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REPORT

1

CYTOLOGICAL ANALYSIS OF TRANSLOCATIONS IN CORN CHROMOSOMES RESULTING FROM IONIZING RADIATION OF THE TEST ABLE ATOMIC BOMB AND X-RAYS AND OF TRANSLOCATIONS FROM OTHER SOURCES

APPENDIX NO. 10
TO THE FINAL REPORT

OPERATION CROSSROADS
JOINT TASK FORCE ONE

DIRECTOR OF SHIP MATERIAL

NAVAL MEDICAL RESEARCH SECTION

(11) 10 Jun[redacted]950, (12) 66p

OPERATION CROSSROADS.

CYTOLOGICAL ANALYSIS OF TRANSLOCATIONS IN CORN CHROMOSOMES RESULTING FROM IONIZING RADIATION OF THE TEST ABLE ATOMIC BOMB AND X-RAYS AND OF TRANSLOCATIONS FROM OTHER SOURCES. *

Report of Naval Medical Research Section, Joint Task Force ONE, on Biological Aspects of Atomic Bomb Tests.

(9) APPENDIX No. 10 to Final rept.,

(14) XFI-16

~~by~~

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INTRODUCTION

This report on studies of chromosome translocations in corn covers an analysis of 588 translocations at the mid-stage prophase. Of these 220 were from the collection of translocations maintained by Dr. E. G. Anderson at the California Institute of Technology, 179 occurred in progenies from dry corn seed treated with measured dosages of X-rays, and 172 occurred in progenies from seed exposed to ionizing radiations from the Test ABLE bomb, July 1, 1946[1].

The analyses of the translocations in the last two groups are part of the cooperative investigation conducted by the Naval Medical Research Section, the U. S. Department of Agriculture, the California Institute of Technology, and Cornell University, to determine the biological effects of ionizing radiations from the atomic bomb.

The articles by Randolph[1] on cytogenetic effects and by Anderson (10) on hereditary effects record certain aspects of these cooperative investigations. and This report presents data showing similarities and differences in the character of the chromosomal disturbances resulting from the different types and dosages of radiation.

The occurrence of reciprocal translocation between non-homologous chromosomes of corn was recognized twenty years ago, and its cytological confirmation was recorded shortly afterwards. The publications of Brink (12), Brink and Burnham (13), Burnham (16, 17, 18, 19, 20, 21, 22), McClintock (26, 27, 28), Brink and Cooper (14, 15), Creighton and McClintock (24), Rhoades (29, 30), Beadle (11), Anderson and his associates (1-10), and Clark and Anderson (23) reported genetic and cytological data concerning certain of the earlier-recognized translocations in corn, and demonstrated the usefulness of translocations in attacking many genetic and cytogenetic problems.

1/For additional details concerning the preparation and exposure of these seeds see R.H. Draeger and Shields Warren, U.S. Nav. Med. Bull. 1947, 47:219-224 and L.F. Randolph, A.E. Longley and Chin Hsuing Li, Science, 1949, 108:13-15.

MATERIAL AND METHODS

Abundant microsporocyte material with the chromosomes well spread and well stained is essential for the analysis of translocations with a minimum of effort. To facilitate the preparation of good pachytene stages, material was collected during the part of the day in which plant growth seemed to be most active. Nearly all translocations studied had been transferred to strains of corn that seemed to have the pachytene chromosomes well spread and that had many of their chromosomes marked by one or more readily-identifiable morphological characters. Thus, the more obvious aids for chromosome studies were introduced into the strains used.

The proper staining of mid-prophase chromosomes of corn is not fully standardized. The method used in preparing acetocarmine smears was modified from time to time to cope with the ageing of stored microsporocyte material. Ageing usually causes the cytoplasm as well as the chromosomes to absorb the stain. When this becomes too pronounced the contrast between cytoplasm and chromosomes is lost. This contrast can be restored almost completely if, after staining, the staining medium is made more acid by adding a small amount of 100% glacial acetic acid to one side of the slide and working it gradually into the stain. If the proper acidity has been approximated, the cytoplasm clears but the chromosomes retain their stain when the cover glass is put on and the slide heated.

Non-homologous pairing in certain types of translocation complexes causes considerable difficulty in determining the points of breakage in a few configurations. This abnormal pairing usually can be detected, when several translocation figures are compared, because of the variable position of the cross that marks the exchange points.

Usually sufficient translocation figures were obtained to fix the points of exchange for each chromosome. Three or more camera lucida drawings of the clearest figures were made and by map rule measurements the distance of the break from the fibre attachment of each chromosome was calculated and recorded as a decimal fraction of the total length of the chromosome arm.

OBTAINED DATA

The material described in this study adds appreciably to the number of translocations available for use in cytogenetic research. The feature emphasized here is a comparison of the effectiveness of various types and dosages of radiation for producing breaks in differenct chromosomes, chromosome arms and sections of chromosome arms.

The term "break" in this discussion is restricted to breaks that subsequently heal with breaks in other chromosomes and produce transmissible reciprocal translocations. Consequently, break frequency, as used, may not include all breaks produced by the radiation.

Distribution of Breaks among the Ten chromosomes

The observed and calculated numbers of breaks in each chromosome resulting from the Bikini treatments are reported in Table 1. Similar data for X-ray treatments are reported in Table 2. Data on the collection of translocations maintained by the California Institute of Technology (C.I.T.), which was assembled from diverse sources, are reported in Table 3 for completeness and to permit comparisons. The data in Tables 1, 2 and 3 are summarized graphically in Figure 1.

Table 1. Chromosome breaks observed in the progeny from seeds exposed to the Test ABLE Bomb at Bikini.

Chromosome	Lot 1	Lot 2	Lot 3			Lot 6	Lot 7	Total		
	Ob	Ob	Ob	C	X^2	Ob	Ob	Ob	C	X^2
	No.	No.	No.	No.		No.	No.	No.	No.	
1	0	0	54	48.0	.75	0	0	54	51.3	.14
2	0	0	32	38.8	1.91	0	1	33	41.4	1.70
3	1	0	30	36.1	1.03	0	0	31	38.6	1.50
4	0	0	30	34.6	.61	0	1	31	36.6	.86
5	3	0	42	34.9	1.44	1	0	46	37.2	2.08
6	1	1	29	28.4	.01	0	0	31	30.3	.02
7	3	0	23	27.3	.68	2	0	28	29.1	.04
8	2	1	43	27.7	8.45	2	0	48	29.5	11.60
9	0	1	24	25.2	.57	1	0	26	26.9	.30
10	0	1	15	21.5	1.97	0	0	16	23.0	2.13
Totals	10	4	322		17.42	6	2	344		20.77

Table 2. Chromosome breaks observed in the progeny from seeds exposed to X-ray treatments.

