Measuring shelf afterlife

SIR — The radioactivity of substances in daily use has been well documented. But it is not common knowledge even to nuclear and health physicists that the fine papers used in high-quality printing, photocopying and writing are indeed radioactive.

Using standard γ-ray spectroscopic methods with a shielded large-volume HpGe detector, we have measured the γ-rays emitted by various paper samples, mostly in the form of unbound scientific journals, magazines and newsprint. In about 24 hours of counting for each sample, the main radiations from paper samples (after room background subtraction) were found to be due to ^{232}Th, ^{226}Ra and ^{40}K. Based on the observed intensity of the most intense γ-ray from each isotope, the absolute activities (pCi per kg dry weight) of selected samples are given in the table.

RADIOACTIVITY LEVELS OF SELECTED PAPER SAMPLES (pCi per kg dry weight)

Sample	^{232}Th	^{226}Ra	^{40}K
Printed in US			
Nature (USA edn)	681 ± 40	275 ± 25	<1,450
Science	795 ± 40	300 ± 25	<1,450
Arctic	15 ± 15	20 ± 2	
Time	667 ± 35	182 ± 20	<1,450
Textbook	506 ± 25	153 ± 15	<1,450
Photocopy paper	266 ± 25	90 ± 20	1,550 ± 150
Newsprint	45 ± 20	20 ± 20	
Printed in UK			
Physics World	844 ± 45	1,310 ± 50	4,550 ± 200
J. environ. Rad.	30 ± 30	50 ± 25	
Printed elsewhere			
Nuclear Phys.	913 ± 50	1,195 ± 50	5,150 ± 200
Austr. J. Phys.	1,810 ± 50	460 ± 40	2,800 ± 200

These data establish the presence of easily detected radionuclides in fine papers. Although we have chosen mainly scientific journals, the activities are expected to be comparable for any publications that use this type of paper. We believe that large differences in absolute activities and in thorium/radium ratios are caused by varying amounts and qualities of the fine clays that are added (a practice started about 50 years ago) to basic paper pulp to produce the durable and high-gloss surfaces used for many colour-illustrated magazines and professional journals. The thorium/radium ratio is determined by the type of fine clays available to paper manufacturers in different continents. The possibility of radioactive printer's ink is excluded by measuring blank photocopy paper.

Our data can provide an estimate of radiation exposure to a person using a library. A seven-shelf bookcase of a typical journal, for example, *Nuclear Physics*, will contain about 0.08 μCi of ^{232}Th, 0.14 μCi of ^{226}Ra and 0.60 μCi of ^{40}K. The dose at the centre of the body of the person standing about 0.4 m in front of the bookcase is about 0.6 μrad h^{-1}. This dose, although small, is comparable to that received by a person living or working in a brick or masonry building (in addition to the normal average background). It is interesting to note that the dose from paper can be reduced by the use of fine papers of low radioactivity as is the case for the journals *Arctic* and the *Journal of Environmental Radiation*. Whether such adjustments to our lifestyles are justified by the dose rates involved is open to question.

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Sexual selection and MHC genes

SIR — Potts *et al.*[1] suggest that mate preferences can account for the high genetic diversity of the major histocompatibility complex (MHC). This follows from a study of enclosed populations of wild-caught mice. In all populations there were fewer offspring homozygous for MHC than would be expected from non-random mating. The main cause of the deficiency of homozygous offspring, according to Potts *et al.*, is that when females mate extraterritorially, they prefer males that are relatively MHC-disparate. Here we suggest other interpretations that need to be excluded, and which have general implications for the study of mating preferences attributed to genetic markers.

One alternative explanation for the dearth of MHC-homozygous offspring is that MHC-heterozygous males are fitter than MHC-homozygous males (which could result from genes linked to the MHC locus). For example they may be more active or have larger home ranges. Second, females may tend to reject MHC-homozygous territorial males because they are less active. So when a female mates extraterritorially, she will have a higher encounter rate with heterozygous males, independent of any potential mate preference. Assume that mating frequency is proportional to encounter rate. If the population is in approximate Hardy–Weinberg equilibrium, then extraterritorial matings will yield more heterozygous offspring.

These possibilities can be tested. The former can be rejected if MHC-heterozygous males are not fitter in ways that affect their mating success. However, such a result is also likely to lessen one reason for mate choice, that heterozygosity at either the MHC or linked loci confers a fitness advantage. The second possibility, that females avoid mating with MHC-homozygous territorial males can be tested by comparing territorial males accepted and rejected as mates.

Doubts can also be raised over the evidence that extraterritorial matings produce an excess of MHC-heterozygous offspring. For extraterritorial matings, Potts *et al.* compare the number of heterozygous and homozygous offspring to that expected "if the female has mated solely with her territorial male". This reveals that these females have an excess of heterozygous offspring compared to that expected if they had mated with their territorial male. But this does not necessarily indicate that females mating extraterritorially prefer relatively MHC-disparate males. For that to be true, the frequency of heterozygous and homozygous offspring from extraterritorial matings should be different from the expectation for a female who engages in extraterritorial matings and who chooses her mate at random. These expected values can be derived directly from the data, which unfortunately have not yet been published.

The finding that mice can discriminate between individuals on the basis of urinary odours related to MHC alleles is suggestive that such a system could be used for mate choice in the wild. Experiments designed to demonstrate that mate choice is influenced by a particular genetic marker must consider two general, additional explanations. The first is related to our example of territory size: any behavioural factor correlated with the genetic marker that tends to make females more likely by chance to encounter males with that marker is a plausible alternative cause of nonrandom