

Is CO₂ euthanasia humane?

SIR — David Freed (*Nature* 11 August, p.482) casts doubts on the humaneness of carbon dioxide for the killing of laboratory animals. I believe that Dr Freed's doubts are, to a large extent, correct as long as one is considering relatively large animals.

In mammals larger than guinea pigs there seems to be a delay in the onset of unconsciousness, and the animals appear distressed (restlessness, deep respiration, salivation, pawing at noses) before they collapse. This distress is believed to result mainly from irritation of the lining of the nasal passages by CO₂ going into solution and forming H₂CO₃. In smaller creatures, such as rat and mouse, the onset of collapse is quick and it seems the animal is unconscious before local irritation of the mucus membranes sets in. It seems that, in small animals, CO₂ penetrates quickly to the depth of the respiratory tract and is absorbed into the blood giving a quick rise to anaesthetic levels. In larger animals the penetration and speed of absorption seem slower and the animals appear disturbed before becoming unconscious.

The Universities Federation for Animal Welfare recommends CO₂ for humane killing of rats, mice and guinea-pigs, but not for larger animals. ROGER EW BANK
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SIR — Dr Freed's letter (*Nature* 11 August, p.482) prompts me to report some results of war-time work on CO₂ intoxication, conducted by a group at the National Institute for Medical Research. The work was virtually unpublished, but an illustrative record of the handwriting of four subjects becoming unconscious while breathing 10, 12.5, 15 and 20 per cent CO₂ in oxygen may be found in *Proc. R. Instn Gt Br.* 41 571-596.

The work arose in connection with shallow-water blackout in divers studying CO₂ accumulation in self-contained breathing sets, possibly due to poor soda-lime canister packing or impaired ventilatory responses during high energy expenditure. Orthodoxy stated at the time (as Dr Freed repeats today) that breathing high concentrations of CO₂ produces an unbearable respiratory stimulation, long before unconsciousness occurs. This is true if air is rebreathed from a bag; then hypoxic and hypercapnic stimuli are combined. If oxygen is rebreathed, however, the hypoxic stimulus is moved, and a different result is obtained. Some respiratory stimulation occurs, rather variable in magnitude from one subject to another, but it is not distressing, and may even be hardly noticed in comparison with the advancing anaesthetic effect of the CO₂. Particularly striking was the experiment on a very experienced aviation physiologist;

after being subjected to rebreathing from a bag of oxygen, without being told the composition of the respired gas, and having lost consciousness on it, he came round saying "I'll swear that was hypoxia!"

By rebreathing, unconsciousness is lost when the CO₂ concentration has risen to about 10 per cent. If a defined mixture is breathed, some subjects become unconscious on 10 per cent in a few minutes, others require 12.5 per cent. The experience is no more disagreeable than any other form of rapid intoxication, and as with alcoholic intoxication, characteristic differences of behaviour appear at the "endpoint". With longer exposures to concentrations in the range 5-10 per cent, the most striking phenomenon is the strong smell of ammonia on return to fresh air, and the most unpleasant is the "CO₂ off-effect", of headache, pallor, "feeling like death", and nausea and vomiting.

On the particular issue of humane killing, therefore, CO₂ appears to me a very suitable anaesthetic. It was, of course, the first anaesthetic ever used for a surgical operation, in animals by Henry Hill Hickman around 1820.

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Power in Washington

SIR — Although it does not affect the argument in "Public enterprise and private sector" (*Nature* 11 August, p.473), the Washington Public Power Supply System (WPPS) was not and is not "... the electricity supplying electric power in the northwestern United States ...", but a peculiar entity formed by a number of Washington public utility districts, operating usually at the county or city level, and having contracted with a number of other northwestern utilities, both public and private, for the sale of nuclear generated power from five reactors, three of which have now been discontinued.

The separate utilities' reluctance to pay for the discontinued plants led to court proceedings which ended in findings that the Washington Public Utility Districts lacked the power to form WPPS originally and that many of the other public utilities lacked the power to enter into the kinds of contracts involved — rather more than a simple current purchase of power. Thus the individual utilities are free of liability (pending resolution of the bondholders' suit for liability because of utility board members' alleged civil fraud and negligence) and WPPS has no other sources of revenue sufficient to service the bonds, and has therefore defaulted.

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Homology redirected

SIR — Hughes (*Nature* 24 March, p. 706) calls attention to the continued misuse of the term *homology*. Mayr *et al.*² proposed the term *dendrogram* for phylogenetic schemes based on contemporary forms (vs. "phylogenetic trees" for such schemes based on fossil evidence) but failed to suggest a term to describe the suggested relationships of the components (Mayr³ still maintains this definition of dendrogram). The inappropriate and erroneous use of *homology* has also troubled me and in 1971⁴ I proposed using the available and related term *paromology* (Gr., partial admission, from παρ (α- subsidiary + ομολογία agreement, admission, Homology. OED). Thus while feathers and hair are homologous to scales, the chromosomal bands of human, gorilla, chimpanzee and orangutan would be paromologous as would be the various forms of cytochrome *c* (ref.5) and myoglobin⁶. Further, while arms and wings are homologues, the *cdc2* gene of *Schizosaccharomyces pombe* and the *cdc28* gene of *Saccharomyces cerevisiae*⁷ would be paromologous as would be the crozier of the ascomycetes and the clamp of the basidiomycetes.

Many of the relationships that scientists are attempting to express today are based on a wide diversity of contemporary forms. There is an urgent need for an acceptable term to express these imputed relationships that will not erode and debase the meaning of homology. I believe paromology and its derivatives could satisfy this need. It could be applied to comparative behaviours, to similar-appearing fossils until such time as they were historically linked, to comparable human artefacts excavated from different sites, and to the many correlative structures found in genetics, molecular and cell biology, and biochemistry. The introduction and consistent use of the "new" set of terms could markedly clarify the presentation and understanding of these two fundamentally different ways of classifying species: on the basis of similarities supported by fossil evidence⁸ or on the basis of similarities alone⁹. This would be particularly true if both classifications were used together.

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