Chromosome	5000-10000 r			15000 r			20000-25000 r			Total		
	Ob	C	X^2	Ob	C	X^2	Ob	C	X^2	Ob	C	X^2
	No.	No.		No.	No.		No.	No.		No.	No.	
1	4	7.7	1.78	22	33.7	4.06	8	11.9	1.28	34	53.3	[illegible]9
2	5	6.3	.27	23	27.2	.64	7	9.6	.70	35	43.0	1.49
3	5	5.8	.11	30	25.4	.83	5	9.0	1.78	40	40.2	.01
4	4	5.5	.41	18	24.0	1.50	9	8.5	.03	31	38.1	1.32
5	9	5.6	2.06	24	24.5	.01	10	8.7	.19	43	38.7	.48
6	8	4.6	2.51	25	19.9	1.31	7	7.1	.01	40	31.6	2.23
7	5	4.4	.08	24	19.1	1.26	7	6.8	.01	36	30.3	1.07
8	5	4.5	.06	25	19.4	1.62	14	6.9	7.31	44	30.5	5.66
9	5	4.1	.20	17	17.7	.03	7	6.3	.08	29	28.1	.03
10	2	3.5	.64	18	15.1	.56	6	5.3	.09	26	23.8	.20
Totals	52		8.12	226		11.82	80		11.48	358		19.48

Table 3. Chromosome breaks observed in the California Institute of Technology collection, certain miscellaneous stocks, and the grand total of all observed breaks.

Chromosome	C.I.T. Collection			Misc. Stocks	Grand Total		
	Ob	C	X^2	Ob	Ob	C	X^2
	No.	No.		No.	No.	No.	
1	53	65.6	2.42	1	142	175.3	6.33
2	56	52.9	.18	2	126	141.5	1.69
3	45	49.3	.38	5	121	133.9	1.24
4	42	46.8	.49	4	108	126.2	2.61
5	56	47.6	1.48	6	151	127.3	4.42
6	43	38.8	.46	1	115	102.6	1.50
7	34	37.2	.28	5	103	99.5	.12
8	40	37.8	.13	5	137	101.0	12.83
9	38	34.4	.38	4	97	92.0	.27
10	33	29.4	.44	1	76	78.6	.08
Totals	440		6.64	34	1176		31.09

The calculated (C) numbers of breaks shown in the above mentioned tables were computed from the observed (Ob) numbers on the basis of chromosome length. Utilizing the total numbers of breaks observed for each treatment and the total length of the 10 chromosomes at the pachytene stage, the expected number of breaks could be computed for each chromosome on the basis of random distribution of breaks over this entire length.

The chi-square tests indicate a non-random distribution of breaks in the bomb treated material, in the X-ray treated material, and in the grand total. The chi-square tests reported in Table 4 also show that the distribution of breaks among the 10 chromosomes is different when Lot 3 is compared with 15000 r X-ray treatment and when the total material from the bomb exposure is compared with the total X-ray material. A critical examination of these data show that the six shortest chromosomes in the X-ray series have more breaks than expected, while the four longest chromosomes have less than the expected number of breaks. No such definite relationship is evident in progenies from the bomb treated seed.

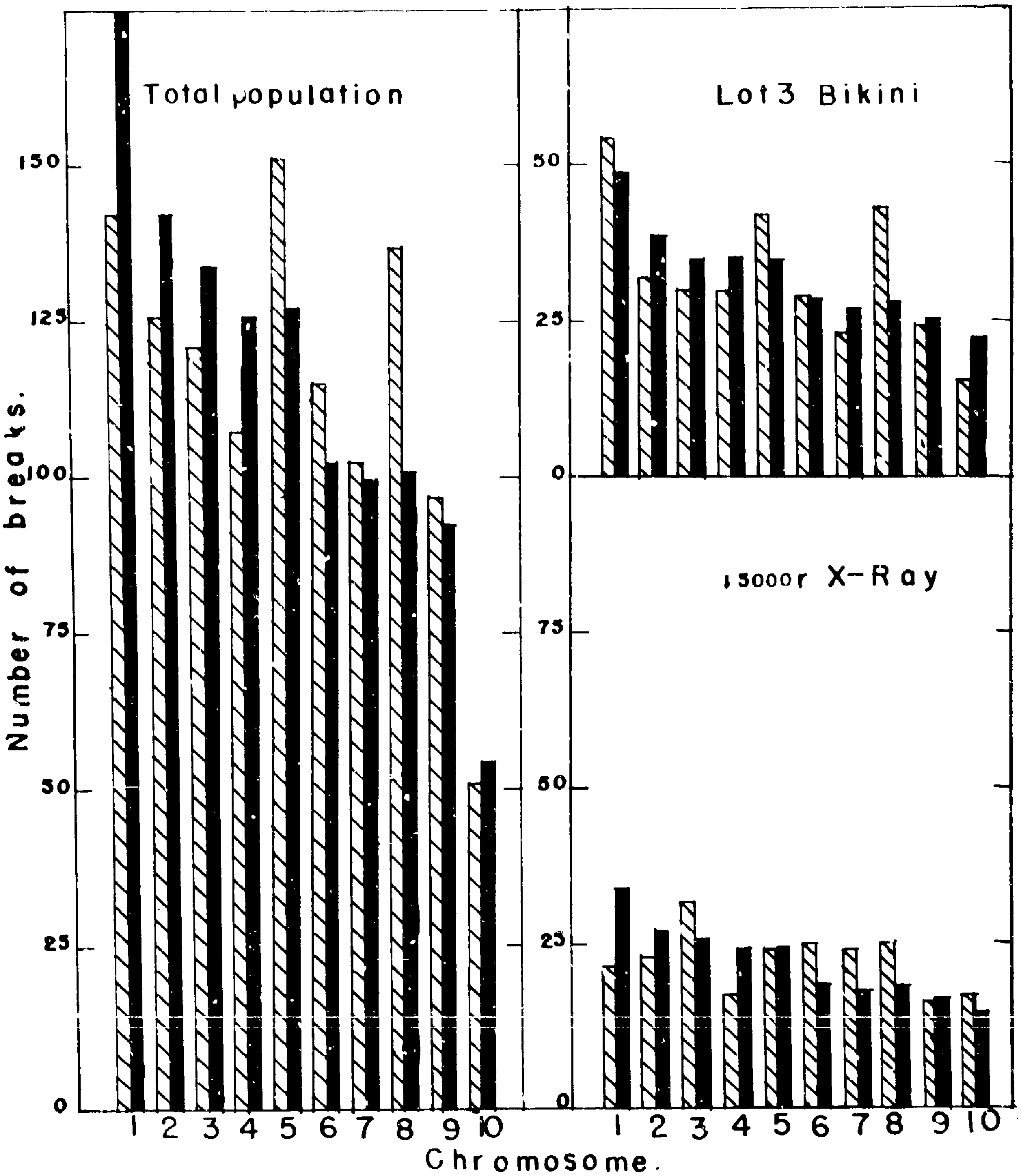

Figure 1. Distribution of breaks among the 10 corn chromosomes. Cross-hatched bars are observed distributions; solid bars are calculated random distributions.

