IVS-1 mutation described by Spritz *et al.*[1,2]. Nine others were studied by S_1 mapping of the erythroid RNA produced, and 8 out of 9 also had the IVS-1 mutation (T-c. Cheng, personal communication). Thus, 12 out of 13 haplotype I chromosomes studied in Mediterraneans had the same mutation. Presumably the majority of individuals homozygous for haplotype I are homozygous for this IVS-1 mutation.

We are therefore led to believe that our sequencing strategy for β^{thal} alleles is a valid one, because β^{thal} alleles are probably under positive selection in $\beta^{A}\beta^{thal}$ heterozygotes causing individual β^{thal} alleles to expand in the population. In other recessive genetic diseases in which positive selection in heterozygotes does not occur, for example galactosaemia, almost all patients may be genetic compounds and our sequencing strategy may not apply.

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Carbon isotope ratios of bone apatite and animal diet reconstruction

OUR model using $\delta^{13}C$ analyses of bone apatite to obtain dietary information from modern and fossil bones[1] has been disputed by Schoeninger and DeNiro who say that carbon isotope ratios in fossil bone apatite cannot be used to obtain dietary information because of postmortem exchange of carbon[2]. We now discuss the evidence.

Although the details of analytical techniques reported by Schoeninger and DeNiro differ from ours, our only significant reservation is their use of 8.5M acetic acid (50:50, v/v) for removal of normal carbonates. We have observed that glacial acetic acid has no appreciable effect on calcite and we wonder if the activity of 8.5M acetic acid is adequate to remove all normal carbonates, a critical pretreatment procedure. We use 1M acetic acid on the whole bone, and again after crushing to <1 mm powder.

The crux of their argument for postmortem exchange of carbon involves evidence from experiments on the ^{14}C dating of bone (refs 10–13 in ref. 2). Their ref. 10 contains no ^{14}C data, but the pertinent information is available elsewhere[3]. The appropriate ^{14}C data from their references 11 and 12, as well as the data from Hassan[3] is presented in Table 1. ^{14}C activities relative to NBS oxalic acid are tabulated for pretreated apatite, for secondary carbonate, and for the age of the sample as it can best be evaluated by dating other materials. In addition, $\delta^{13}C$ analyses of bone apatite and of secondary carbonates are listed where available. Ref. 13 in ref. 2 did not use either collagen or apatite fractions and presents only data on samples which are likely to be contaminated, and thus is not considered here.

Most bone samples of archaeological interest are found in relatively near surface unconsolidated materials and are subjected to contamination with modern carbonate from downward percolating waters (relative ^{14}C activity 1.000). Such a situation is confirmed by all six examples in Table 1 where ^{14}C activities of secondary carbonates were measured. Using a ^{14}C activity of 1.000 for the exchanging carbonate, and a ^{14}C activity appropriate for the independently accepted true age of each sample, we can easily calculate the maximum amount of carbonate exchange that might have occurred for each of the analyses in Table 1. The largest possible exchange indicated is 6.9%, and the average indicated exchange is 3.0%. Whether this is actual isotopic exchange with bone apatite, or simply imperfect removal of modern secondary carbonates, cannot be demonstrated from these data. It is clear, however, that isotopic exchange of carbonate with bone apatite is limited to a few per cent.

Having demonstrated that exchange of carbonate with bone apatite is very limited, let us examine the effect of the maximum indicated exchange on the isotopic data ($\delta^{13}C$) used for dietary information. In the references cited by Schoeninger and DeNiro there are four bone samples for which $\delta^{13}C$ analyses on both apatite and normal carbonates are reported (See Table 1). The carbonate $\delta^{13}C$ analyses differ from the apatite $\delta^{13}C$ analyses by 0.2–4.8‰. A 3% exchange of carbon would lead to an error in $\delta^{13}C$ analysis of an apatite amounting to only 0.00–0.15‰. This is less than the probable analytical error of the apatite $\delta^{13}C$ analysis itself. Such an error cannot significantly affect dietary interpretations using bone apatite $\delta^{13}C$ analyses.

Having shown that postmortem exchange does not seriously affect $\delta^{13}C$ analyses of bone apatite, we must still comment on the actual data presented by Schoeninger and DeNiro[2]. Our paper[1] was based on data from 26 samples, 24 of herbivores and 2 of humans. Subsequent research in our laboratories has indicated that the model we put forward is applicable only to herbivores. Both carnivores and omnivores (including humans) require different models because of the complexity of their diets. Models are being developed which will readily explain most of Schoeninger and DeNiro analyses (18 of their 24 fossil samples are carnivores or omnivores). Our interpretation of bone apatite $\delta^{13}C$ analyses[1] appears to give appropriate dietary information for herbivores as old as 2 Myr (ref. 4). We continue to anticipate that $\delta^{13}C$ analyses on bone apatite from fossil bones will make valuable contributions to Quaternary and Pleistocene research.

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Table 1 ^{14}C and ^{13}C data from Schoeninger and DeNiro citations

Sample name and data source	^{14}C Activity of apatite	Expected ^{14}C activity*†	^{14}C Activity of carbonate*‡	Maximum carbon exchange (%)	$\delta^{13}C$ apatite	$\delta^{13}C$ carbonate‡
Folsom bison[3]	0.322	0.272	1.068	6.9	−6.8	−6.4
Blackwater Draw mammoth[3]	0.280	0.249	1.216	4.1	+1.8	−3.0
Domebo mammoth[3]	0.277	0.255	NA§	3.0	−4.9	−7.0
Trolinger Bog mastodon[3]	0.060	0.061	0.915	−0.1	−11.4	−7.1
Hudson Meng bison (ref. 11 in ref. 2)	0.327	0.295	1.153	4.5	NA§	NA§
Lehner mammoth (ref. 12 in ref. 2)	0.289	0.246	0.862	5.7	NA§	NA§
Hell Gap bison (ref. 12 in ref. 2)	0.324	0.343	0.917	−2.9	NA§	NA§

* ^{14}C activities are relative to modern (1950) carbon. † Expected activity is based on best independent estimates of age. ‡ Carbonate is the secondary carbonate usually evolved with acetic acid. § Not analysed or analyses not available.