Biological Effects of UV-Radiation Generated Within the Living Organism

Irradiation by the electromagnetic radiation of wave-length $\lambda = 1850–3800$ Å (i.e. the UV-radiation) produces well-known[1–3] biological effects on microorganisms, cell and tissue cultures, as well as on mammalian skin. Since, contrary to the X-rays, the UV-radiation is absorbed already by the skin or subdermal connective tissues, its effect is observable directly only on the surface area where the absorption takes place. Hardly any information is available, therefore, on the direct effect of UV-radiation on the internal organs.

For the investigation of this effect, the possible means of generating UV-light within the living organism, organ or tissue were studied. Considering the fact that upon irradiation with X- or β-rays some solids and liquids are known to emit electromagnetic radiation with wave-lengths lying in the UV-range, experiments were performed with the aim to utilize this physical phenomenon for producing UV-radiation in organs and cavities of the living body.

Tests on a large number of liquid and solid targets for the production of UV-radiation have shown that one of the convenient methods to produce a radiation in the biologically most effective range of wave-lengths ($\lambda = 2300$ to 2800 Å) is the irradiation with externally produced X-rays of calcium fluoride (CaF_2) crystals sealed in quartz ampules. The wave-length spectrum of the radiation thus produced, shown in Figure 1, is seen to lie in the range $\lambda = 2400–3500$ Å.

It has been observed in microbiological and cytological studies that DNA synthesis is inhibited by UV-radiation. Thus, the most useful biological target for the study of the effect of UV-radiation seemed to be an organ where the DNA synthesis is well appreciable and where the emitter of UV-light can be conveniently introduced. For this reason the small intestine of rats was chosen for the first experiments.

Materials and methods. The cylindrical CaF_2 target sealed in 3 mm diameter, 6 mm long quartz tube was introduced into the intestine of the experimental animal (Figure 2). For irradiation Super Liliput 200 type X-ray tube with a performance of 180 kV, tube current 4 mA was used, placed at a distance of 50 cm from the target with 0.5 mm thick Cu filter between tube and target.

The total intensity of the UV-radiation emitted from the CaF_2 crystal could not be determined by direct measurement since no appropriate detector with known wave-length dependence and calibrated sensitivity is available for the time being which would be needed for measuring the low intensity UV-radiation in the presence of high X-ray background.

Estimations were therefore made by making use of the known efficiency data on CaF_2-like scintillators. The output power of the X-ray tube in erg/sec units could be evaluated for the given experimental conditions from the tabulated data of JAEGER[4]. Calculating with the absorption of this output power and the averaged atomic number of the CaF_2 crystal, the energy absorbed per unit mass of the CaF_2 target can be estimated as being of the order of $10^2–10^3$ erg/sec. Knowing the conversion efficiency of CaF_2, i.e. the ratio of the X-ray power input absorbed to the UV-light emitted per unit time, to be of the order of 10^{-2}, the UV-light output from the CaF_2 target is estimated to be 1 erg/sec.

All experiments were performed on the columnar epithelium covering the jejunal villi of rats of either sex weighing 200–300 g. Anaesthetized with pentobarbitone (4 mg/100 g; Nembutal, Rhône-Poulenc, Paris), the animals were laparotomized, the jejunum was exposed, and jejunotomy done about 2 cm distal to the duodenum. The gut was washed thoroughly with Tyrode's solution at 37 °C, and the washing fluid allowed to flow into the colon. Through the opening into the jejunum 1 quartz tube containing CaF_2 crystal and 1 empty tube were placed into the jejunal lumen and each was fixed in the gut using minute tweezers. The guts were placed back into the abdominal cavity and the animals subjected to irradiation with 120 R (air dose). Irradiation completed, the sites of the tubules were marked with fine seroserous sutures and the tubules themselves lifted out through the opening established by jejunotomy now closed. Penicillin (100,000 I.U.) was placed into the abdominal cavity to prevent peritonitis, and the abdominal wall was closed.

1 R. W. KAPLAN, in *Strahlenbiologie, Strahlentherapie, Nuklearmedizin und Krebsforschung* (Eds. H. R. SCHINZ, H. HOLTHUSEN, H. LANGENDORFF, B. BAJEWSKY, G. SCHUBERT; Georg Thieme Verlag, Stuttgart 1959).

2 O. A. TROWELL, in *Cells and Tissues in Culture* (Ed. E. N. WILLMER; Academic Press, London, New York 1966), vol. 3.

3 P. DANIELS JR., D. BROPBY and W. Z. LOBITZ JR., J. invest. Derm. *37*, 351 (1961).

4 R. C. JAEGER, *Dosimetrie und Strahlenschutz. Physikalische und technische Daten* (Georg Thieme Verlag, Stuttgart 1959), p. 140.

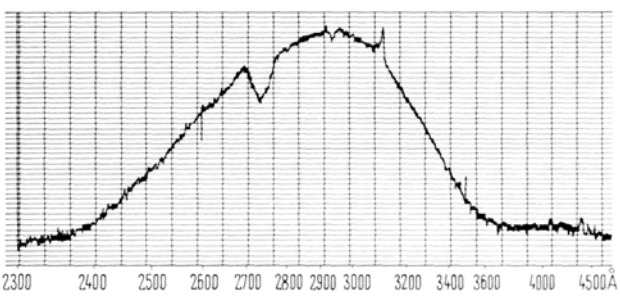


Fig. 1. Range of wave-lengths of UV-radiation emitted by CaF_2 crystals.