Table 4. Comparison of the chromosome breaks observed in the progeny from seeds exposed to the Bikini and X-ray treatments.

Chromosome	Chi-square values for the comparison indicated	
	Lot 3 and 15000r	Totals for Bikini and X-ray
1	5.15	8.77
2	.02	.02
3	3.78	1.86
4	.72	.06
5	1.88	.80
6	1.22	1.86
7	3.58	1.47
8	1.54	.71
9	.00	.14
10	4.45	5.25
Totals	22.32	20.63

Distribution of Breaks among the Twenty Chromosome Arms

The distribution of breaks among the twenty chromosome arms is presented in Tables 5, 6 and 7 and figure 2 in much the same manner as the data for whole chromosomes given in Tables 1, 2 and 3 and figure 1. The numbers of breaks in chromosome arms 3S, 7L, 9S, 10S and 10L, are below the expected frequency in Lot 3 of the bomb-treated groups and above the expected in the 15000 r X-ray treated groups. This relationship between observed and expected number of breaks is reversed when arms 1L, 4S, 5S and 7S are compared. Both groups have more than the expected number of breaks in chromosome arms 5L, 6L, 8S, and 8L, and below the expected number in arms 1S, 2S, 2L, 3L, 4L and 9L.

Table 5. Numbers of breaks observed in each chromosome arm in the progeny from seeds exposed to the Test ABLE Bomb at Bikini.

Chromosome	Arm	Lot 1	Lot 2	Lot 3			Lot 6	Lot 7	Total		
		Ob No.	Ob No.	Ob No.	C No.	X^2	Ob No.	Ob No.	Ob No.	C No.	X^2
1	S	0	0	20	20.9	.04	0	0	20	22.3	.24
	L	0	0	34	27.1	1.76	0	0	34	29.0	.86
2	S	0	0	13	17.2	1.03	0	1	14	18.4	1.06
	L	0	0	19	21.6	.31	0	0	19	23.0	.70
3	S	1	0	11	12.0	.08	0	0	12	12.8	.05
	L	0	0	19	24.2	1.12	0	0	19	25.8	1.79
4	S	0	0	14	13.1	.06	0	0	14	14.0	.00
	L	0	0	16	21.2	1.28	0	1	17	22.6	1.39
5	S	1	0	23	16.0	3.06	0	0	24	17.0	2.88
	L	2	0	19	18.9	.00	1	0	22	20.2	.16
6	S	0	0	6	6.9	.12	0	0	6	7.4	.26
	L	1	1	23	21.5	.29	0	0	25	22.9	.19
7	S	1	0	10	7.3	1.00	0	0	11	7.7	1.41
	L	2	0	13	20.0	2.45	2	0	17	21.4	.90
8	S	1	0	12	6.6	4.42	1	0	14	7.0	7.00
	L	1	1	31	21.1	4.65	1	0	34	22.5	5.88
9	S	0	0	8	8.9	.09	1	0	9	9.5	.03
	L	0	1	16	16.3	.06	0	0	17	17.4	.02
10	S	0	1	4	5.7	.51	0	0	5	6.1	.14
	L	0	0	11	15.8	1.46	0	0	11	16.9	2.06
Totals		10	4	322		23.79	6	2	344		26.69

Table 6. Numbers of breaks observed in each chromosome arm in the progeny from seeds exposed to X-ray treatments.

Chromosome	Arm	5000 and 10000 r		15000 r			20000 and 25000 r		Total		
		Ob	C	Ob	C	X^2	Ob	C	Ob	C	X^2
		No.	No.	No.	No.		No.	No.	No.	No.	
1	S	3	3.4	9	14.7	2.21	6	5.2	18	23.2	1.17
	L	1	4.4	13	19.0	1.89	2	6.7	16	30.1	6.60
2	S	3	2.8	9	12.1	.79	4	4.3	16	19.1	.50
	L	2	3.5	14	15.1	.08	3	5.4	19	23.9	1.00
3	S	2	1.9	15	8.4	5.19	0	3.0	17	13.3	1.03
	L	3	3.9	15	17.0	.24	5	6.7	23	26.9	.57
4	S	1	2.1	8	9.2	.16	1	3.3	10	14.6	1.45
	L	3	3.4	10	14.9	1.61	8	5.3	21	23.5	.27
5	S	4	2.6	9	11.2	.43	5	4.0	18	17.7	.01
	L	5	3.1	15	13.3	.22	5	4.7	25	21.0	.76
6	S	3	1.1	7	4.6	1.25	2	1.7	12	7.7	2.40
	L	5	3.5	18	15.1	.56	5	5.3	28	23.9	.70
7	S	1	1.2	5	5.5	.05	2	1.8	8	8.1	.00
	L	4	3.2	19	14.0	1.79	5	5.0	28	22.2	1.52
8	S	1	1.1	5	4.9	.01	6	1.6	12	7.3	3.03
	L	4	3.4	20	14.8	1.83	8	5.3	32	23.5	3.07
9	S	2	1.4	8	6.2	.52	4	2.2	14	9.9	1.70
	L	3	2.6	9	11.5	.54	3	4.1	15	18.2	.56
10	S	0	.9	6	4.0	1.00	2	1.4	8	6.2	.52
	L	2	2.5	12	11.1	.07	4	3.9	18	17.6	.01
Totals		52		226		19.19	80		358		26.87

