However, when it was desirable to have some four-gallon pots of soil in which plants could be grown under controlled conditions, several difficulties had to be overcome. The use of Livingston's auto-irrigator cones for supplying water in other pot work[3] suggested the idea that internal watering would be ideal for watering controlled cultures. When soil in large pots is to be used, some method must be found to cover the soil with a cotton seal that will not be wetted by the moist soil. This has been accomplished by placing an inch mulch of very coarse gravel over the soil. Various pieces of apparatus have been devised to work a cotton seal around the stem of a sterile seedling. A number of these are suitable. It has been found that the double cylinder described by Fred[4] can easily be inserted in the large cotton seal covering the pot.

A more complete description of this apparatus appears in the June issue (Vol. 20, No. 6) of the *Journal* of the American Society of Agronomy.

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SPECIAL ARTICLES

THE EFFECTS OF RADIUM IN PRODUCING LETHAL MUTATIONS IN DROSOPHILA MELANOGASTER

MULLER'S[1] recent discovery that X-rays produce gene mutations in fruit flies is one of the most notable events in the field of pure biology in this century.

The experimental modification of the germ-plasm is an old problem. Many investigators have tried their hands at it. All sorts of chemical and physical agents: serums, high and low temperatures, alcohol, continuous and intermittent rotation, ultra-violet light and probably other agents have been imposed upon different species of organisms. But the genes remained stable.

In an attempt to alter the genes in the albino rat the authors administered alcohol fumes daily to ten successive generations of rats. Treatment was begun at twenty days of age and continued until the animals were fully adult. The soma cells were badly injured: nearly all the individuals were rendered blind, they were stunted in growth, hair development was interfered with and numerous other evidences of degeneration appeared. But all these were merely somatic changes. The genes would not play fair. They took the alcohol but refused to alter. The young of ten generations of alcoholic ancestors were both physically and mentally the equals of the controls and in some cases slightly superior. This has been the common experience of all who have tried to modify the gene constitution of either plants or animals.

Now comes the change. The treatment of fruit flies with X-rays brings gene mutations in such bewildering rapidity that it is impossible to breed and study them all. In some of Muller's experiments the rate of mutation among progeny of irradiated parents was 15,000 per cent. greater than among the controls. On one Sunday afternoon forty mutations were found. Prior to the use of the X-ray, if one mutation were found in forty Sunday afternoons the time would have been considered well spent.

Radium is as effective as X-rays in causing mutations and in certain respects has advantages over the latter. Two of these advantages are: (1) Ease of controlling and repeating exact dosages, and (2) the possibility of separating the different rays involved to determine which ones are effective in altering the gene.

Experiment I. Wild type males were exposed to 150 milligrams of radium for six hours.[2] The flies were confined in shell vials 2½ x 1 inches. The vials contained one inch of cooked banana-agar food, and the open ends were covered with two layers of gauze. The radium needles were attached with adhesive tape to the gauze.

Immediately following treatment these males were mated, in pairs, to females having the genes for scute (sc), vermilion (v), forked (f), and bobbed (bb) in one X-chromosome and a gene (C) to prevent crossing over, a lethal gene (1), and the bar gene (B) in the other X-chromosome. The F_1 females were of two classes, bar and not-bar. The bar-eyed females were mated to their brothers, one pair to a tube, to produce the F_2 generation. Due to the presence of the lethal gene half the sons in this generation are killed. If a new lethal mutation arose as the result of the radium treatment the other half of the sons would inherit it and not appear. Hence no males would hatch in that particular tube. To determine the number of lethal mutations occurring as a result of the radium treatment it was only necessary to count the number of tubes in which there were one hundred per cent. females.

The numbers in the first experiment were too small to give a reliable percentage of mutation. There

[3] Deatrick, E. P., "Porous Clay Auto-irrigator Cones for Watering Potted Soil and Plants," Jour. Amer. Soc. Agron., 19, 252–255, 1927.

[4] Fred, E. B., "Laboratory Manual of Soil Bacteriology," p. 161.

[1] Muller, H. J., 1927, "Artificial Transmutation of the Gene," SCIENCE, 66: 84–87.

