

similar assemblages are found in middle Pleistocene and other early contexts in neighboring parts of Southeast Asia (9). Also, the balance of evidence indicates only a weak relationship between Mode 4 industries and the spread of modern humans (8). In northeast and central Asia, these industries appear to have locally developed (10) and subsequently diffused into Europe and the Near East, rather than originating in Africa (11, 12).

Collectively, these data suggest that the cultural and genetic history of Australasia is more complex than a single dispersal model such as "Out-of-Africa 2" allows.

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#### References

1. K. Huoponen, T. G. Schurr, Y.-S. Chen, D. C. Wallace, *Hum. Immunol.* **62**, 954 (2001).
2. S. M. van Holst Pellekaan, M. Ingman, J. Roberts-Thomson, R. M. Harding, *Am. J. Phys. Anthropol.* **131**, 282 (2006).
3. J. C. Presser, A. J. Deverell, A. Redd, M. Stoneking, *Pap. Proc. R. Soc. Tasmania* **136**, 35 (2002).
4. J. Friedlaender *et al.*, *Mol. Biol. Evol.* **22**, 1506 (2005).
5. M. J. Pierson *et al.*, *Mol. Biol. Evol.* **23**, 1966 (2006).
6. R. G. Roberts, R. Jones, M. A. Smith, *Nature* **345**, 153 (1990).
7. W. Shawcross, *Archaeol. Oceania* **33**, 183 (1998).
8. R. Foley, M. M. Lahr, *Camb. Archaeol. J.* **7**, 3 (1997).
9. A. Brumm *et al.*, *Nature* **441**, 624 (2006).
10. P. J. Brantingham, A. I. Krivoshapkin, L. Jinzeng, Y. Tserendagva, *Curr. Anthropol.* **42**, 735 (2001).
11. M. Otte, A. Derevianko, *Antiquity* **75**, 44 (2001).
12. X. Gao, C. J. Norton, *Antiquity* **76**, 397 (2002).

#### Response

I APPRECIATE SMITH *ET AL.*'S SUPPORT FOR my general model of a progressive loss in the genetic and technological diversity as modern human populations dispersed from their African homeland to other parts of the world. However, I find the remainder of their arguments unconvincing.

Despite the high genetic diversity of modern Australian and New Guinea populations, the current genetic data indicate unambiguously that all of these populations derive ultimately from the two out-of-Africa mtDNA lineages M and N (in turn derived directly from the African L3 lineage) and from the Y chromosome founder lineages C and F (1–5). Any subsequent diversity in these populations must derive from genetic mutations that occurred after the original out-of-Africa dispersal around 50,000 to 60,000 years ago [(1, 2, 4, 5); my Report].

I am equally unconvinced by their observations on the archaeological data. My own

#### CORRECTIONS AND CLARIFICATIONS

**Reports:** "Dual infection with HIV and malaria fuels the spread of both diseases in sub-Saharan Africa" by L. J. Abu-Raddad *et al.* (8 Dec. 2006, p. 1603). The first sentence of the paper, "In Africa, an estimated 40 million people are infected with HIV, resulting in an annual mortality of over 3 million (1), while over 500 million clinical *Plasmodium falciparum* infections occur every year with more than a million malaria-associated deaths..." is incorrect. These numbers refer to worldwide numbers for both infections, not just in Africa. The number of HIV-infected persons in Africa is approximately 25 million, and the number of malaria infections is roughly 350 million.

**Perspectives:** "How fast does gold trickle out of volcanoes?" by C. A. Heinrich (13 Oct. 2006, p. 263). In line 7 of the first full paragraph of column 3, "10 to 20 mg" should be "10 to 20  $\mu$ g."