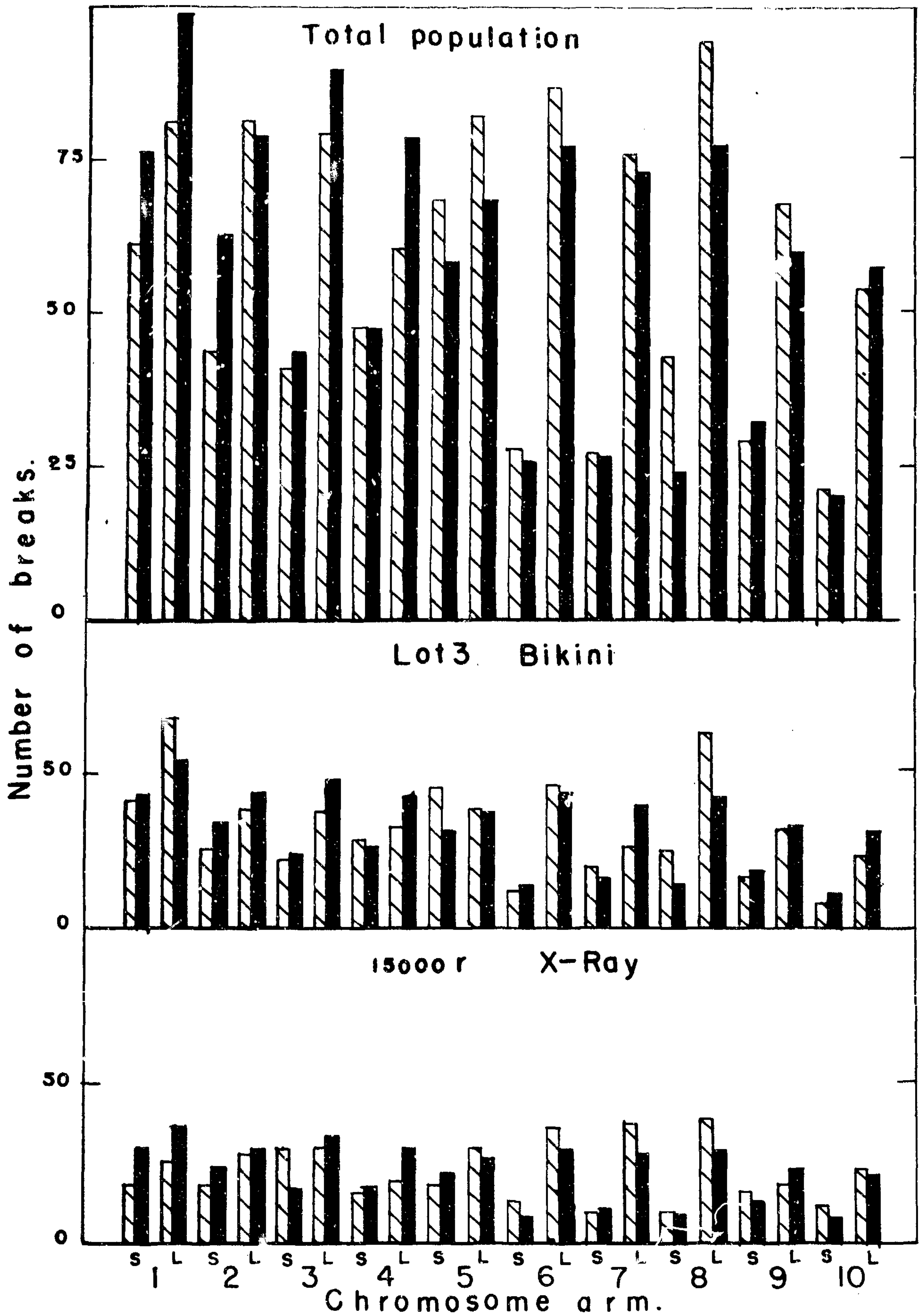

Fig. 2. Distribution of breaks among the 20 chromosome arms. Cross-hatched bars are observed distributions; solid bars are random distributions.

Table 7. Numbers of breaks observed in each chromosome arm of the California Institute of Technology collection, certain miscellaneous stocks and the grand total of all observed breaks.

Chromosome	Arm	C.I.T. Collection Ob No.	C.I.T. Collection C No.	C.I.T. Collection X^2	Misc. Stocks Ob No.	Grand Total Ob No.	Grand Total C No.	Grand Total X^2
1	S	22	28.6	1.52	1	61	76.3	3.08
	L	31	37.0	.97	0	81	99.0	3.27
2	S	14	23.5	3.84	0	44	62.8	5.63
	L	42	29.4	5.40	2	82	78.7	.14
3	S	11	16.3	1.13	1	41	43.6	.16
	L	34	33.0	.00	4	80	90.3	1.17
4	S	21	17.9	.54	3	48	47.8	.00
	L	21	28.9	2.16	1	60	78.3	4.29
5	S	25	21.8	.47	2	69	58.2	1.99
	L	31	25.8	1.05	4	82	69.0	2.43
6	S	10	9.5	.03	0	28	25.3	.28
	L	33	29.3	.47	1	87	77.3	1.23
7	S	8	9.9	.36	0	27	26.5	.01
	L	26	27.3	.06	5	76	73.1	.12
8	S	13	9.0	1.78	4	43	24.0	15.15
	L	27	28.8	.11	1	94	77.1	3.72
9	S	6	12.1	3.08	0	29	32.4	.35
	L	32	22.3	4.22	4	68	59.7	1.17
10	S	8	7.8	.05	1	22	20.9	.06
	L	25	21.6	.54	0	54	57.7	.24
Totals		440		27.78	34	1176		44.49

Chi-square tests shown in table 8 indicate appreciable differences between the Bikini and X-ray treatments in the distribution of breaks among the 20 chromosome arms. Since the Bikini and X-ray groups represent comparable samples from the progenies of each treatment, the different effects on some of the chromosomes and chromosome arms suggest an association between the frequency of breaks and differences in the morphological features of the chromosomes. A consideration of this possibility is postponed until the distribution of breaks within each of the twenty chromosome arms is presented.

Table 8. Comparisons of the breaks observed in each chromosome arm in the progeny from seeds exposed to the Bikini and X-ray treatments.

Chromosome	Arm	Chi-square values for the comparison indicated: Lot 3 and 15000r	Chi-square values for the comparison indicated: Totals for Bikini and X-ray
1	S	4.05	.38
	L	12.99	10.62
2	S	.00	.09
	L	.03	.03
3	S	4.98	1.63
	L	.25	.53
4	S	.59	1.43
	L	.23	.62
5	S	8.13	1.95
	L	.25	.19
6	S	1.54	5.32
	L	.26	.15
7	S	1.18	1.04
	L	7.26	6.01
8	S	3.38	.45
	L	.24	.32
9	S	1.01	2.29
	L	.80	.41
10	S	2.38	1.51
	L	3.27	3.75
Totals		52.82	38.72

Distribution of Breaks along the Twenty Chromosome Arms in 5 Micron Sections

Table 9 shows the distribution of breaks along the arm by 5 micron sections beginning at the fibre attachment for each chromosome arm of each radiation group. These distributions in major groups are shown graphically in figures 3 and 4. The table also shows the calculated number of breaks derived by dividing the total population of the group among the sections according to the length of chromosome thread present in each. These sections, beginning at the fibre attachments, total 100, 99.8, 96.4, 75.2, 68., 57., 41.8, 17.2 and 1.5 microns long respectively, for sections one to nine, respectively.

The chi-square tests show that the observed and calculated distributions are significantly different for most major groups and that the distribution of the breaks in the Bikini-treated material is different from that treated by X-rays, giving a X^2 value of 25.19.

This comparison clearly indicates a preponderance of breaks in the ten microns adjacent to the fibre attachments and a dearth of breaks in the distal portions of the arms. The latter seems more pronounced in the X-ray than in the Bikini material.

The unmistakable prevalence of breaks adjacent to the fibre attachment suggests that the heavily staining material so prominent near the fibre attachment in many chromosome arms is responsible in part for the non-random distribution of breaks along the chromosome arms.

Table 9. Observed and calculated numbers of breaks in each 5 micron section of the twenty chromosome arms (beginning at the fibre attachment) of the different groups of material.

