suggest that scientists and engineers do not differ in these respects from other workers. Indeed, industrial studies made in mass-production environments have indicated that the industrial worker, too, desires to share in program development, to make suggestions about his work and the work of his shop, and to have adequate responsibility and authority to do his job.[7] Apparently the characteristics that are commonly supposed to distinguish scientific personnel from all other types of individuals are, in fact, simply variations of degree, rather than differences of kind.

One final observation should be made in respect to the differences in attitude patterns that apparently characterized the respondents from some laboratories as compared with those from others. These differences were not presented in the formal report for a number of reasons, one of which was that in several instances there were too few respondents to permit valid statistical comparisons to be made. Nonetheless, it was evident that the quality of morale among respondents from the several participating laboratories did differ, with some laboratories having seemingly engendered more favorable attitudes. This suggests that there is need for the development of attitude-measuring instruments that can be used on a repetitive basis to appraise morale in individual government laboratories. Such devices should materially assist in the location of trouble spots and would represent a necessary first step in the development of improved morale.

[7] Fritz Roethlisberger. *Management and Morale.* Cambridge, Mass.: Harvard Univ. Press (1941); Elton Mayo. *Social Problems of an Industrial Civilization.* Cambridge: Harvard Univ. Press (1945).

# *Technical Papers*

## Recovery from Radiation Injury[1]

**L. O. Jacobson, E. L. Simmons, E. K. Marks, and J. H. Eldredge**

***Argonne National Laboratory, the Department of Medicine, the Institute of Radiobiology and Biophysics of the University of Chicago, and the College of the University of Chicago***

The $LD_{50}$[2] for intact young adult mice[3] has been shown to be in the neighborhood of 550 r, whereas the $LD_{50}$ for mice with lead-shielding of the exteriorized spleen during exposure to total-body x-radiation is about 1,025 r (*1, 2*). In contrast to the hematopoietic changes seen after the same exposure without spleen-shielding, no anemia, and only a transient leucopenia, appeared in spleen-shielded mice exposed to 1,025 r. This was attributed to the fact that ectopic blood formation was intensified in the shielded spleen within 48 hr after the exposure, and recovery of other hematopoietic tissue occurred within 8 days. In the animals without spleen-shielding, no recovery of hematopoietic tissue occurred before death. This brief report attempts to clarify some of the factors involved in this observation.

The techniques employed in these experiments are essentially similar to those reported previously (*2*). Tissues were encased in ¼-in. thick lead shields. The x-radiation was generated in a 250-kvp machine operating at 15 ma. The target distance was 59 cm. All animals were anesthetized with Nembutal (0.072 mg/g) during irradiation.

As is shown in Table 1, lead-shielding of part of the exteriorized liver, the exteriorized intestine, the entire head, or one hind leg, including the thigh, enhances survival of mice exposed to 1,025 r total-body x-radiation. Survival under these circumstances is considerably less than for spleen, shielding. Shielding one exteriorized kidney does not enhance survival. Recovery of the irradiated hematopoietic system and of the gastrointestinal tract, as judged by histopathologic study, is essentially complete within 8 days in spleen-

TABLE 1

SURVIVAL OF MICE EXPOSED TO 1,025 r X-RADIATION WITH LEAD PROTECTION OF VARIOUS TISSUES

| No. animals | Tissue lead-shielded | Survival (%) | Hematopoietic recovery (8 days) |
|---|---|---|---|
| 135 | Exteriorized spleen (0.1 g) | 77.7 | Complete (++++) |
| 93 | None | 0 | 0 |
| 15 | Exteriorized lobe of liver (0.8 g) | 33 | Nearly complete (+++) |
| 15 | None | 0 | 0 |
| 15 | Exteriorized intestine (2.5 g) | 26.6 | Nearly complete (+++) |
| 15 | None | 0 | 0 |
| 18 | Head (3.0 g) | 27.7 | Only partial (+) |
| 12 | None | 0 | 0 |
| 15 | Right hind limb, including thigh (1.5 g) | 13 | Not studied |
| 28 | Exteriorized right kidney (0.19 g) | 0 | 0 |
| 8 | None | 0 | 0 |

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[2] Dosage required to kill 50% of animals in 28 days.

[3] CF-1. Raised by Carworth Farms—homozygous for recessive genes aa, bb, cc.

