superoxide ion. The resulting reduction in superoxide concentration decreases tissue damage due to toxic concentrations of superoxide and this decrease in damage is the radioprotective effect.

Other radioprotective agents also contain electron accepting groups and may act similarly.

Yours, etc.,
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Vitamin C and radioprotection

(In reply)

THE EDITOR—SIR,

Gregory raises the question of the mechanism through which vitamin C exerts the radioprotective effect observed by us in Chinese hamster ovary cells (O'Connor *et al.*, 1977). The data we presented was such that in its own right it gave no indication of a likely mechanism. Consequently the basis for the effect was considered equally likely to be physiological or chemical. A chemical mechanism was intended to imply a direct interaction between ascorbate and some radiation induced factors in the cell. On the other hand a physiological mechanism was intended to convey a more complex process whereby the cell was altered by the presence of ascorbate in such a way that it was subsequently more resistant when challenged with radiation.

It should be possible to go some way towards distinguishing between chemical and physiological effects through relatively simple experiments designed to determine the time required for the effect to appear. Chemical effects are likely to become evident almost instantaneously as they depend only on the presence of the agent during irradiation. Physiological effects such as those produced by protracted hypoxia (Foster *et al.*, 1971; Alper, 1977) or by Miracil–D (Bases, 1970) may take longer to appear and may be induced by the presence of the agent before or after the irradiation without the necessity for the agent being present during irradiation. Much more sophisticated experiments would be required to distinguish between the two chemical-type mechanisms discussed by Gregory. However, it does appear from his comments and from recent evidence that the protective effect of vitamin C is very likely to be chemical in origin (Biaglow and Jacobson, 1977; Gregory, preceding letter; Redpath and Wilson, 1973).

Regardless of the detail of the mechanism, the evidence presently available demonstrates that vitamin C is a radioprotective agent. This may appear to give rise to a problem when administering high doses of the vitamin to patients undergoing radiotherapy (Cameron and Pauling, 1974) as some tumours have substantially higher levels of vitamin C than surrounding normal tissues (Moriarty *et al.*, 1977 a,b). Therefore it is possible that the tumour may be protected to a greater extent than normal tissue. In the case of hypoxic tumours, however, vitamin C would be unlikely to add to the protective effect of oxygen deficiency since the mechanism underlying both protective states appears to be the inhibition of the formation and/or fixation of free radicals (Redpath and Wilson, 1973; Lett *et al.*, 1967; Chapman *et al.*, 1973). Therefore, with hypoxic tumours, vitamin C could leave the sensitivity of the tumour unaltered while protecting surrounding normal tissue, thereby offering a therapeutic advantage. This is a reversal of the usual procedure undertaken to enhance the therapeutic ratio, in which attempts are made to sensitise the tumour relative to surrounding tissues.

The overall position of ascorbate in relation to radiotherapy requires further study in the light of recent data presented by Biaglow and Jacobson (1977). They reported an interaction between ascorbate and hypoxic-cell sensitizing compounds (*e.g.* Flagyl or Ro–07–0582) leading to oxidation of the ascorbate. This gives rise to the possibility of increased oxygen consumption, which could lead to even greater radioprotection for the tumour and negate the effect of the nitrocompounds. Formation of toxic products is another possibility. This could be beneficial by killing tumour cells or deleterious by leading to side effects such as neurotoxicity (Fowler *et al.*, 1976).

Therefore in view of all the possible interactions between vitamin C, nitrocompounds and radiation, it is evident that the vitamin needs careful scrutiny under a variety of conditions before its proper place in the management of radiotherapy patients can be determined.

Yours, etc.,
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Lead aprons and film badges

THE EDITOR—SIR,

I have read with interest the questions raised by your correspondents Dr. Bray and Dr. Sear whether a film badge should be worn over or under a protective lead apron.

The key point is that if the film badge is worn on top of the apron then it will greatly overestimate the exposure received by the user. The answer is not simple.

The United States Nuclear Regulatory Commission in Title 10 Code of Federal Regulations, Part 20 (10 CFR 20) states that any individual in a restricted area in any period of one calender quarter should not be exposed to a dose in excess of 1.25 rem to the following part(s) of the body: whole body, gonads, active blood-forming organs, head and trunk, lens of eye.

It is not true that by wearing the film badge on the collar the exposure to the head and trunk could be measured. The permissible limiting factor is the exposure to the eyes. To determine that this is not exceeded, some authorities recommend wearing the film badge on the collar or attaching it to eye glasses. Neither of these answers is totally satisfactory where an active person is involved, but some state regulatory agencies are requiring this. The wearing of the film badge under the apron is likewise a less than desirable choice as it underestimates eye exposure by significant quantities. Hence the answer is not simple. One practical solution to this problem which may not be acceptable to others for aesthetic reasons is to wear the film badge on the forehead using a head band or if it is a TLD chip it could be placed on the forehead using a temporary adhesive, as a Tilak (beauty spot) worn by Indian ladies for aesthetic and cultural reasons.

Yours, etc.,

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Alterations in the manuscript of Röntgen's publication "Ueber eine neue Art von Strahlen" (1895)

THE EDITOR—SIR,

Reading F. Freund's article "Lenard's share in the discovery of X-rays" in the 1946 issue of your Journal, I was struck by a passage that opposes Röntgen's statement that he had made his discovery when experimenting with a Hittorf tube. The passage reads: ". . . it can be reasonably assumed that he [Röntgen] experimented with a Lenard tube, when on November 8, 1895, a barium platinocyanide screen was lying at a distance beyond the range of cathode rays and started to fluoresce. This assumption can be confirmed by Rontgen's (1895) original manuscript 'A New Kind of Rays'. He writes: '. . . and covered the Lenard apparatus with a tightly-fitting coat of thin cardboard. . .', but crossed 'Lenard apparatus' out and wrote instead 'the tube'. . ."

The only author who seems to have contradicted this view was Etter (1946), when he commented that this "hardly proved that Röntgen used the Lenard tube exclusively".

In my opinion one can disagree with Freund (1946) on the much firmer ground that the change in the manuscript was never made in the form Freund assumed.

I came to my conclusion on consulting a reproduction of the first page in question (Fig. 1). Careful inspection of the correction in the fifth line led to the following observations:

(1) The last of the three crossed-out words, to which Freund refers, is unmistakably "Apparat".
(2) The preceding crossed-out word, which according to Freund might have been "Lenard'schen", certainly covers not more than 15 mm, whereas the word "Lenard'schen", as it appears earlier in the text, has a length of 26 mm.
(3) The only remaining possibility that fits Freund's theory is that Röntgen wrote "Lenard Apparat" ("Lenard" having the correct length), but this would imply a rather strong deviation from normal German usage.
(4) The still visible part of the first letter of this crossed-out word shows more resemblance to the capital E, as it occurs in the manuscript, than to the capital L.
(5) In my opinion Röntgen first started to write "den Entladungsapparat", but broke off before the letter g was written. He may have done so, because he realized at this point that he had used the word "Entladungen" in the previous line. So he crossed out the unfinished word "Entladun" (having a length of about 15 mm) and wrote instead "Apparat". Then realizing that the word "Apparat" had also been used nearby and might in addition confusingly refer to the "Rumkorff", he crossed out "den Apparat" and finally wrote down "die Röhre".

I conclude that the considered alterations made by Röntgen in his manuscript serve no other than stylistic purposes, and quite tally with the classical conception of his article, in which the style was to match the beauty of his discovery.

Yours, etc.,

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(*illustration overleaf*)