Group	Section	Chromosome and arm																				Total		
		1		2		3		4		5		6		7		8		9		10				
		S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	Ob	C	χ^2
		No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	
Lot 3	0-5 u	4	9	2	0	3	5	5	4	5	3	1	3	6	5	4	7	4	5	2	4	81	58.3	3.84
	5-10 u	3	10	5	4	5	3	5	4	7	5	5	10	4	0	8	6	1	6	2	4	97	56.2	25.37
	10-15 u	2	2	2	4	3	1	3	2	3	0		4		2		3	3	2		1	37	50.3	3.52
	15-20 u	1	2	3	2		2	1	2	3	4		[illegible]		1		3		2		1	28	43.8	5.70
	20-25 u	4	1	1	3		1		1	3	2		0		1		2		0		1	20	39.6	9.70
	25-30 u	5	4		5		3		2	2	5		2		2		5		1			36	33.2	.24
	30-35 u	1	1		1		1		1				3		2		5					16	24.4	3.65
	35-40 u		3				3															8)	14.7	3.06
	40-45 u		2																			2)		
																						Total		60.57
Total Bikini	0-5 u	4	9	2	0	3	5	5	4	5	3	1	3	7	7	6	7	4	6	2	4	87	62.3	10.60
	5-10 u	3	10	5	4	5	3	5	4	7	5	5	12	4	1	8	6	1	[illegible]	3	4	101	62.2	24.20
	10-15 u	2	2	2	4	3	1	3	2	3	1		4		2		4	4	2		1	40	53.3	3.32
	15-20 u	1	2	4	2	1	2	1	2	4	5		1		1		3		2		1	32	46.8	4.68
	20-25 u	4	1	1	3		1		1	[illegible]	2		0		1		3		0		1	22	42.3	9.72
	25-30 u	5	4		5		3		2	2	5		2		2		6		1			37	35.5	.06
	30-35 u	1	1		1		1		2		1		3		2		5					17	26.0	3.11
	35-40 u		3				3								2							6)	15.6	4.74
	40-45 u		2																			2)		
																						Total		59.40
5000-10000 r	0-5 u	1	0	0	0	1	1	1	2	1	1	0	1	0	0	0	2	1	0	0	0	12	9.4	.72
	5-10 u	2	0	1	0	0	0		0	1	2	2	2	1	0	1	0	1	0		0	13	9.3	1.47
	10-15 u		0	1	0	1	0		0	0	1	1	0		1		1		0		1	7	8.1	.15
	15-20 u		0	0	0		1		0	2	0		1		0		1		2		1	8	7.1	.11
	20-25 u		0	0	2		0		0		0		0		1				1			4	6.4	.90
	25-30 u		0	1			1		1		1		1		2							7	5.4	.47
	30-35 u		0																			0)	6.2	4.36
	35-40 u		1																			1)		
	40-45 u																							
																						Total		3.18

Table 9. (cont'd.)

Group	Section	1 S No.	1 L No.	2 S No.	2 L No.	3 S No.	3 L No.	4 S No.	4 L No.	5 S No.	5 L No.	6 S No.	6 L No.	7 S No.	7 L No.	8 S No.	8 L No.	9 S No.	9 L No.	10 S No.	10 L No.	Total Ob	Total C	Total X^2
15000 r	0-5 u	1	0	1	2	5	3	3	4	3	3	0	4	2	4	4	2	3	0	6	3	53	40.9	3.58
	5-10 u	3	7	2	4	7	3	3	1	3	7	7	3	3	5	1	3	5	1		2	70	40.8	20.90
	10-15 u	2	0	1	[illegible]	1	1	0	1	1	2		5		2		3		1		3	26	36.3	2.45
	15-20 u	1	1	1	1	2	4	2	2	0	0		1		2		5		4		1	27	30.8	.47
	20-25 u	0	3	3	1		0		2	2	2		1		4		2		2		3	25	27.3	.23
	25-30 u	2	1	1	2		3		0		1		2		2		2		1			17	23.3	1.70
	30-35 u		0		1		1						2				3					7)	27.4	13.74
	35-40 u		1																			1)		
	40-45 u																							
																						Total		43.12
20000-25000 r	0-5 u	1	0	0	2	0	1	1	1	3	1	1	0	0	3	3	3	2	0	2	2	26	14.5	9.12
	5-10 u	2	0	1	1		0		2	1	2	1	1	2	0	3	3	1	0		0	20	14.4	2.15
	10-15 u	1	0	1			0		3	1	0		2		0		0	1	0		1	10	12.5	.50
	15-20 u	0	0	1			0		1		1		1		1		0		2		1	8	10.9	.77
	20-25 u	0	0	1			2		0		1		1		1		2		1			11	9.9	.08
	25-30 u	1	0				1		1													3	6.7	3.38
	30-35 u	1	1				1															3)		
	35-40 u		0																			0)	9.7	3.75
	40-45 u		1																			1)		
																						Total		19.38
Total X-ray	0-5 u	3	0	1	4	6	5	5	7	7	5	1	5	2	7	7	7	6	0	8	5	97	64.3	10.59
	5-10 u	7	7	4	5	7	3	3	3	5	11	10	6	6	5	5	6	7	1		2	100	64.7	22.67
	10-15 u	3	0	3	3	2	1	0	4	2	3	1	7	0	3		4	1	1		5	43	56.5	2.82
	15-20 u	1	1	2	1	2	5	2	3	2	1		3		3		6		8		3	45	48.7	.67
	20-25 u	0	3	4	3		2		2	2	3		2		6		4		4		3	38	44.0	.82
	25-30 u	3	1	2	2		5		2		2		3		4		2		1			27	36.3	2.66
	30-35 u	1	1		1		2						2				3					10	27.1	10.80
	35-40 u		2																			2)		
	40-45 u		1																			1)	16.3	10.85
																						Total		61.48

Table 9 (cont'd.)

