Chapter 4. Archaeological Dating Methods

4.1. Dendrochronology and other tools
4.2. Dating with radioactive clocks
4.3. Mapping change and development
4.4. Migration and colonization
4.5. Accelerator mass spectrometry (AMS)
4.6. AMS applications
4.7. Uncertainties and corrections

“Everything which has come down to us from heathendom is wrapped in a thick fog; it belongs to a space of time we cannot measure. We know that it is older than Christendom, but whether by a couple of years or a couple of centuries, or even by more than a millennium, we can do no more than guess”

Rasmus Nyerup, 1802
Archbishop James Ussher (1581-1656). Ussher calculated that the first day of creation was on Sunday Oct. 23, 4004 B.C.

In 1650 the result of his efforts was published in Latin: *Annales veteris testamenti, a prima mundi origine deducti*. In 1658 the first English edition *The Annals of the Old and New Testament* was published.
The Need for Reliable Dating

The calendar date of an archaeological event or artifact is one of the most important pieces of information to be determined in archaeology. These calendric dates are the skeleton that link historical events and correlate and define archaeological findings within the historical context.

Several methods have been developed to determine the age of archaeological samples. They vary from systematic categorization based on ornamental and artistic structure of artifacts initially, towards a wide range of more science based methods. The latter have mostly been developed during the second half of the twentieth century as unique applications of scientific methods that have been developed in biology, chemistry, and physics.
# Archaeological Clocks

- **Biology**
- **Chemistry**
- **Physics**
- **Radioactive Dating**

<table>
<thead>
<tr>
<th>Method</th>
<th>Age Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dendrochronology</strong></td>
<td>(&lt;7 000 y)</td>
</tr>
<tr>
<td><strong>FUN test</strong></td>
<td>(&lt;100 000 y)</td>
</tr>
<tr>
<td><strong>Amino-Acid clock</strong></td>
<td>(&lt;100 000 y)</td>
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<tr>
<td><strong>Hydration and Diffusion</strong></td>
<td>(&lt;100 000 y)</td>
</tr>
<tr>
<td><strong>Archaeomagnetism,</strong></td>
<td>(6 My)</td>
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<tr>
<td><strong>Oxygen isotope ratios</strong></td>
<td>(1 My)</td>
</tr>
<tr>
<td><strong>$^{14}$C method</strong></td>
<td>(&lt;100 000 y)</td>
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<tr>
<td><strong>K-Ar method</strong></td>
<td>(&gt;100 000 y)</td>
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<tr>
<td><strong>Uranium-series</strong></td>
<td>(500 000 y)</td>
</tr>
<tr>
<td><strong>Fission tracking</strong></td>
<td>(50 000 – 10 M y)</td>
</tr>
<tr>
<td><strong>Thermoluminiscence</strong></td>
<td>(100 - 30 000 y)</td>
</tr>
<tr>
<td><strong>Electronspinresonance</strong></td>
<td>(1000-1 M y)</td>
</tr>
</tbody>
</table>
Dendrochronology or tree-ring dating is the dating of past events through study of tree ring growth.

Trees showing sensitive rings are affected by slope gradient, poor soils, or too little moisture.

Trees showing complacent rings have generally constant climatic conditions such as high water table, good soil, or protected locations.
Each vertical line in the above graph represents one year. The yellow bars that appear on three of the graph's lines represent narrow rings. The narrower the annual ring, the longer the line. The "b" indicates a year with an unusually wide tree ring, a dashed line marks a year where that tree failed to produce a visible ring.
Building a chronology

a. Modern Spessart oak growing on the hills above the R. Main, a Rhine tributary.
b. Watterbacher, Haus
c. Büdingen, Schloss
d. Büdingen, Remigiuskirche
e. Büdingen, Stadtkirche
f. Aschaffenburg, Haus
g. Nieder-Weisel, Kapelle
h. Kassel, Brüderkirche
i. Gelnhausen, Brauhaus
j. Altenhausslau, Kirchturm
k. Gelnhausen, Haus Kuhgaske
l. Ebrach, Kloster
m. Büdingen, Remigiuskirche
n. Echzell, Kirche
o. Bösgesäss, Rost
p. Steinbach, Basilika
q. Ilbenstadt, Basilika
r. Büdingen, Schlosshof. Rost
s. Winkel, Graues Haus
t. Büdingen, Remigiuskirche
Dating old paintings!

