

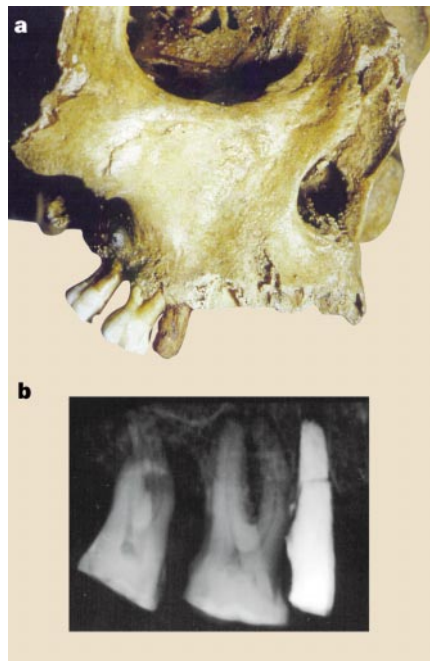
# False teeth of the Roman world

The history of dental implants has been looked at before<sup>1-4</sup> but there have been no documented cases of a functional implant from ancient times. We report here a wrought iron dental implant of a right second upper premolar from a Gallo-Roman necropolis at Chantambre (Essonne, France), from the first or second century AD. The implant and the socket fit perfectly together and the osseointegration appears viable.

Since the 1960s the dental profession has been divided on the issue of dental implants<sup>5</sup>. Thanks to the osseointegration principle<sup>6,7</sup>, ideas about suitable interfaces between the bone and the implant have made considerable progress, and it has been shown that it is not desirable to insert fibrous tissue<sup>8</sup>. The discovery of an osseointegrated implant from a Gallo-Roman population shows that direct contact between the implant and the bone can be obtained using surprisingly basic technology.

The individual in question, a man who was over 30 years old when he died, is dated to the end of the first century AD or the beginning of the second century by associated pottery and radiocarbon dating. There is a piece of metal where the right second upper premolar would have been (Fig. 1a) which has been severely corroded, preventing magnification for the study of the microstructure. The central part, however, has not been affected. X-ray microanalysis (energy dispersive spectroscopy), together with scanning electron microscopy of the apical fragment, identify it as iron or non-alloy steel. The main chemicals are iron and oxygen; nevertheless the presence within a particular section of dark zones — bearing traces of silicon (0.73%) and calcium (0.26%) — and of clear zones shows that some zones are more oxidized than others. This may imply that the metal was given its shape through a hot-hammering and folding process.

The retro-alveolar X-ray (Fig. 1b) shows that the alveolar wall and the pseudo-root



**Figure 1** Details of the false tooth. **a**, Antero-lateral view of the skull. The iron-made dental implant is where the right second upper premolar would have been. **b**, Retro-alveolar X-ray of the right maxilla. The implant was dropped after being handled and it broke near its apical third into two pieces that were then glued together again. The line of breakage is visible on this X-ray picture. The alveolar wall and the pseudo-root fit perfectly together. Only an area one to two millimetres high in contact with the mesial alveolar wall shows an absence of contact between the bone and the implant.

fit perfectly together without peri-implant radiolucent areas, which is considered to be one of the success criteria for the implant of a dental prosthesis<sup>9</sup>. According to available data<sup>5</sup>, osseointegration requires a minimum of three to six months. The minor reactions of the periodontium indicate that the subject was probably fitted with his implant more than a year before he died. The osseointegration implies that the man who made the implant used the original tooth as

a model. The implant was probably set by impaction soon after the tooth loss. Chance played a part in this success, but the technical choices were, in retrospect, conducive to osseointegration. Furthermore, although iron is surely not the ideal metal for dental implants, its rugged surface must have provided satisfactory adhesion to the bone<sup>10</sup>.

Because it is osseointegrated and in a good anatomical position, this implant might have been functional. We cannot know why it was inserted. But the early disappearance of the left molars might have given the subject the desire to keep an active right side.

This case, in addition to its exceptional aspect and the technical craft it required, gives remarkable clues about medicine and anatomy in this rural community of the first or second century AD. This implant reflects the potential of early medicine and the validity of the osseointegration principle<sup>4,5</sup>.

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## Breeding phenology and climate...