Group	Section	Chromosome and arm																				Total		
		1		2		3		4		5		6		7		8		9		10				
		S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	Ob	C	χ^2
		No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.			
C. I. T.	0-5 u	4	5	5	7	4	3	9	5	5	5	3	1	5	7	6	4	3	8	5	10	109	79.6	10.86
	5-10 u	7	5	3	9	3	6	2	8	6	8	4	10	2	9	7	7	2	11	3	6	120	79.4	21.21
	10-15 u	3	4	1	7	2	4	8	3	5	5	3	4	1	0		3	1	8		2	64	68.8	.33
	15-20 u	0	9	3	5	3	6	2	1	4	3		7		1		3		1		5	53	59.9	.79
	20-25 u	3	3	2	2		5		2	1	7		5		7		3		4		2	46	54.1	1.21
	25-30 u	4	4		7		3		1	2	3		3		2		5					34	45.4	2.86
	30-35 u	1	0		5		0		1				3				2					12	36.3	13.82
	35-40 u		1				1															2	20.1	
	40-45 u																							
																							Total	50.68
Grand Total	0-5 u	12	14	8	11	13	21	20	17	18	14	5	9	14	22	23	18	13	15	16	19	302	21[illegible]9	37.39
	5-10 u	17	22	12	19	15	12	12	15	21	26	19	28	12	17	20	19	10	19	6	12	333	21[illegible]7	88.04
	10-15 u	8	6	6	14	7	8	11	9	10	10	4	15	1	6		11	6	11		8	149	182.2	8.06
	15-20 u	2	12	9	8	6	13	5	6	10	9		12		5		13		13		9	132	160.1	.29
	20-25 u	7	7	7	8		8		5	6	12		7		16		10		8		6	107	144.7	9.82
	25-30 u	12	9	[illegible]	15		13		5	4	10		8		8		13		2			101	121.4	3.43
	30-35 u	3	2		7		3		8		1		8		2		10					39	88.9	28.01
	35-40 u		6				4															10)	53.8	30.75
	40-45 u		3																			3)		
																						Total		188.78

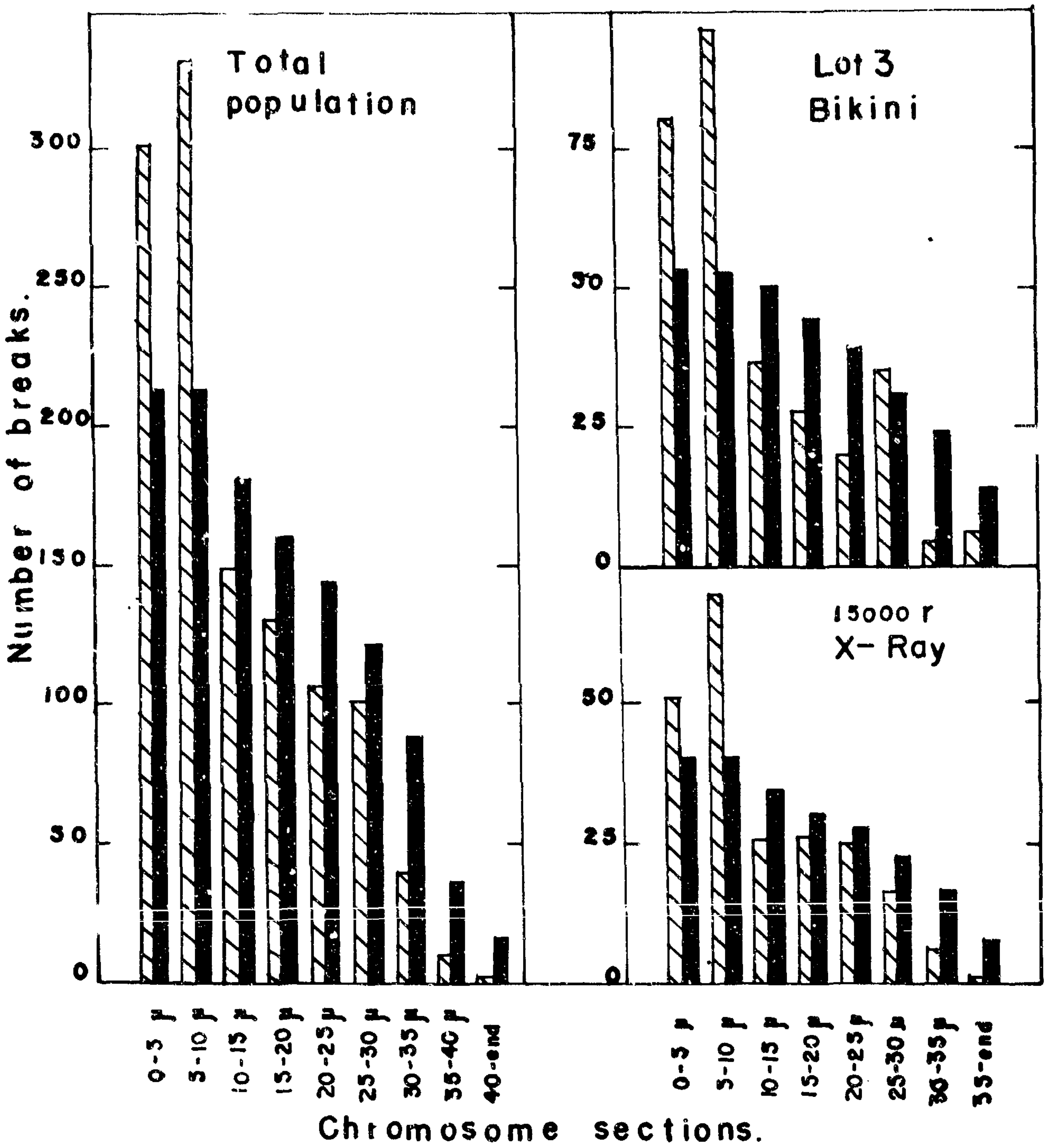

Fig. 3. Distribution of breaks in 5-micron sections of the chromosomes beginning at the fibre attachment. Cross-hatched bars are observed distributions; solid bars are calculated random distributions.