#### TECHNICAL COMMENT ABSTRACTS

#### COMMENT ON "Rapid Advance of Spring Arrival Dates in Long-Distance Migratory Birds"

Christiaan Both

Jonzén *et al.* (Reports, 30 June 2006, p. 1959) proposed that the rapid advance of spring migration dates of long-distance migrants throughout Europe reflects an evolutionary response to climate change. However, most migrants should not advance their migration time because the phenology of their breeding grounds has not changed. It is more likely that migration speed has changed in response to improved environmental circumstances.

Full text at [www.sciencemag.org/cgi/content/full/315/5812/598b](http://www.sciencemag.org/cgi/content/full/315/5812/598b)

#### RESPONSE TO COMMENT ON "Rapid Advance of Spring Arrival Dates in Long-Distance Migratory Birds"

Niclas Jonzén, Andreas Lindén, Torbjørn Ergon, Endre Knudsen, Jon Olav Vik, Diego Rubolini, Dario Piacentini, Christian Brinch, Fernando Spina, Lennart Karlsson, Martin Stervander, Arne Andersson, Jonas Waldenström, Aleksi Lehikoinen, Erik Edvardsen, Rune Solvang, Nils Chr. Stenseth

Both's comment questions our suggestion that the advanced spring arrival time of long-distance migratory birds in Scandinavia and the Mediterranean may reflect a climate-driven evolutionary change. We present additional arguments to support our hypothesis but underscore the importance of additional studies involving direct tests of evolutionary change.

Full text at [www.sciencemag.org/cgi/content/full/315/5812/598c](http://www.sciencemag.org/cgi/content/full/315/5812/598c)

impression is that the earliest Australian technologies are far too simple, generalized, and "expedient" (as they seem to accept) to support any specific technological links with other technologically simple and expedient technologies, such as those from Flores and other earlier Pleistocene sites in southeast Asia (my Report). I am not aware of any convincing Levallois or other "Mode 3" (Middle Palaeolithic) technologies in Australia and see no reason why the Australian technologies should not be viewed as heavily simplified or "devolved" forms of Upper Palaeolithic ("Mode 4") technologies, under

the influence of varying raw material effects and other purely local economic adaptations (my Report). I note that they make no reference to the apparent similarities between the forms of the early Australian "horse-hoof" cores and simple forms of single-platform blade cores (my Report). And I am totally unconvinced by the arguments for purely local origins of Upper Palaeolithic/Mode 4 technologies in northeast and Central Asia [my Report; (6)]. To employ these data to support some form of multiregional, as opposed to African, origins for modern Australian populations would seem to be poorly founded in either the genetic or archaeological data.

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#### References

1. P. Forster, *Philos. Trans. R. Soc. London B* **359**, 255 (2004).
2. P. Forster, personal communication.
3. T. Kivisild *et al.*, *Genetics* **172**, 373 (2006).
4. P. Mellars, *Proc. Natl. Acad. Sci. U.S.A.* **103**, 9381 (2006).
5. M. Richards, H.-J. Bandelt, T. Kivisild, S. Oppenheimer, *Nucleic Acids Mol. Biol.* **18**, 223 (2006).
6. P. Mellars, *Evol. Anthropol.* **15**, 167 (2006).

#### Letters to the Editor

Letters (~300 words) discuss material published in *Science* in the previous 6 months or issues of general interest. They can be submitted through the Web ([www.submit2science.org](http://www.submit2science.org)) or by regular mail (1200 New York Ave., NW, Washington, DC 20005, USA). Letters are not acknowledged upon receipt, nor are authors generally consulted before publication. Whether published in full or in part, letters are subject to editing for clarity and space.

# Comment on "Rapid Advance of Spring Arrival Dates in Long-Distance Migratory Birds"

Christiaan Both

Jonzén *et al.* (Reports, 30 June 2006, p. 1959) proposed that the rapid advance of spring migration dates of long-distance migrants throughout Europe reflects an evolutionary response to climate change. However, most migrants should not advance their migration time because the phenology of their breeding grounds has not changed. It is more likely that migration speed has changed in response to improved environmental circumstances.