TABLE 2

SURVIVAL OF MICE EXPOSED TO 1,025 r WITH LEAD PROTECTION OF THE SURGICALLY MOBILIZED SPLEEN WITH REMOVAL OF THE SPLEEN AT VARYING INTERVALS AFTER X-RAY

| No. mice used | Spleen-shielding | Interval of splenectomy after irradiation | Survival (%) |
|---|---|---|---|
| 24 | Yes | Within 10 min before x-ray | 0 |
| 24 | " | Within 5 min after x-ray | 0 |
| 54 | " | 1–6 hr after x-ray | 66 |
| 95 | " | 2 days after x-ray | 39 |

shielded mice (*2*). Recovery of these tissues in liver- or intestine-shielded animals at 8 days is nearly as far advanced as in the spleen-shielded animals, whereas after lead-shielding of the head, recovery of the tissues is minimal at this interval and nil after kidney-shielding.

The survival of mice in which the circulation to the shielded spleen is clamped off during exposure of the animal to 1,025 r (the clamp is released immediately thereafter) is approximately the same as the survival of animals with spleen-shielding without clamping.

Surgical extirpation of the shielded spleen at intervals after exposure to 1,025 r shows that a beneficial effect on survival, on regeneration of hematopoietic tissue, and on regeneration of the gastrointestinal tract has already been exerted if the shielded spleen has been left intact in the circulation for 1–6 hr (Table 2).

Transplantation of 4 spleens (total weight *ca.* 10 mg) from mice 1–12 days old into the peritoneal cavity of mice immediately after exposure of the recipient adult mice to 1,025 r total-body x-radiation significantly increases the survival of the irradiated mice and hastens regeneration of hematopoietic and gastrointestinal tissue (Table 3). Similar transplantation

TABLE 3

SURVIVAL OF MICE EXPOSED TO 1,025 r X-RADIATION WITHOUT LEAD PROTECTION OF THE SURGICALLY MOBILIZED SPLEEN WITH AND WITHOUT IMPLANTATION OF SPLEENS FROM YOUNG MICE AFTER X-RAY

| No. mice used | Spleen implants within ½ hr after irradiation | Survival (%) | Hematopoietic recovery (8 days) |
|---|---|---|---|
| 112 | None | 0 | None |
| 63 | 4 spleens from 1–12-day-old mice | 38 | Complete |
| 18 | 2 spleens from 4–5-wk-old mice | 45 | Not studied |
| 24 | 4 spleens from 1–8-day-old mice implanted 2 days after irradiation of the recipient | 20 | " " |

of 4 fresh spleens from mice 1–8 days old into adult mice 2 days after exposure to 1,025 r total-body x-radiation likewise enhances survival, but not so effectively as earlier transplantation.

These facts indicate that in contrast to the action of glutathione (*3*), cysteine (*4*), $O_2$ deprivation (*5*), or cyanide (*6*), which must be administered before or during irradiation in order to reduce the expected radiation mortality, the factor involved in the shielding or transplant experiments is unnecessary during the actual irradiation and is definitely effective after irradiation.

These experiments involving spleen- or liver-shielding or spleen transplants strongly suggest that the factor responsible for recovery from radiation under these conditions is a substance of a noncellular nature. It seems unlikely that (1) cells migrate out from the shielded or transplanted tissue and are responsible for the enhancement of recovery, or (2) that irradiation of tissue produces a "toxin" and that the shielded or implanted tissues exert a direct detoxifying action upon contact with the "toxin." Our present efforts are concentrated on attempts to study the efficacy of simple water extracts of spleen and embryonic tissue on survival and hematopoietic recovery of irradiated mice. The potential implications of these findings in the therapy of radiation injury and in certain other clinical states are obvious.


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## Nitrogen Fixation by Sulfate-reducing Bacteria Indicated by Nitrogen/Argon Ratios[1]


Frederick D. Sisler and Claude E. ZoBell

*Scripps Institution of Oceanography, University of California, La Jolla*


In the course of investigations (*1*) on the utilization of molecular hydrogen by autotrophic, anaerobic, sulfate-reducing bacteria belonging to the genus *Desulfovibrio,* evidence was obtained for the fixation of free nitrogen. In preliminary experiments inverted vials in pairs were placed in glass-stoppered bottles filled with sea water, which served as a suitable mineral medium for the growth of $H_2$-utilizing sulfate reducers. One vial was filled with $H_2$ and the other with $N_2$ as an "inert" control.

It soon became evident, however, that $N_2$ was not inert in the presence of hydrogenase-producing species


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