain is required to discover whether the $\delta^{15}$N signal is exhibited further down the food chain. It would be useful to perform a series of experiments to discover what such effects might be expressed in Orcadian vegetation. It is likely that manuring, agriculture and animal management were
linked, possibly in a culturally normative manner that may have been regionally specific. British practices are likely to have differed according to land availability, possibly also with soil differences and intensity of domestic animal exploitation.

It is likely that agricultural success inadvertently led to the development of many of the pathological lesions recorded. With sufficient food from cultivation of the land and a possible cultural disaffinity for the sea, there would not have appeared to have been any need to exploit marine resources to a degree that might have saved the community as a whole from avitaminosis C and iron deficiency anaemia. Detrimental effects may have been exaggerated by low vitamin D levels caused by low winter insolation and limited meat availability.

Agriculture requires settlement and possession of land. Intensive investment of effort, especially fertilisation, creates value in existing plots. Accumulation of surplus becomes necessary and value develops in labour. Neolithic Orkney therefore had a spectrum of valuable resources – goods, land and slaves - that could be taken by force: potential for raiding as well as trading. The data from this study indicate a spectrum of interpersonal violence that runs from ‘fisticuffs’ through sustained assault to varied examples of perimortem weapon injury.

Whilst evidence for interpersonal violence has been repeatedly described for Neolithic Britain, the high prevalence at Isbister, on an Orcadian island was unexpected. It was noted on site visits in the south of South Ronaldsay that the Scottish coast is highly visible and dominates the landscape: the eye seems drawn across the Pentland Firth. One might imagine that this was the case in
the past. Water forms a communications route and not necessarily a barrier, with South Ronaldsay the likely first landfall from Scotland. Organised violence, possibly on a scale to be described as warfare may be implicated and is supported by the large wall around the defensively sited high-status settlement at Ness of Brodgar. Ethnological parallels suggest that people believed to possess supernatural powers are especially targeted in conflicts (e.g. Balikci 1970:189-192; Chagnon 1988; Chacon 2007) and this may explain the high prevalence of trauma in individuals with obvious pathologies at Isbister.

The form of some cranial injuries suggests potential links with stone objects that have been described as ‘symbols of power.’ Power symbolism may be idiosyncratic in certain manifestations but the mace and axe seem to have very clear associations with interpersonal violence (compare Neolithic ‘symbols of power’ with items in Haddon 1900 or Serrano 1946:Plate 42 for example). Several objects from Neolithic sites in Orkney fit this model, some of which are perforated whilst others may be hand-held equivalents. Interpretation of the Neolithic as a period of peace cannot be sustained and the widespread use of these symbols may indicate a violent social ethos for much of western Europe.

Endemic violence may then have influenced the formation of wider social groupings for defence and control of aggression. This could drive society to centralise authority. Such an authority would probably require taxation or tribute, amassing stores that might then serve as a buffer against famine. This could then support large-scale communal projects such as building monumental tombs, stone circles, henges and in particular explain the Ness of Brodgar
monuments. This may also have influenced the monumentalisation of chambered cairns overlooking cultivated land and transport routes as a widely visible advertisement that the local population was large and powerful enough to perform such building feats, possessed of supernatural powers and therefore not safe to assault (if so, then apparently failing in this last regard).

There are areas that require further investigation, especially to discover whether incremental patterns are repeated in other individuals. Ideally, teeth from known sex individuals should be sampled, covering as long an age range as possible. Sampling should follow the sigmoid form of development by cutting along the development increments, perhaps using a projected image from thin section microscopy or radiography as a guide. The neonatal line should be used as a particular marker where appropriate, to identify antenatal signals. Incremental sampling on a fine scale requires a conceptual shift from bulk bone collagen because there is much less (time) averaging in the signal although averaging is still present because the isotopic signal reflects the body’s ambient amino acid reservoir. This needs to be investigated, especially as sample sizes decrease and reflect more time-specific conditions. The next step of development may be sampling across osteons in bone, utilising stratigraphy to discover isotope signal variations later in life (cf. Ortner and Yong 1975; Brady et al. 2008).