One of the great ecological concerns about climate change is that the phenology of different trophic levels responds at different rates (1), causing a mismatch between the timing of peak food requirements and peak food availability (2, 3). My colleagues and I have argued that long-distance migratory birds in particular have problems in responding appropriately to climate change. At their wintering grounds, migrants cannot accurately predict the phenology of their breeding grounds and, as a solution, they have evolved clock mechanisms to start their spring migration (4). These endogenous mechanisms have become maladaptive because of climate change, and at present birds arrive too late at their breeding sites (5). A change in migration time requires either an evolutionary change in the time of year that clocks instruct the birds to fuel and go or a phenotypic reaction to changed environmental conditions.

Jonzén and co-workers (6) recently showed that African-Palearctic long-distance migrants have advanced their spring migration time through Italy and southern Fennoscandia, and they argued that this is the expected evolutionary change. This is an important claim, suggesting that the inadequate timing responses may be only temporary and that at present rapid evolution solves the birds' problems. I agree that the

observed advances are an interesting phenomenon and that an evolutionary response in migration time is indeed expected. However, I strongly disagree that the observed effects are caused by such an evolutionary response.

An evolutionary change is a change in gene frequencies within populations, and in the present case it requires genetic variation for migration time as well as consistent selection for early migration. We showed that selection for early breeding and arrival increased for Dutch pied flycatchers *Ficedula hypoleuca* in response to climate change (5), and Jonzén *et al.* (6) used this as the backbone for their suggestion of evolutionary change. However, they failed to take into account key information about the precise breeding populations to which the study birds belonged. Most species examined have their distributional center of gravity in Fennoscandia and Northern Russia (7, 8), where spring temperatures have not increased during the last decades and egg-laying dates have not advanced (9). This lack of change in selection for early arrival and breeding makes the suggested evolutionary response unlikely.

Two alternatives can explain the observed changes in migration time: (i) migration is faster because environmental conditions during migration improved, or (ii) the mixture of birds from different breeding populations changed, and these populations differ in migration dates. Jonzén *et al.* (6) have overlooked the second hypothesis, but they discuss and reject the first

option, assuming it unlikely that climate change has improved conditions for migration in Africa. However, improved conditions in North Africa may be responsible for the advanced passage through Italy, because they correlate with arrival and breeding in several migrants (10, 11). Furthermore, rainfall has increased in the Sahel since the early 1980s (12), probably improving conditions during migration for many species.

In conclusion, the suggestion of a climate-driven evolutionary change (6) is weak because phenotypic responses are likely, and selection for earlier arrival and breeding has not increased in the majority of populations studied by Jonzén *et al.* There is little doubt that evolutionary changes will occur in the near future, but it is difficult to predict whether these will be sufficient to meet the requirements of climate change. Even if we accept the assertion of an evolutionary response, for pied flycatchers the advance in passage time through Italy (0.21 days per year) is still far less than the advance of their food peak on the Dutch breeding grounds (0.78 days per year) (13).

## References and Notes

1. G. R. Walther *et al.*, *Nature* **416**, 389 (2002).
2. M. E. Visser, C. Both, *Proc. R. Soc. Lond. B. Biol. Sci.* **272**, 2561 (2005).
3. C. Both, S. Bouwhuis, C. M. Lessells, M. E. Visser, *Nature* **441**, 81 (2006).
4. E. Gwinner, *Ibis* **138**, 47 (1996).
5. C. Both, M. E. Visser, *Nature* **411**, 296 (2001).
6. N. Jonzén *et al.*, *Science* **312**, 1959 (2006).
7. G. Zink, *Der Zug Europäischer Singvögel. Ein Atlas der Wiederfunde beringter Vögel* (Vogelzug-Verlag, Möggingen, 1973).
8. E. J. M. Hagemeijer, M. J. Blair, *The EBCC Atlas of European Breeding Birds: Their Distribution and Abundance* (T & AD Poyser, London, 1997).
9. C. Both *et al.*, *Proc. R. Soc. Lond. B. Biol. Sci.* **271**, 1657 (2004).
10. C. Both, R. G. Bijlsma, M. E. Visser, *J. Avian Biol.* **36**, 368 (2005).
11. A. P. Møller, T. Szep, *J. Evol. Biol.* **18**, 481 (2005).
12. M. Hulme, R. Doherty, T. Ngara, M. New, D. Lister, *Climate Res.* **17**, 145 (2001).
13. C. Both, M. E. Visser, *Glob. Change Biol.* **11**, 1606 (2005).
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# Response to Comment on "Rapid Advance of Spring Arrival Dates in Long-Distance Migratory Birds"

