(approximately 50 mg) could in no way account for the amount of glucose contributed by renal tissue. As can be seen from the data, renal glycogen did not disappear but increased slightly in amount during the period glucose was being released into the blood stream. It is obvious, therefore, that the glucose contributed to blood by the kidney arises from noncarbohydrate precursors. The renal output of glucose is larger than can be attributed to temporary storage of glucose as glycogen with subsequent glycogenolysis and release of glucose to the blood stream.

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## The Effect of Exercise upon the Lethality of Roentgen Rays for Rats


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The extent of biological damage resulting from exposure to roentgen rays can be altered by physical and chemical measures that alter the metabolic level of the test organism. The mortality rate of irradiated homeothermic animals can be increased by exposure to the physical stress of a hypothermic environment following irradiation (*6*, *10*). Irradiated poikilothermic organisms, such as fertilized *Ascaris* eggs (*3*), frogs (*9*), chick embryos (*11*), and newborn rats (*4–6*), show evidence of greater resistance or repair when kept at low temperature. In several of these studies (*3–5*, *11*), the lowered metabolic activity of the organism is indicated as the explanation for increased resistance to radiation. It is of interest to note that anoxic conditions favor survival of organisms and enhance tissue resistance to radiation (*1*, *5*, *8*).

Treatment of mice with thyroxine greatly increases the lethality of a given dose of ionizing radiation—an increased oxygen consumption was also demonstrated (*2*). Kirschner *et al.* (*7*) demonstrated that rats that died following potentially lethal doses of x-rays had higher postirradiation metabolic rates than those that survived, although both groups showed rises above normal.

Such studies suggest that conditions tending to increase the metabolic rate would also increase the lethal effects of roentgen rays. In order to investigate further the role of metabolic level in determining radiosensitivity, vigorous exercise was selected to provide a physiological means of increasing the metabolic rate as an alternative to stimulation by drugs or changes in the physical environment of the organism.

TABLE 1

TOTAL MORTALITY TO RATS* FOR EACH DOSE LEVEL OF X-RAYS DELIVERED TO THE WHOLE BODY

| | Not irradiated, exercised | Irradiated, not exercised | Irradiated, exercised |
|---|---|---|---|
| 600 r | | | |
| Initial No. | 18 | 30 | 26 |
| No. died | 0 | 0 | 13 |
| % Died | 0 | 0 | 50 |
| 700 r | | | |
| Initial No. | 26 | 38 | 26 |
| No. died | 0 | 13 | 24 |
| % died | 0 | 44 | 92 |
| 860 r | | | |
| Initial No. | 21 | 30 | 33 |
| No. died | 0 | 25 | 33 |
| % died | 0 | 83 | 100 |

* Animals were observed for 90 days.

Male rats of Sprague-Dawley strain bred in this laboratory were used throughout this study. For each dose level studied, all animals were from litters whelped at approximately the same time and were of similar weight (± 8%). The exercised animals performed a standardized exhaustive exercise test for rats, which was developed in this laboratory (*12*). In this test, they were allowed to swim individually in tanks of water until they were exhausted. The animals were exercised for ten trials prior to irradiation in order to adapt them to the conditions of testing. After irradiation they were exercised daily, five times per week throughout the study. At each radiation-dose level employed, nonirradiated animals were exercised concurrently with the irradiated animals, but no deleterious effects of the performance test per se were observed. The duration of exercise was found to be 15–30 min per trial with a weight load of 10 g attached to each animal.

Because the number of animals that could be exercised per day was limited, irradiation at each dose level was performed on different days and with slightly different radiation factors, as follows: Radiation factors for 600 r were: 250 kv x-rays, 15 ma; 1.3-mm copper filter; target distance, 27 in.; 25 r/min air dose. For 700 r and 860 r the factors were: 240 kv x-rays, 8 ma; 0.6-mm copper filter; target distance, 39 in.; 8.5 r/min air dose.

