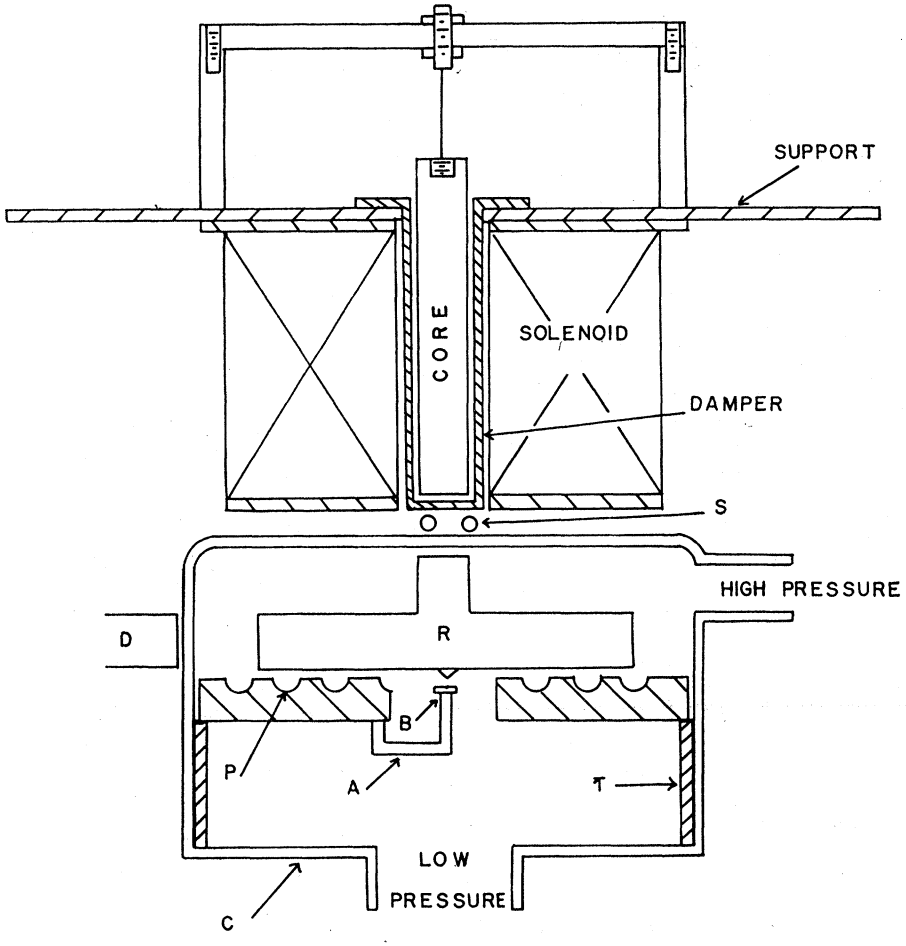

Fig. 1. Molecular pump with magnetically suspended rotor.

pressure of the lubricant in the bearings or by the fact that it was not possible to bake out the pumping system. For example, von Friesen (*4*) reported a pressure of 6.7×10^{-7} mm-Hg on the low-pressure side and 0.05 mm-Hg on the high-pressure side of his molecular pump. The pressure ratios usually vary from 10^2 to 10^6. According to theory (*6*), these pressure ratios should continue to hold at extremely low pressures.

In the course of some measurements of the gaseous friction on a magnetically suspended rotor spinning in a high vacuum, a considerable amount of molecular pumping was encountered. Since this pumping system can be baked out and is free of lubricated bearings, it appears worth while to indicate its possible use in producing very high vacua.

Figure 1 illustrates the principle of the method. The steel rotor *R* is freely suspended inside a vacuum-tight glass chamber *C* by the axial magnetic field of the solenoid, which is situated above the chamber. The sensing copper coil *S* is used to regulate the current through the solenoid in such a way as to maintain the rotor at the desired vertical position in the chamber. The rotor is spun by a rotating magnetic field produced by the drive coils *D*, located outside the glass chamber; that is, the rotor operates as the armature of an induction motor. A detailed description of the magnetic suspension and drive circuits has been published previously (*7*).

The pumping takes place between the spinning lower surface of the rotor *R* and the stationary upper surface of the plate *P*. Grooves are cut in the upper surface of *P* which spiral out from the axis to the periphery. The plate *P* is made of nonmagnetic low-vapor-pressure metal. The gas molecules are driven from the axis to the periphery by the spinning rotor. The clearance between the rotor and the plate *P* can be made 0.05 cm or less, while the depth of the grooves is of the order of 1 cm, the exact depth depending upon the pumping speed and the size of the rotor. The stainless-steel safety stop *B* is mounted on an arm *A* in such a way as not to obstruct the inlet to the pump. The plate *P* is supported on a closely fitting aluminum or copper foil washer which in turn is supported by a carefully ground glass telescoping tubing *T*. This permits the clearance that is necessary for differential expansion of *P* and *C* and at the same time provides a seal between the lower and upper chambers. With the solenoid removed, the entire system may be baked out for as long as necessary.