Niclas Jonzén,<sup>1</sup> Andreas Lindén,<sup>2</sup> Torbjørn Ergon,<sup>4</sup> Endre Knudsen,<sup>4</sup> Jon Olav Vik,<sup>4</sup> Diego Rubolini,<sup>5</sup> Dario Piacentini,<sup>6</sup> Christian Brinch,<sup>4</sup> Fernando Spina,<sup>6</sup> Lennart Karlsson,<sup>7</sup> Martin Stervander,<sup>8</sup> Arne Andersson,<sup>8</sup> Jonas Waldenström,<sup>9</sup> Alekski Lehikoinen,<sup>3</sup> Erik Edvardson,<sup>10</sup> Rune Solvang,<sup>10</sup> Nils Chr. Stenseth<sup>4\*</sup>

Both's comment questions our suggestion that the advanced spring arrival time of long-distance migratory birds in Scandinavia and the Mediterranean may reflect a climate-driven evolutionary change. We present additional arguments to support our hypothesis but underscore the importance of additional studies involving direct tests of evolutionary change.

Both (*1*) questions our suggestion that the advanced spring arrival time of long-distance migratory birds in Scandinavia and the Mediterranean may reflect a climate-driven evolutionary change (*2*). A key premise of our interpretation is that spring is arriving earlier in the breeding areas we considered and that most birds are laying eggs earlier than before. Yet Both argues that the species we studied breed mainly in Fennoscandia and northern Russia, where springs have not become warmer, nor has egg-laying advanced. However, recovery of birds banded at the Nordic observatories and at Capri clearly show that Scandinavia (and, to some extent, the Baltic) is where most individuals of the studied species breed (*3–7*). Overall, contrary to Both's assertions (*1, 8*), it is well documented that spring green-up advanced by about 0.5 days/year from 1982 to 2001 in most of Scandinavia and western Russia (*9*). This is

likely to have contributed to earlier peak insect abundance for breeding migrants. Likewise, April and May were warmer between 1991 and 2005 than in the period 1961 to 1990 in Sweden (*10*). However, trends in spring timing do vary within regions, with spring coming later in snow-rich mountain areas, for example (*9*).

Both (*1*) suggests two alternative explanations for the observed change in migration timing of long-distance migrants, neither of which are supported by the available evidence. His first suggestion is that the sizes of populations arriving early might have increased relative to later-arriving populations of the same species. In general, the populations breeding farthest to the north are the last to migrate through our study sites (*11*). If such populations in most species were declining relative to earlier-arriving populations, this might explain our results. However, there is no evidence that this has generally occurred. In Finland, populations have increased in the south relative to the north only in two of the seven long-distance migrant species included in our study (*12*).

Both also suggests that spring migration could be faster as a result of improved ecological conditions en route (*13*), such as increased Sahel rainfall and North African spring temperatures (*1, 13*). However, a reanalysis of our data from Capri indicates that the observed advance in migration dates is unaffected by taking these seemingly favorable conditions into account (*14*). The possibility that some unmeasured environmental cue might have induced a phenotypic shift in the onset of migratory activity or speed of migration in Africa cannot be ruled out. Nevertheless, our result is suggestive, and the next step would be to search for direct evidence of microevolution. For instance, a comparison of individual-

and population-level changes in phenotypic traits may quantify to what degree the observed changes in mean phenotypic traits are caused by plasticity or genetic adaptation (*15*).