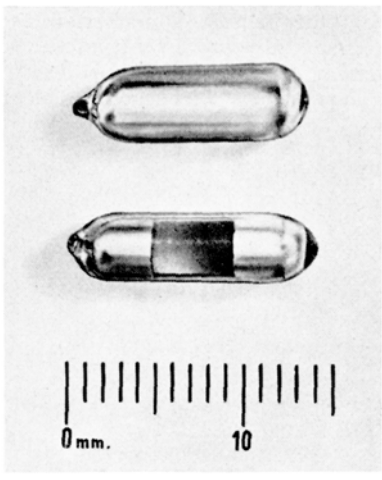
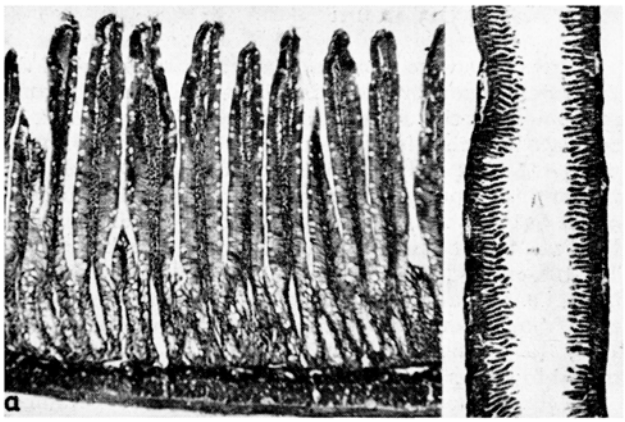
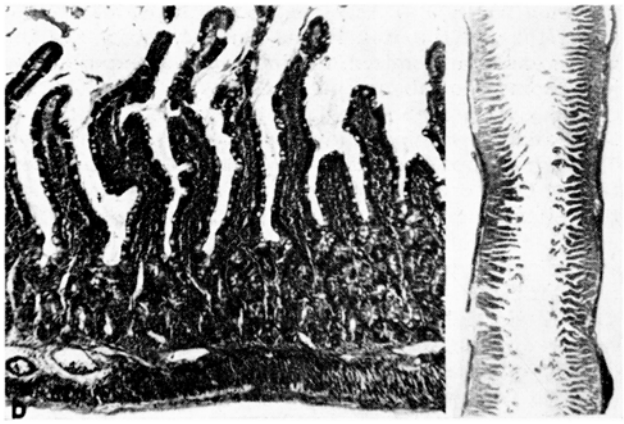


Fig. 2. One empty quartz tube and one containing CaF_2.





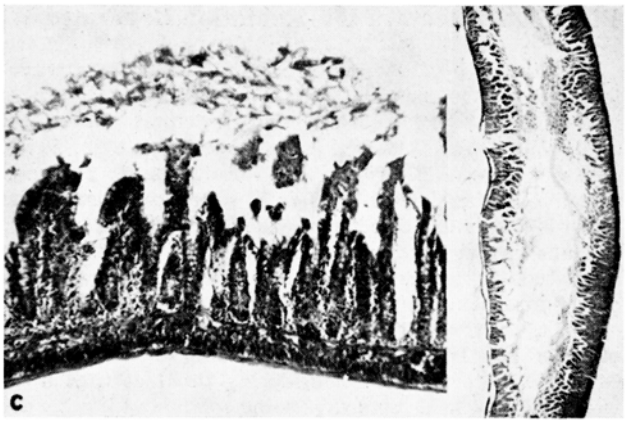


Fig. 3. Rat jejunum, Azan staining. × 10 and × 80, respectively. (a) Control (not irradiated). (b) The effect of X-ray irradiation on the jejunum, with an empty tube placed into it (120 R). (c) The effect of X-ray irradiation on the jejunum, with a tube in it containing CaF_2 crystals (120 R + UV).

At 3, 6, 12 and 24 h after irradiation the animals were decapitated, the marked pieces of gut removed, fixed in 4% formalin, embedded in paraffin, and sections of 10 μ thickness, cut parallel to the longitudinal axis of the fragments, were stained with Azan.

Results. The intestinal fragments irradiated with X-rays only, i.e. the places in the gut of the empty quartz tubules or no tubules, showed but moderate histological damage (Figure 3b). Shrinkage of the epithelium covering the villi, pyknotic cell nuclei and, at places, loss of epithelium were observed. The intestinal mucosa was conspicuous for hyperaemia extending to both the villi and the submucosa. The muscular layer remained unaffected, except for the occasional presence of vast Pleyer's patches with lymphocytic infiltration of the surrounding intestinal mucous membrane. The crypts of Lieberkühn were intact.

In those parts of the small intestine which had been exposed to the combined action of X-rays and UV-light, i.e. in the places of the tubules with CaF_2 crystals within them, far more severe damage was observed (Figure 3c). Shrinkage and desquamation of the epithelium covering the villi was much more pronounced; here and there the intestinal mucosa too was desquamative; and only the crypts remained, but these were highly hyperaemic. The intestinal wall was ulcerated. The muscular layer showed no sign of damage.

The experiments described appear to be evidence that UV irradiation of internal organs in vivo is possible by the application of an external source of radiation.

Zusammenfassung. Eine Methode wird beschrieben, die es ermöglicht, UV-Strahlung innerhalb des Dünndarms in vivo zu erzeugen. Die induzierte Strahlung verursacht am Zottenepithel des Rattenjejunums eine wesentlich stärkere Schädigung als die zur Induktion verwendete Röntgenstrahlung.

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