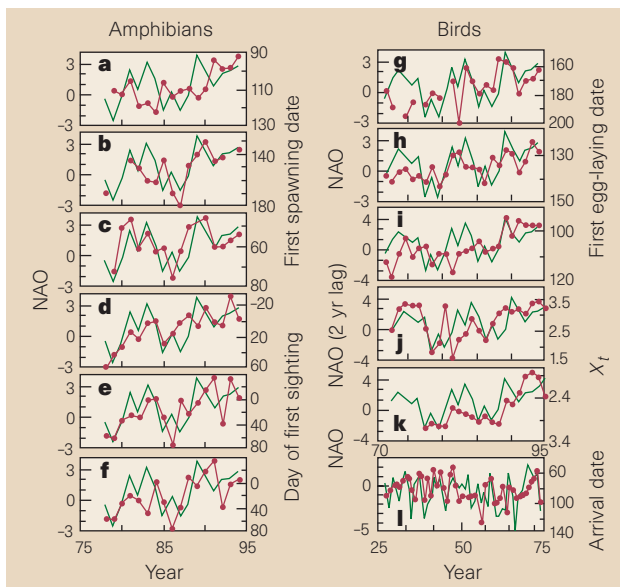
European amphibians and birds have been breeding consistently earlier over the past two to three decades<sup>1,2</sup>. These changes have been attributed to the observed trends in increasing average spring temperatures in Europe<sup>3</sup> producing earlier growing seasons<sup>4</sup> and increased forage availability. Here we show that variations in breeding of Euro-

pean amphibians and birds are influenced by variations in a natural, large-scale atmospheric phenomenon, the North Atlantic Oscillation (NAO). Our results support the proximate cause (that is, increase in spring temperatures) of the altered breeding phenology as suggested previously<sup>1,2</sup>, but by extending previous analyses as well as integrating data from other bird species, they also suggest that organisms with complex life histories respond to year-to-year variations in their abiotic environment.

The NAO determines most interannual

fluctuation in winter temperatures in the northern Atlantic region, and is correlated with global as well as regional temperature fluctuations<sup>5,6</sup>. Also, the NAO influences the atmospheric export of dust from North Africa, thereby inducing significant fluctuations in regional radiative budgets in the North Atlantic region<sup>7</sup>. The increase in the NAO index over the past 20–30 years (Fig. 1) has contributed significantly to the increase in average winter temperature across Europe<sup>6</sup>. The contribution of the NAO to temperature changes complicates

**Figure 1** Variations in amphibian and bird breeding. **a–f**, Temporal variation in first spawning date in *Bufo calamita* (**a**), *Rana kl. esculenta* (**b**) and *R. temporaria* (**c**), and temporal variation in first day of sighting in *Triturus vulgaris* (**d**), *T. helveticus* (**e**) and *T. cristatus* (**f**). **g–i**, Temporal variation in first egg-laying date in *Miliaria calandra* (**g**), *Phylloscopus collybita* (**h**) and *Pica pica* (**i**). **j–l**, Temporal variation in log-transformed breeding numbers ( $X_t$ ) in UK populations of *Pluvialis apricari* (**j**) and *Actitis hypoleucos* (**k**), and in arrival date of a Norwegian population of *Alauda arvensis* (**l**). Superimposed on each figure is the NAO index (grey line). In coastal Europe, high, positive values of the NAO indicate warm, moist winters, whereas unusually cold, dry winters are indicated by low, negative NAO values<sup>5</sup>.



Least-squares correlation coefficients between the NAO and breeding characteristics are, for the non-detrended and detrended (in brackets) time series, as follows (italic type indicates significance,  $P < 0.05$ ): **a**,  $-0.13$  ( $0.23$ ); **b**,  $-0.52$  ( $-0.44$ ); **c**,  $-0.57$  ( $-0.49$ ); **d**,  $-0.59$  ( $-0.33$ ); **e**,  $-0.50$  ( $-0.25$ ); **f**,  $-0.41$  ( $-0.39$ ); **g**,  $-0.50$  ( $-0.37$ ); **h**,  $-0.56$  ( $-0.50$ ); **i**,  $-0.34$  ( $-0.17$ ); **j**,  $0.41$  ( $0.37$ ); **k**,  $-0.68$  ( $-0.51$ ); **l**,  $-0.59$  ( $-0.60$ ). Detrending was performed by linear regression. All correlations were checked for autocorrelation. The NAO index was obtained from the Climate Analysis Section (Colorado, USA) internet home page (<http://www.cgd.ucar.edu:80/cas/climind/>). Data on amphibians are from ref. 1; data on first egg-laying dates are from ref. 2; data on UK breeding numbers are from refs 10, 11 and D.W. Yalden (unpublished); and data on arrival dates are from ref. 12.

the interpretation of climatic responses to greenhouse gases, so the possible links between atmospheric circulation and greenhouse gases need further exploration<sup>6</sup>.