After irradiation with 600 r, 50% of the exercised rats died, and all nonexercised irradiated rats survived (Table 1 and Fig. 1). Exhaustive exercise of less than 30-min duration per day was sufficient to induce a 50% mortality at this dose of x-rays. At a dose (700 r) that was somewhat lethal (44%) to nonexercised animals, there was a doubling in the incidence of mortality (92%) among exercised animals. At a highly lethal dose (860 r), animals that were exercised showed symptoms of roughened coat, diarrhea, and crusted nares much sooner after irradiation than did their nonexercised controls. With


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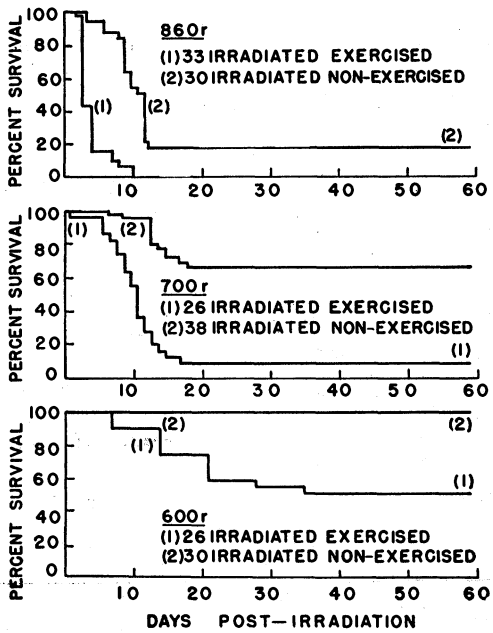


FIG. 1. Effect of exhaustive exercise upon postirradiation survival.

doses (700 r–860 r) that are, to a degree, lethal for non-exercised animals, the exercised animals had a much shorter postirradiation survival time, as well as a higher mortality rate.

As the animals were immersed in water during the period of exercise, it became necessary to know whether exposure to water without exercise would alter the mortality of irradiated rats. After a dose of 860 r, 30 irradiated rats were immersed to the neck in the swimming tanks 20 min daily for 3 weeks in wire containers that did not permit the animals to exercise, without altering the mortality rate from that of nonexposed irradiated rats. To determine whether exercise prior to irradiation would alter the mortality rate, a group of 20 rats, irradiated with 860 r, was exercised exhaustively for ten trials before irradiation and given no further treatment. The mortality rate was similar to that of nonexercised irradiated animals; hence it appears that the mortality rate is altered only if the animals are exercised after irradiation.

The increase in mortality with exercise following irradiation could not be correlated with alterations in total body weight. The time at which minimum body weight had been reached following radiation was similar for exercised and nonexercised animals. The weight loss was not sufficiently greater in exercised animals to provide evidence for a correlation between weight loss and increased mortality.

It is apparent that the lethality of roentgen rays at the doses studied (600 r, 700 r, and 860 r) is increased by the repeated performance of vigorous exercise following irradiation. It is suggested that the increased mortality observed with animals exercised after irradiation provides additional evidence of the relation between radiosensitivity and metabolic level.


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# Adaptive Production of Amylase and Lipase by Three Species of Fungi[1]


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Recently, it was found that several bacteria and yeasts form certain enzymes adaptively (*4, 6, 9*). The present paper describes what appears to be adaptive production of amylase and lipase by three fungi.

*Aspergillus flavus* Link, *A. terreus* Thom, and a species of *Penicillium* tentatively identified as *P. notatum* Westling were grown at room temperature in 250-ml Erlenmeyer flasks containing 50 ml of medium. The basal medium for all the experiments was that of Czapek-Dox (*8*). Sucrose and soluble starch were compared as carbon sources of amylase production, and sucrose was compared with Mazola corn oil as a carbon source for lipase production.

*Amylase.* Twenty milliliters of a 1% agar solution containing 0.1% soluble starch and, as a preservative, 1 part formaldehyde in 1,500 parts of medium, was dispensed into each of several Petri dishes and allowed to harden. Filter paper disks 15 mm in diam were dipped into a solution or suspension of the material to be tested for amylase activity, the excess was drained off, and the disks were placed on the agar. Four disks were applied to each plate, three disks containing active material and one containing material heated in boiling water to serve as a control. The dishes were incubated at 30° C for 24 hr, and then were flooded with iodine-potassium iodide. The diameter of the clear zone around each disk was used as a measure of the amount of amylase present (*5*).

The amylase activities of the mycelium, and of the culture liquid in which the mycelium was growing, were tested. The mycelium was ground in several changes of

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