Baseline data is required from low trophic level organisms and longitudinal studies are required. Little is known about the variation in seaweed isotope signals and because of the extreme variation in local conditions on rocky shores, this would require a major research project to ascertain. Little is known
about the contribution of littoral fauna or of tissue selection to human and
domesticated animal isotopic signatures. The possibility that animals were
foddered on fertilised crops needs to be examined. Parallel stable isotope
assays on bioapatite would further help to refine interpretations of diet.

Taphonomic effects need to be more fully explored, especially the coatings of
‘varnish’ and intrasite variations. Further radiocarbon dating is required to test
the relationships between skeletal features and better define the periods of
deposition and their relationships with development of different sites.

In the absence of detailed chronology, an assumption that both the Banks and
Isbister collections each represents a single uniform population has been
imposed for interpretative purposes. This assumption may justifiably be
criticised, since the dating and demographic evidence suggests an extended
(possibly interrupted) period of deposition at Isbister. Further detailed
radiocarbon study would be required to resolve this.

The existing skeletal reports from several sites are inadequate. Although other
analyses are underway (e.g. Quanterness, Knowe of Rowiegar), Hambledon
Hill requires a full examination, Point of Cott should be revised, Banks needs to
be completed and other surviving collections should be identified and studied
using standardised recording methods (e.g. consistent with the Global History of
Health Project (Steckel et al. 2011)). Supposed animal bone assemblages
should particularly be examined for misidentified human remains.
It is in some ways unfortunate that the largest British corpora of Neolithic human remains should come from Orkney. The island nature of the landscape limits the probable exploitation area and permits definition of subsistence techniques for the population represented in the tomb but may inhibit extension of the conclusions to other populations. Some traits may be due to the manner of intensive exploitation of local resources, less necessary elsewhere. Dietary deficiencies may not occur with such high prevalence if other foods – including wild winter foods - were more readily available than on a small northerly island. Inbreeding might be less common where access to larger populations was more likely.

Congenital conditions, physique, demographic structure and trauma appear to indicate similarities with southern British Neolithic populations, echoed in settlement and society. It has become clear that even in Orkney, the Neolithic lifestyle was fraught with both immediate and subtle dangers, physical and supernatural. The remote northerly island location compounded the risks attendant on the culturally accepted subsistence strategies and profoundly affected the health of the community. The development of scurvy, with its complications, was one result. Many features that were important to these interpretations had been reported from Neolithic tombs in the nineteenth century and since but were subsequently ignored. Many early researchers instead concentrated on heredity and ritual: a great irony is that they ignored skeletal evidence considered useful here and, whilst creating the foundation for modern bioarchaeology, directed research towards potentially inappropriate questions, based on misleading assumptions (as shown above in pp9ff).
Neolithic sites in Orkney do not appear rare but prehistoric human remains are very sparse once time depth is considered. An apparent high quality of survival has been accompanied by much loss without adequate record. The void in physical evidence has sometimes been partly addressed through overtly theoretical approaches: 'A Contribution to the Collective Representation of Death' (Hertz 1960) and 'The Rites of Passage' (Van Gennep 1960) are almost compulsory references in mortuary analyses but contribute little to understanding the Neolithic. Analogies are often invoked from particular ethnographic accounts but may impose inappropriate normative views, disregarding the wide variation known worldwide. These features have led to the construction of elaborate models of Neolithic life, which are often entertaining, sometimes interesting and may occasionally have something of value. Despite ultimately being exercises in speculation, they may unfortunately sometimes be treated as demonstrated facts, especially in the secondary literature, where models can achieve paradigmatic status. I have argued here against several such edifices and sought to use the new evidence identified in developing alternative hypotheses, inevitably with some defined assumptions but hopefully without imposing too many unnecessary normative anachronisms.

Human remains are the most direct and powerful evidence available for archaeological study, especially for prehistory. It is increasingly apparent that early studies failed to record or interpret skeletal evidence adequately. Revisiting older assemblages is clearly of exceptional value and it is unfortunate that so much potentially significant material was disposed of in the past. This is
a lesson that needs to be made clear, especially in the face of movements for skeletal reburial.

So I prophesied as I was commanded: and as I prophesied, there was a noise, and behold a shaking, and the bones came together, bone to his bone.

And when I beheld, lo, the sinews and the flesh came up upon them, and the skin covered them above; but there was no breath in them.

Ezekiel 37:7-8

Figure 293. Archaeological interpretations may be incorrect.

(Calvin and Hobbes from Watterson 1990:166)
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