The peripheral speed is determined by the strength of the rotor but can easily be made twice the average molecular speed. The diameter of the rotor can be varied over as large a range as desired. If by means of modern pumping procedures the region around the periphery of the rotor is evacuated to a pressure of 10^{-9} or 10^{-10} mm-Hg, then a pumping ratio of 10^4 would give a pressure of 10^{-13} to 10^{-14} mm-Hg near the axis. If two or more such pumps were operated in series or in parallel and the glass chamber *C* were surrounded by an evacuated glass envelope, the pressure probably could be much further reduced. Another important factor is that the pumping speed can be made quite high. Also, the pump may be refrigerated—say, by liquid nitrogen—after the bake-out process and while it is in operation. This should greatly increase the effectiveness of the pump. With appropriate changes in the drive system, stainless-steel or other nonmagnetic vacuum chambers may be used instead of glass (*8*).

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31 August 1959

Effect of Ultraviolet Pretreatment on Yield of Mutations by X-rays in Wheat

Abstract. A decrease in the yield of chromosomal aberrations in root meristems of wheat induced by four different doses of x-rays has been found to occur when the seeds are pretreated with ultraviolet radiation. However, in X_2 generation, the mutation rate for combined treatment is lower than for x-rays alone in lower dosages and higher than for x-rays alone in higher dosages.

Pre- or post-treatments combining such radiations as ultraviolet light or infrared with ionizing types have not been tested for their effects on mutation in higher plants. Swanson (*1*) has demonstrated that pre- or post-treatment with ultraviolet light will reduce the amount of chromosomal damage induced by x-rays in *Tradescantia*. In *Aspergillus*, combined ultraviolet and x-ray doses induced more mutations

Table 1. Frequency of occurrence of chromosome aberrations in x-ray and ultraviolet plus x-ray treatments.

X-ray dose (r)	Direct treatment		Ultraviolet pretreatment	
	No. of cells examined	Mean No. of aberrations ± S.E.*	No. of cells examined	Mean No. of aberrations ± S.E.*
11,000	218	1.11 ± 0.21	285	0.70 ± 0.13
16,000	139	1.68 ± 0.31	187	0.92 ± 0.25
22,000	146	2.90 ± 0.39	133	1.53 ± 0.24
33,000	109	3.67 ± 0.46	200	1.76 ± 0.38

*Standard error.

Table 2. Frequency of mutations after x-ray treatment and ultraviolet plus x-ray treatment.

Dose (r)	No. of families	No. of plants examined	Number of mutants of type								Mutation	
			Chloro-phyll	Short straw	Fine straw	Spel-toid	Dense ear	Lax ear	Awn char-acters	Others*	Total No.	Rate per X_1 plant progeny (%)
Control												
	99	2350	0	0	0	0	0	0	0	0	0	0
Ultraviolet alone												
	98	4900	0	0	0	0	0	0	0	0	0	0
X-rays alone												
11,000	60	7281	0	4	8	8	4	2	1	2	29	48.3
16,000	43	5093	0	3	4	6	4	1	4	6	28	65.1
22,000	27	3750	0	1	1	4	0	0	2	12	20	74.1
33,000	29	3967	0	0	0	8	4	0	1	2	15	51.7
Ultraviolet plus x-rays												
11,000	66	8250	0	1	4	2	2	1	1	3	14	21.2
16,000	64	8060	3	6	0	6	2	2	3	2	24	37.5
22,000	51	6750	0	4	0	7	6	4	5	15	41	80.4
33,000	47	5200	0	4	0	14	4	5	7	12	46	97.8

*These include grass clumps (early and late types) and mutations in the color and hairiness of glumes and in grain color.

than the sum for the two radiation treatments applied separately (see the review by Muller, *2*). We have carried out a similar experiment in bread wheat (*Triticum aestivum* L., $2n = 42$), and the results are summarized in this report.

Seeds of C.591, a highly stable and homogeneous variety of bread wheat characterized by a fully bearded ear-head, white and pubescent glumes, amber-colored grains, and medium maturity, were subjected to the following treatments: (i) ultraviolet light for 1 hour; (ii) 11,000, 16,000, 22,000, and 33,000 r of x-rays; and (iii) pretreatment with ultraviolet for 1 hour followed by irradiation with 11,000, 16,000, 22,000, and 33,000 r of x-rays. A germicidal mercury-vapor tube which had an active radiation chiefly at wavelength 2537 A was used for ultraviolet treatment. Together with the control, there were thus ten lots of seeds, with 100 seeds per treatment.