Lukas Cranach the Elder (1472-1553)

<table>
<thead>
<tr>
<th>Painting</th>
<th>Total Rings</th>
<th>Last Ring</th>
<th>External Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portrait of a Gentleman</td>
<td>163</td>
<td>1521</td>
<td>signed 1528</td>
</tr>
<tr>
<td>Portrait of a Young Girl</td>
<td>145</td>
<td>1519</td>
<td>attrib. 1520</td>
</tr>
<tr>
<td>Portrait of H. Melber</td>
<td>146</td>
<td>1520</td>
<td>signed 1526 years</td>
</tr>
</tbody>
</table>

A triptych by Rogier van der Weyden

The right panel is in the Metropolitan Museum of Art in New York. The remaining two-thirds in the Capilla Real, Granada. A second triptych is in Berlin. The Metropolitan-Granada altarpiece was thought, on art historical grounds, to be the original and the Berlin altarpiece a copy.
The Berlin altarpiece has a last preserved ring from 1406. With a median sapwood allowance of 15 years, the felling date should be around 1421, early in Rogier's career. The wood of the Metropolitan altarpiece cannot have been cut before 1482, ~ two decades after Rogier's death in 1464. Dendrochronology demonstrates that some art-historical opinions must be revised: Berlin has the early painting from Rogier van der Weyden's lifetime. New York and Granada have the posthumous copy.
Dating back in time
"Methuselah" was found to be 4,723 years old and remains today the world's oldest known living tree.

Tree-ring dating ~7000 years backwards
Chemical Methods

Fluorine (FUN) Test: A dating method that measures the amount of fluorine, nitrogen, and uranium in bones. Older bones have more fluorine and uranium and less nitrogen. But because decomposition happens at different speeds in different places, it's not possible to compare bones from different sites.

On December 18, 1912, Charles Dawson and Arthur Smith Woodward claimed the discovery of the remains of an early human fossil, *Eoanthropus dawsoni*. It was found in a shallow gravel pit near the village of Piltdown in the County of Sussex. It became known as the Sussex Man, and then Piltdown Man, the name that stuck.
The Fluorine Test

Analysis of fluorine content in the jawbones in 1948 indicated much lower fluorine content than justified by claimed age ⇒ Orangutan jaw
Amino Acid Dating: The method is based on that certain types of amino acids exist in two alternative structural forms. Their chemical composition is identical but the atoms arrangement is reversed in one of the forms. The two forms are called L (laveo-) and D (dextro-) form. In living systems the L-form is synthesized, but after death these L-forms undergo a slow transformation and change to D-form. The process is called racemization. The extend of racemization correlates with time and can be used for dating.
Amino-Acid Dating

\[ L \rightleftharpoons D \]

\[ \frac{dL}{dt} = -k_L \cdot L + k_D \cdot D \]

\[ t = \frac{1}{2 \cdot k_{L,D}} \cdot \ln \left( \frac{1 + D/L}{1 - D/L} \right) \]
Paleomagnetism

At the time of their formation, iron-bearing rocks and sediments may acquire a **natural remnant magnetism**. This primary magnetism aligns parallel to the existing magnetic field of the Earth. In a sense, a rock becomes a compass capturing its orientation to the Earth's magnetic field in its structure.

Today the orientation of the magnetic field of the Earth is directed downward in the northern hemisphere and upward in the southern hemisphere. Earth's magnetic field periodically reverses its polarity (~every 800,000 years). During the time of reversed polarity, a compass needle would point south. These reversals make excellent markers in the geologic record because they are global. The age of these reversals can be determined by radiometric dating. The age of a fossil can be determined by correlating the position of the strata of rock where it was found and where a reversal occurs.
Rock Signatures

Paleo-Chronology over 5 Million years
(green indicates present direction of earth’s magnetic field)
Stable Isotope $^{18}$O/$^{16}$O ratio

Stable isotope data derived from mineral and biological materials can provide a variety of insights into environmental conditions, it is mostly used in geochronology and correlation. Oxygen isotopes ($^{18}$O/$^{16}$O) are widely used in the correlation of Quaternary marine sediments. Oxygen isotope concentrations in mollusk shell and algal material normalize with seawater while the organisms are alive. During periods of glaciation, large volumes of $^{16}$O become trapped in glacial ice, enriching ocean water in the heavier oxygen isotope. Oxygen isotope data extracted from shell-bearing sediments provide information about cycles of glaciation (and climate change), and can be used for relative dating.
The observed $\delta^{18}O$ fluctuations represent the major climate variations earth has experienced over the last 120,000 years, beginning with the onset of the last ice age period through the Holocene period of human evolution.
Climate correlation with human history and development

2500 Years of European Climate Variability and Human Susceptibility
Ulf Büntgen, et al. *Science* 331, 578 (2011);