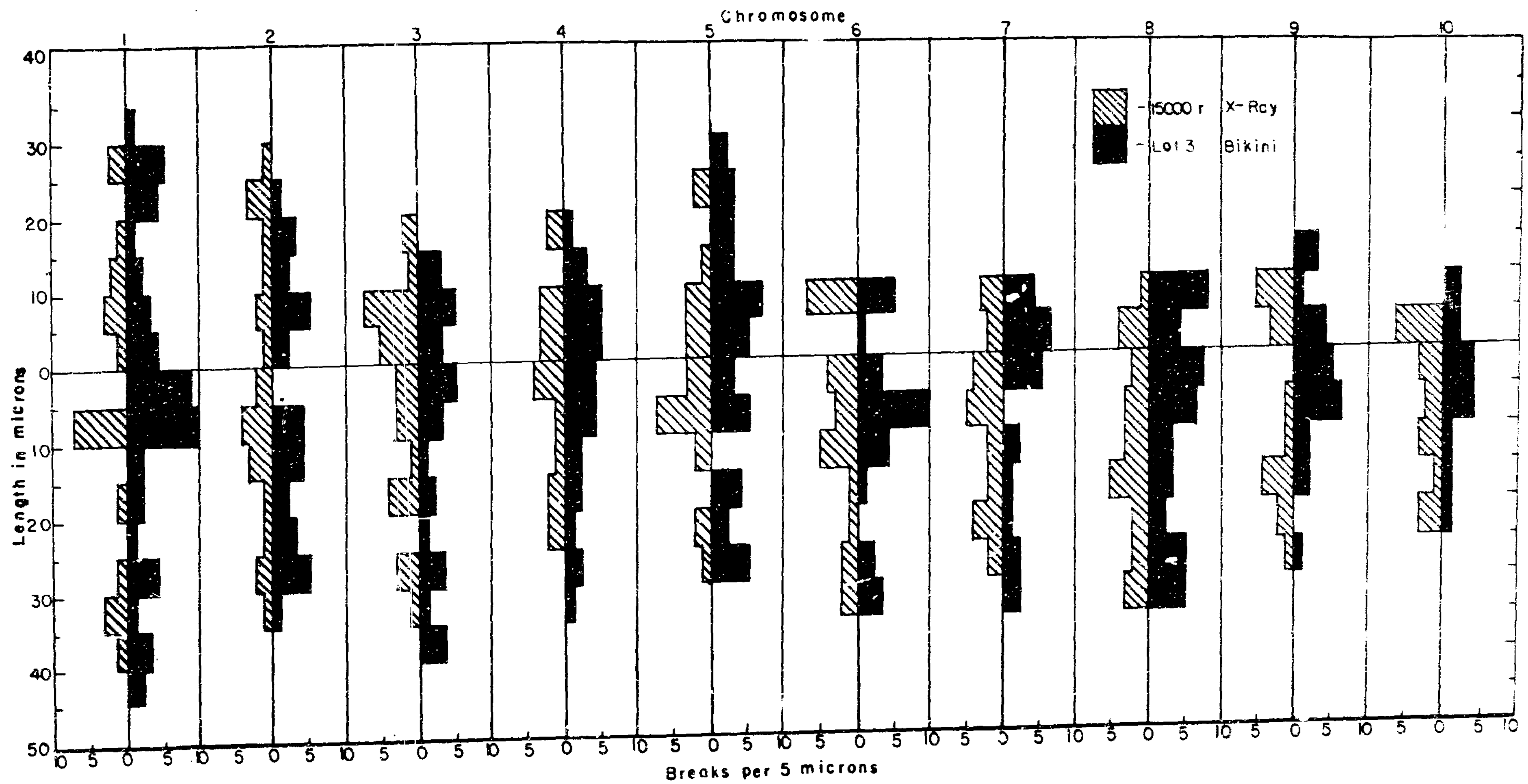

Fig. [illegible]. Comparative distribution of the breaks occurring in the 15000r X-ray treatment and Lot 3 Bikini.

Distribution of breaks among groups of Chromosome arms.

The observation that the Bikini and X-ray treatments caused the number of breaks to depart from the expected number in the same direction in some chromosome arms and in the opposite direction in others, suggested a regrouping of the data. It was thought that morphological features that cause differences in staining intensity may contribute to differences in the number of breaks in different chromsome arms subjected to the same treatment and to the same chromosome arms subjected to different treatment.

A personal element is likely to enter into any attempt to ascribe definite morphological characteristics to a chromosome or a group of chromosomes. The chromosomes of corn have characteristic markings that make it possible to identify each one. Certain morphological features that are common to groups of chromosome arms are listed below.

Chromosome arms 3S, 7L, 9S, 10S and 10L stain heavily adjacent to the fibre attachments.

Chromosome arms 1L, 4S, 5S and 7S stain lightly throughout their length.

Chromosome arms 5L, 6L, 8S, and 8L have mixed heavily-and lightly-staining areas throughout much of their length. Chromosome arm 6S seems to fit best into this group.

Chromosome arms 1S, 2L, 2S, 4L and 9L have a distal heavily-staining region.

The data in Table 9 have been rearranged and summarized in Table 10 and Figure 5. The percentage distribution of breaks is given in Table 10 instead of actual numbers of observed and expected breaks. The percentage distributions permit a more ready comparison of the effects of the different radiation treatments and of the differences in the morphological features of the chromosome arms and sections of arms. The ratio of the observed to the expected percentage of breaks shows the departure of each group from the expected or general mean. These tabulations do not lend themselves to statistical treatment, but seem useful in the search for clues to explain why the treatments affect certain chromosomes, chromosome arms and sections of chromosome arms differently. A comparison of the rearranged data from the Bikini and X-ray treatments shows the differences and the similarities in the distributions expected, since these were the basis for the separation of the arms into 4 groups.

Table 10. Percentage distribution of breaks among four groups of chromosome arms and three sections of each group, and ratios of observed to calculated distributions.

Chromosome arm	Sections	Calculated[1]	Total population Breaks Ob	Total population Ob/C	Bikini Breaks Ob	Bikini Ob/C	X-ray Breaks Ob	X-ray Ob/C	Lot 3 Breaks Ob	Lot 3 Ob/C	15000 r Breaks Ob	15000 r Ob/C
		pct.	pct.		pct.		pct.		pct.		pct.	
3S,7L,9S,10S,10L		19.4	18.9	.98	15.7	.81	23.7	1.22	14.6	.75	26.6	1.37
1L,4S,5S,7S		19.7	19.1	.97	24.1	1.22	14.5	.74	25.2	1.28	15.4	.79
5L,6S,6L,8S,8L		23.3	28.4	1.17	29.3	1.26	34.0	1.30	27.9	1.20	28.8	1.23
1S,2S,2L,3L,4L,9L		37.6	33.6	.90	30.8	.82	31.4	.83	32.3	.86	29.2	.78
3S,7L,9S,10S,10L	0-10 u	46.6	64.4	1.38	63.0	1.35	62.4	1.34	63.8	1.37	66.7	1.43
"	10-20 u	32.8	21.2	.65	24.1	.73	22.3	.68	23.4	.71	18.3	.56
	20u-end	20.6	14.4	.70	12.9	.63	15.3	.74	12.8	.62	15.0	.73
1L,4S,5S,7S	0-10 u	36.8	59.1	1.61	62.6	1.70	67.3	1.83	63.0	1.71	68.5	1.86
	10-20 u	29.7	24.4	.82	18.1	.61	13.5	.45	17.3	.58	11.5	.39
	20u-end	33.5	16.5	.49	19.3	.57	19.2	.57	19.7	.59	20.0	.60
5L,6S,6L,8S,8L	0-10 u	38.9	54.2	1.40	55.4	1.42	57.8	1.49	56.7	1.46	52.3	1.35
"	10-20u	25.7	22.2	.86	17.8	.69	22.9	.89	16.7	.65	24.6	.96
	20u-end	35.4	23.6	.67	26.8	.76	19.3	.55	26.6	.75	23.1	.65
1S,2S,2L,3L,4L,9L	0-10 u	28.8	45.2	1.57	43.4	1.50	38.4	1.33	44.2	1.54	37.9	1.32
	10-20 u	28.8	26.6	.93	24.6	.85	31.2	1.08	24.1	.84	33.3	1.16
	20u-end	42.4	28.2	.67	32.0	.76	30.3	.71	31.7	.75	28.8	.68

1/ Computed on the basis of relative chromosome length.