Both (*1*) argues that our report suggests that the inadequate timing responses may only be transient and that rapid evolution may solve the birds' mismatch of arrival time and peak food availability (*2*). However, such perfect compensation is not to be expected. The optimal temporal shift in arrival date is always less than the shift in the food peak date because of the survival costs of early arrival (*16*). Hence, despite an evolutionary response, bird populations might still face a temporal mismatch of resources and breeding, which may cause population declines (*17*). In our view, phenotypic plasticity and evolutionary response are not mutually exclusive, and the latter remains a likely explanation for the general trend of earlier springtime arrival of long-distance migrant birds.

## References and Notes

1. C. Both, *Science* **315**, 598 (2006); [www.sciencemag.org/cgi/content/full/315/5812/598b](http://www.sciencemag.org/cgi/content/full/315/5812/598b).
2. N. Jonzén *et al.*, *Science* **312**, 1959 (2006).
3. V. Bakken, O. Runde, E. Tjørve, *Norwegian Bird Ringing Atlas*, Vol. 2 (Stavanger Museum, Stavanger, Norway, 2006).
4. Swedish Museum of Natural History, Bird Ringing Centre, [www.nrm.se/rc](http://www.nrm.se/rc).
5. Finnish Museum of Natural History, Finnish Ringing Centre, [www.fmnh.helsinki.fi/english/zoology/ringing](http://www.fmnh.helsinki.fi/english/zoology/ringing).
6. Italian Ringing Centre, Istituto Nazionale per la Fauna Selvatica, [www.infs.it](http://www.infs.it).
7. N. Jonzén *et al.*, *Ornis Svecica* **16**, 27 (2006).
8. C. Both *et al.*, *Proc. R. Soc. Ser. B* **271**, 1657 (2004).
9. R. Stöckli, P. L. Vidale, *Int. J. Remote Sens.* **25**, 3303 (2004).
10. The Swedish Meteorological and Hydrological Institute, Fact sheet no. 29 (in Swedish) (2006).
11. A. Hedenström, J. Pettersson, *Vår Fågelvärld* **43**, 217 (1984).
12. R. Väisänen, *Linnut-vuosikirja* **2005**, 83 (2005).
13. C. Both, R. G. Bijlsma, M. E. Visser, *J. Avian Biol.* **36**, 368 (2005).
14. The linear trend in on the median arrival date, when taking into account the Sahel wet season (June to October) rainfall, the mean of February to April temperatures at Tunis, and the winter North Atlantic Oscillation (*2*), was  $-0.27$  days/year (95% confidence interval,  $-0.40$  to  $-0.15$ ; the species set is considered as fixed, and the variance of the mean is calculated from the uncertainty of the species-specific effects), which is in line with the temporal trend reported in (*2*). Meteorological information was obtained from (*18*) and (*19*) for Sahel rainfall and Tunis temperature, respectively.
15. A. P. Møller, J. Merilä, *Adv. Ecol. Res.* **35**, 111 (2004).
16. N. Jonzén, A. Hedenström, P. Lundberg, *Proc. R. Soc. Lond. B. Biol. Sci.* **274**, 269 (2007).
17. C. Both, S. Bouwhuis, A. Offermans, C. M. Lessells, M. E. Visser, *Nature* **441**, 81 (2006).
18. Joint Institute for the Study of the Atmosphere and Ocean, [http://jisao.washington.edu/data\\_sets/sahel](http://jisao.washington.edu/data_sets/sahel).
19. National Oceanic and Atmospheric Administration, National Climate Data Center, Global Historical Climatology Network, version 2; <http://iridl.ldeo.columbia.edu/SOURCES/NOAA/NCDC/GHCN/v2>.

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