[2] The radium used in these experiments was loaned by the Barnard Free Skin and Cancer Hospital in St. Louis. Our appreciation of this courtesy is hereby expressed.

were one hundred and ten tubes of controls and thirty-one tubes of the treated. No mutations occurred in the controls, while four out of the thirty-one treated tubes showed lethal mutations. This is a mutation rate of 12.9 per cent. While numbers so small as these may have little value in themselves they pointed the direction for further work.

Experiment II. This experiment was an exact repetition of the first one, with the addition of a group in which gamma rays only were permitted to reach the flies during treatment. This was accomplished by enclosing the glass vial containing the flies in a cylinder of soft lead. The lead in this cylinder was two millimeters thick and effectively stopped both the alpha and beta rays. Since it also reduced the amount of gamma rays the time of treatment was extended from six to thirteen hours.

The following table gives the results of the second experiment. In the column marked "dosage" it will be noted that 140 milligrams of radium were used instead of the usual 150 milligrams, one ten mg. needle not being available at that particular time.

	Dosage	Number F_2 tubes	Number lethal mutations	Percentage of mutation
Control	———	423	0	0
Radium	140 mg. radium 6 hours	426	35	8.2
Gamma rays only	150 mg. radium 13 hours	426	12	2.8

Five hundred tubes each of controls, "all radium" and "gamma only," were made up. All sterile tubes were eliminated from the experiment, so the numbers in column 3 of the table represent fertile pairs.

In the "all radium" group the mutation rate is 8.2 per cent., while in the first experiment it was 12.9 per cent. The reasons for this difference are at least two: first, there were ten milligrams less of radium and, second, the difference in size between the two samples, thirty-one tubes in the first experiment and 426 in the second, might well give a difference as great as this. There is a striking difference between the rate of mutation in the "all radium" group (8.2) and the "gamma only" group (2.8). This may be due to the fact that the beta rays are also effective in causing mutations, or, as we have learned since, the time was not sufficiently extended to give the same amount of gamma radiation as in the "all radium" group. More probably both factors were responsible for the difference.

As the results stand now the two experiments show that radium emanations produce lethal mutations in Drosophila and that gamma rays alone will also do the same thing. This is the first step in the analysis of just what elements in radium and X-rays are responsible for the results obtained. Further work on the analysis of the three rays of radium is now under way.

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THE NATURE OF THE ACIDIC SUBSTANCE FORMED ON THE HYDROLYSIS OF ACACIA

DURING the course of a study of the acid polysaccharides occurring in plants, we have had occasion to devote considerable time to the chemistry of acacia or gum arabic.

The plant gums, as is well known, are salts of very complex organic acids, usually with calcium, magnesium and potassium. These complex acids are built up of hexose, pentose and methyl pentose units in combination with the acidic part of the molecule. Many gums liberate carbon dioxide on heating with 12 per cent. hydrochloric acid,[1] and they give the naphtho-resorcin test.[2] It is therefore believed that they contain *uronic* acid units.[3]

But little work has been done on the acidic nucleus of gums since the researches of O'Sullivan.[4] This author found that arabic acid—from gum arabic—on heating with dilute sulphuric acid yielded an acid of lower molecular weight which he called λ-arabinosic acid and which was stable enough to resist the action of 3 to 4 per cent. sulphuric acid—at 100°—for several hours. He assigned to the substance the formula $C_{23}H_{38}O_{22}$ from the results of the analysis of its barium salt.

We have planned to make an extensive study of gum arabic in this laboratory, and as a part of our program have submitted a botanically authentic sample of the gum to hydrolysis with dilute sulphuric acid under much the same conditions as those employed by O'Sullivan.

The acidic product of the hydrolysis appears to be identical with the λ-arabinosic acid of the earlier investigator. The substance has been isolated and analyzed in the form of its calcium salt. The analytical

[1] Nanji, Patton, Ling, *J. Soc. Chem. Ind.*, 44, 253T (1925); Anderson and Sands, *J. Am. Chem. Soc.*, 48, 3172 (1926).

[2] Tollens, Ber. 41, 1788 (1908).

[3] Widsoe and Tollens, Ber. 33, 132 (1900); see also ref. (1).

[4] *J. Chem. Soc.*, 45, 41 (1884); *ibid.*, 59, 1029 (1891); *ibid.*, 79, 1164 (1901).