Our analyses reveal that, after a period of increasingly warm winters (high positive NAOs from 1970 to 1994), both amphibians and birds bred consistently earlier, as documented in previous analyses<sup>1,2</sup>. However, variations in breeding phenology of several species also showed significant year-to-year responses to fluctuations in the NAO about the trend (Fig. 1). This was particularly obvious for the skylark, where the data covered a 50-year period (Fig. 1l). Moreover, the NAO influenced annual breeding numbers in populations of golden plover (Fig. 1j) and common sandpiper (Fig. 1k).

By applying autoregressive analysis on breeding abundance with the NAO as a covariate (see ref. 8 for technical details), we found the most parsimonious autoregressive structures to be (coefficients  $\pm$  s.e.m.) for plover:

$$X_t = (2.43 \pm 0.15) + (0.32 \pm 0.24)X_{t-1} - (0.39 \pm 0.24)X_{t-2} + (0.09 \pm 0.05)NAO_{t-1} + (0.14 \pm 0.06)NAO_{t-2} + (0.05 \pm 0.06)NAO_{t-3} + \epsilon_t$$

and for sandpiper:

$$X_t = (2.61 \pm 0.35) + (0.90 \pm 0.14)X_{t-1} - (0.06 \pm 0.02)NAO_{t-1} + \epsilon_t$$

where  $\epsilon_t$  is a random variable with zero

mean and constant variance  $\sigma^2$ . This analysis supports our correlations (Fig. 1j, k), but also demonstrates the simultaneous effect of density dependence, which, for the plover, counteracted the effect of the NAO. Whereas for plovers, cold winters (negative NAO) limit breeding<sup>10</sup>, for sandpipers warm, snowy winters (positive NAO) are limiting<sup>11</sup>; the opposite effect of NAO on the two waders is confirmed by our analyses.

Our results, combined with recent studies on marine species showing the effect of NAO on pelagic primary production and zooplankton abundance in the North Sea<sup>9</sup>, thus add to the growing body of evidence<sup>13,14</sup> on the traceable influence of climatic fluctuations on ecological processes.

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## ...temperature and egg-laying trends

Crick *et al.*<sup>1</sup> showed that the laying dates for many British birds have become earlier during 1971–95, which they ascribe to warmer springs resulting from global warming. We provide partial support for this view from a great tit population in Oxfordshire.

Since 1947, the Edward Grey Institute of Field Ornithology has maintained records of the breeding biology of great tits, *Parus major*, in Marley Wood, part of Wytham Wood near Oxford. Among the data collected are the annual laying dates (the mean date of the laying of the first egg by each pair) of the population. We also have access to detailed weather data collected by the University's Radcliffe Meteorological Station (courtesy of the School of Geography), about 3.5 km east of the centre of the study plot. Here we use, as a measure of spring temperature, the sum of the maximum temperatures for each day from 1 March to 25 April, which we have previously shown to be the best of several such measures<sup>2</sup>.

Our data for the great tit conform with the finding of Crick *et al.*<sup>1</sup>, for other species, that the laying date has become earlier since 1970 (Fig. 1a). However, we can find no evidence of such a trend before 1970; in the 24 years 1947–70 there was no significant trend towards earlier breeding, whereas in the 27 years since 1970 the trend towards earlier breeding is highly significant. Crick *et al.*<sup>1</sup> make the assumption that the earlier laying dates of the birds that they studied were due to increasing spring temperatures. We can confirm this for the great tit. Laying date is strongly related to spring temperatures (Fig. 1b), being earlier in years with high than with low temperature sums.

There is no evidence that the birds are now breeding earlier, relative to the spring weather, than they were formerly; the slope of the relationship has not changed between the two periods (Fig. 1b). The trend towards earlier breeding seems to come about solely because of the increasing temperatures in the spring (Fig. 1c). There seems to have been a large amount of variation in spring temperatures in the 1950s and up to 1962. In 1963–70 springs were rather cool, but since 1970 there has been a generally upward trend, accelerating