These seeds were germinated, and cytological studies were carried out at metaphase in root-tip smears prepared from material fixed 24, 48, and 72 hours, respectively, after germination. Single and two-hit aberrations were scored separately but were pooled (due weight being given to two hit-aberrations and so on) for calculating the mean number of chromosome aberrations per cell (Table 1). Ultraviolet treatment alone did not induce any chromosome breakage; some degree of chromosome stickiness was the only discernible effect. The X_1 plants were grown during 1956, and the seeds from all plants which survived and flowered were harvested and stored separately. The X_2 progenies were raised in 1957, and the population was carefully scored for all phenotypically detectable mutations. Mutation frequency, expressed as a percentage of mutations per X_1 plant progeny, was calculated for all the treatments (Table 2). No spontaneous mutation was observed in the large amount of control material of this variety grown each year, and no mutations occurred in seeds irradiated with ultraviolet alone.

From the data in Table 2, it is seen that ultraviolet pretreatment caused, in comparison with the effects of x-rays alone, a reduction in the mutation rate at 11,000 and 16,000 r and an increase in the mutation rate at 22,000 and 33,000 r. The cytological data (Table 1) showed a significant reduction in the frequency of chromosome aberrations at all x-ray dosages following ultraviolet treatment. Since a majority of the induced mutations in bread wheat appear to be chromosomal in origin (*3*), the effect of ultraviolet in causing a reduction in the extent of chromosomal aberrations induced by x-rays by promoting restitution may be responsible for the decreased mutation rate observed in the combined ultraviolet and x-ray treatments at 11,000 and 16,000 r. The same consequence of ultraviolet pretreatment may account for the increase in mutation rate observed for 22,000 and 33,000 r, since in plants treated with 22,000 and 33,000 r of x-rays alone a large proportion of mutant gametes apparently carry several chromosome structural changes and are, as a result, either inviable or at a competitive disadvantage. This inference is supported by the fact that while X_1 plants from 22,000- and 33,000-r x-ray treatments showed 15- to 20-percent pollen sterility, the sterility was only 4 to 6 percent at the same x-ray dosages in plants pretreated with ultraviolet. A study of the possible synergism between ionizing radiations and other mutagenic agents such as ultraviolet in higher plants may have, therefore, to be carried out at various dosage combinations for a clear understanding of the nature of the interaction involved.

The types of mutations observed and their relative proportions were more or less similar in all the treatments; the X_2 progeny from plants treated with ultraviolet plus 16,000 r of x-rays, however, differed from the others in showing albina mutations. Albinas have not so far been recorded in mutation experiments in bread wheat (*3, 4*). None of the 21 nullisomics in this species show chlorophyll deficiency (*5*). Furthermore, Sears (*6*) has shown that the dominant allele of Neatby's virescent gene *v*, located in chromosome III, is a member of a triplicate series concerned with chlorophyll development, the other two genes being situated on chromosomes XII and XVI, which are homoeologous with chromosome III. The high phenotypic stability of the chlorophyll apparatus in mutation experiments in bread wheat thus seems to be due to the presence of several unlinked factors controlling this character. Study of the root-tip chromosomes of an albina seedling from a parent plant treated with ultraviolet plus 16,000 r of x-rays showed that the mutant had the normal somatic chromosome number, $2n = 42$. A comparative study of the karyotypes of albina and control C.591 plants did not reveal any detectable difference. Thus, ultraviolet pretreatment appears to induce in some way the factors controlling chlorophyll development to mutate, although these factors remain unaffected by even high doses of x-rays (*7*).

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13 July 1959

Carbon Dioxide Fixation in Marine Invertebrates: A Survey of Major Phyla

Abstract. Fourteen species of marine invertebrates representing 12 phyla were kept in sea water containing $NaHC^{14}O_3$ for 1 hour. All of them fixed CO_2 into acids of the Krebs citric acid cycle. In most species the major portion of the radioactivity recovered after chromatography was in succinic, fumaric, and malic acids. The findings favor the hypothesis that both CO_2 fixation and the citric acid cycle are virtually universal among marine invertebrates.

The finding of the reaction of CO_2 with propionate to form succinate in isolated tissue of the oyster (*1*) is one of the few demonstrations of CO_2 fixation in invertebrates. The only other marine invertebrate which has been investigated is the developing sea-urchin egg, which incorporates $C^{14}O_2$ into several fractions of organic material (*2*). In order to determine the extent of CO_2 fixation among marine invertebrates, animals representing 12 phyla were examined in this study (*3*).

The animals used in the experiments reported here were collected in the vicinity of Beaufort, North Carolina, during the summer months, and were used immediately after collection (*4*). After cleaning and weighing, whole animals or pieces of tissue were incubated in stoppered 125-ml flasks with filtered sea water to cover them. From 5 to 120 μc of $NaHC^{14}O_3$ were added from a syringe, giving concentrations in the medium of 0.5 to 5.3 μc/ml in all except the sponge. Details of each experiment are recorded in Table 1. Metabolic activity was halted after 60 minutes of incubation by placing the living material in cold acetone, and homogenization was begun at once. Organic acids were extracted according to the method of Frohman, Orten, and Smith (*5*), chromatographed with known acids on paper, and counted as described previously (*1*). The relative map positions of the acids agreed quite well with those reported by Carles *et al.* (*6*) for similar solvent systems.

The results of 14 experiments are

Table 1. Conditions of experiments on uptake of $NaHC^{14}O_3$ by marine invertebrates. Incubation time was 60 minutes in each case.

Species	No. of specimens	Fresh wt. (gm)	Volume of sea water (ml)	$NaHC^{14}O_3$ (μc)	Temp. (°C)
Hymeniacidon heliophila (sun sponge, Porifera)	Several branches	1.50	8.5	120	23.5
Aiptasia pallida (anemone, Cnidaria)	40	9.0	5.2	20	28.0
Bdelloura candida	150	0.53	6.0	32	28.0
Stylochus zebra (flatworms, Platyhelminthes)	1	0.07	1.0	5	28.5
Cerebratulus lacteus (ribbon worm, Nemertea)	1	0.74	10.0	25	27.2
Chaetopterus variopedatus (tube worm, Annelida)	1	19.0	10.5	50	30.5
Callinectes sapidus (blue crab, Arthropoda)	Digestive gland: 1	3.34	6.0	32	27.2
Limulus polyphemus (horseshoe crab, Arthropoda)	Digestive gland: 1	44.0	20.0	50	27.6
Crassostrea virginica (oyster, Mollusca)	Mantle tissue: 22	20.0	100.0	120	28.0
Bugula neritina (bryozoan, Ectoprocta)	Many colonies	50.0	100.0	50	24.0
Lingula unguis (lampshell, Brachiopoda)	Soft parts: 6	3.84	9.5	25	24.5
Leptosynapta inhaerens (sea cucumber, Echinodermata)	25	13.0	6.0	32	27.0
Saccoglossus kowalevskii (acorn worm, Hemichordata)	Pieces: 6	2.01	6.0	32	26.0
Styela plicata (tunicate, Chordata)	6	24.0	24.5	25	28.0

Table 2. Percentage of radioactivity in organic acids after exposure of animals to $NaHC^{14}O_3$.

Species	Count/min*	Acids†								Total recovery
		Suc	Fum	Mal	Cit	Iso	αKg	Unkn	Lac	
Hymeniacidon heliophila	613	61.2	25.5	12.3	0		0		0	99.0
Aiptasia pallida	1101	52.0	3.4	10.1	7.1		3.5		0	76.1
Bdelloura candida	4275	4.0	0.8	10.4	0.2	0.4	0.3	65.5	1.1	82.7
Stylochus zebra	260	8.7	3.7	17.4	0.9	18.8	0	41.9	0.9	92.3
Cerebratulus lacteus	1123	79.7	0.5	27.4	0		0		0	107.6
Chaetopterus variopedatus	2305	60.8	9.3	12.6	0.7		1.2		9.6	94.2
Callinectes sapidus	1983	82.0	6.6	9.4	0.1		3.4		2.5	104.0
Limulus polyphemus	844	21.6	20.5	17.5	6.0		3.2	6.3	17.4	92.5
Crassostrea virginica	2633	99.0	0.7	1.4	0		0		0	101.1
Bugula neritina	658	53.5	8.0	2.0	0	0		0	0	63.5
Lingula unguis	1651	92.9	1.7	0.6	0	0	0		0.4	95.6
Leptosynapta inhaerens	1293	20.8	8.1	16.8	7.5	17.4	10.0	4.2	0.9	85.3
Saccoglossus kowalevskii	3399	66.0	4.8	12.2	0.4	0.4	0.3	5.0	1.5	90.6
Styela plicata	507	30.5	3.6	15.8	5.7	6.5	1.5	6.9	1.1	71.6

* Radioactivity of acetone extracts at origin of chromatograms. † Succinic, fumaric, malic, citric, isocitric, α-ketoglutaric, unknown, and lactic acids, respectively.