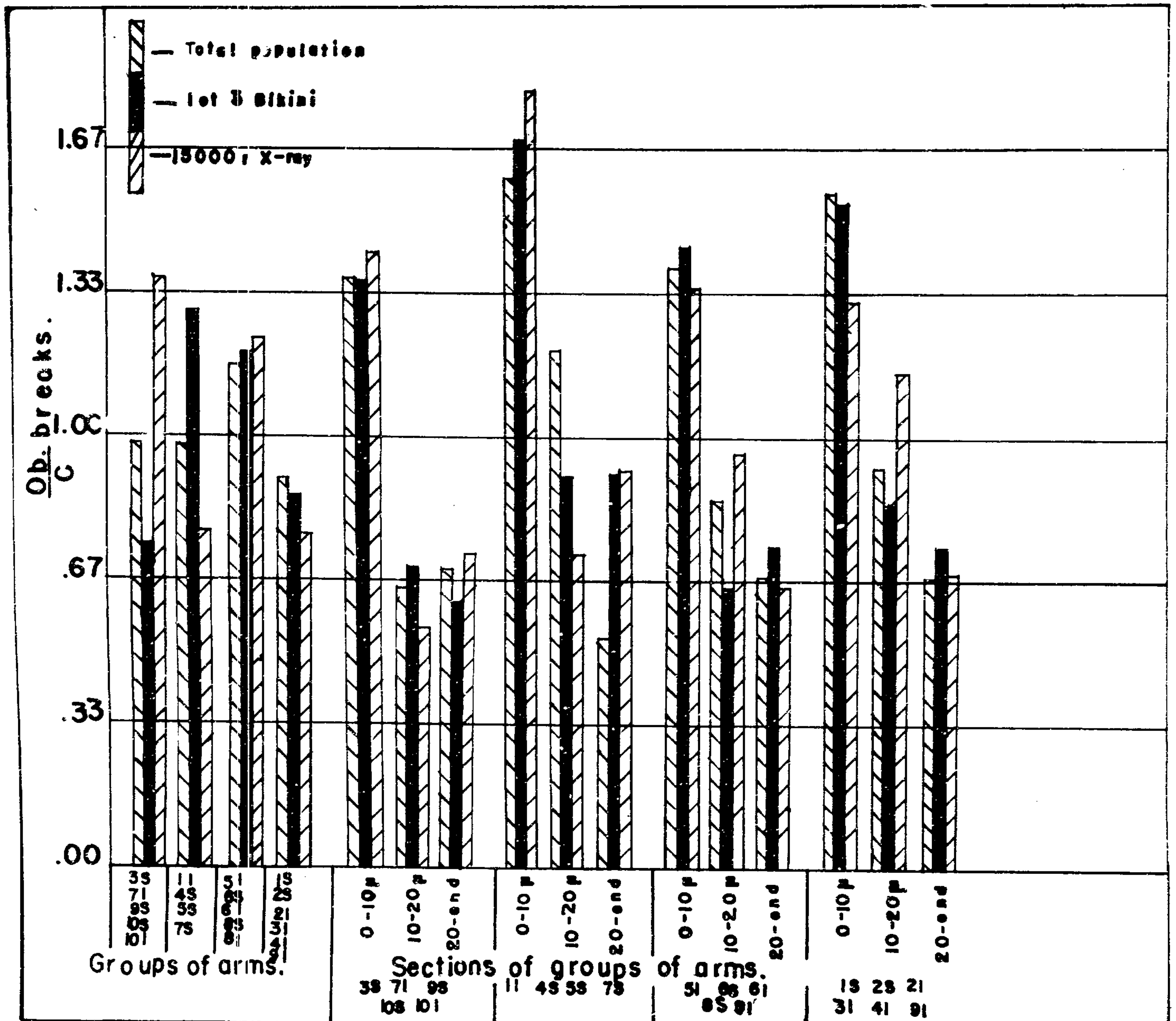

Fig. 5. Ratios of observed to calculated breaks occurring in 4 groups of chromosome arms and in 3 sections of each group of arms.

The distribution for the total population approaches the calculated distribution both in the group of arms that stain heavily adjacent to the fibre attachment and in the group staining lightly throughout their entire lengths, due to combining the data from different treatments. The other two groups of arms have departures from the calculated similar to those in the sub-populations.

The distribution of breaks within chromosome arms in random populations from the Lot 3 Bikini and the 15000 r treated seed will be examined critically. Both treatments give the greatest departure from the expected in the ten micron region adjacent to the fibre attachment in the group of arms that stain lightly throughout. In the 15000 r material the departure from the expected in the ten microns adjacent to the fibre attachment decreases as the distal sections of the arms stain more heavily. In the Lot 3 material the departure from the expected in the ten microns adjacent to the fibre attachment decreases as this section of the chromosome arms stains more heavily.

The two distal sections of the chromosome arms, if combined, show that the Lot 3 material closer to the expected than the 15000 r material in the two groups of arms that stain lightly distally, while the relationship is reversed in arms that have distal heavily-staining areas.

It is concluded from these comparisons that the Bikini treatment was slightly less effective than the X-ray treatment in producing breaks in heavily staining regions and slightly more effective in lightly-staining regions of the chromosome arms, and that the number of breaks in different sections of a chromosome arm seems to be associated with differences in staining intensity.

The data in Table 10 show somewhat different distributions of breaks between the 15000 r X-ray treatment and the total X-ray population. These differences led to the comparisons in Table 11 and Figure 6 of the average position of breaks in the low, medium, and high X-ray and the Bikini treatments.

The av age population of these four randomly-maintained progenies shows that as the X-ray dosage increases, the proportion of breaks near the fibre attachment also increases and that Lot 3 from Bikini has a mean position of breaks that suggests a dosage intensity intermediate between the low and medium X-ray dosages.

A subdivision of the total population of breaks of each progeny into the four groups of chromosome arms shows that the mean position of the breaks approaches the fibre attachment as the dosage increases in the case of arms that stain heavily adjacent to the fibre attachment and, except for the low dosage X-ray treatment, in arms that stain mixed heavily and lightly throughout. The other two groups of arms show little to indicate a consistent change in the mean position of breaks resulting from differences in radiation treatments.

The mean position of breaks seems to indicate that high dosages produce proportionately more breaks than low dosages in heavily-staining sections of chromosome arms, and the chromosome arms staining heavily adjacent to the fibre attachment offer the best material for differentiating between radiation treatments.

Table 11. The average position of breaks in four different radiation treatments for all and for four subdivisions of the chromosome arms.

Chromosome Arms	Position of Breaks			
	Lot 3 Bikini	5000 & 10000 r	1500	20000 & 25000 r
All	.424	.439	.408	.373
3S 7L 9S 10S 10L	.416	.537	.359	.328
1L 4S 5S 7S	.383	.433	.370	.382
5L 6S 6L 8S 8L	.471	.404	.438	.338
1S 2S 2L 3L 4L 9L	.420	.422	.426	.426

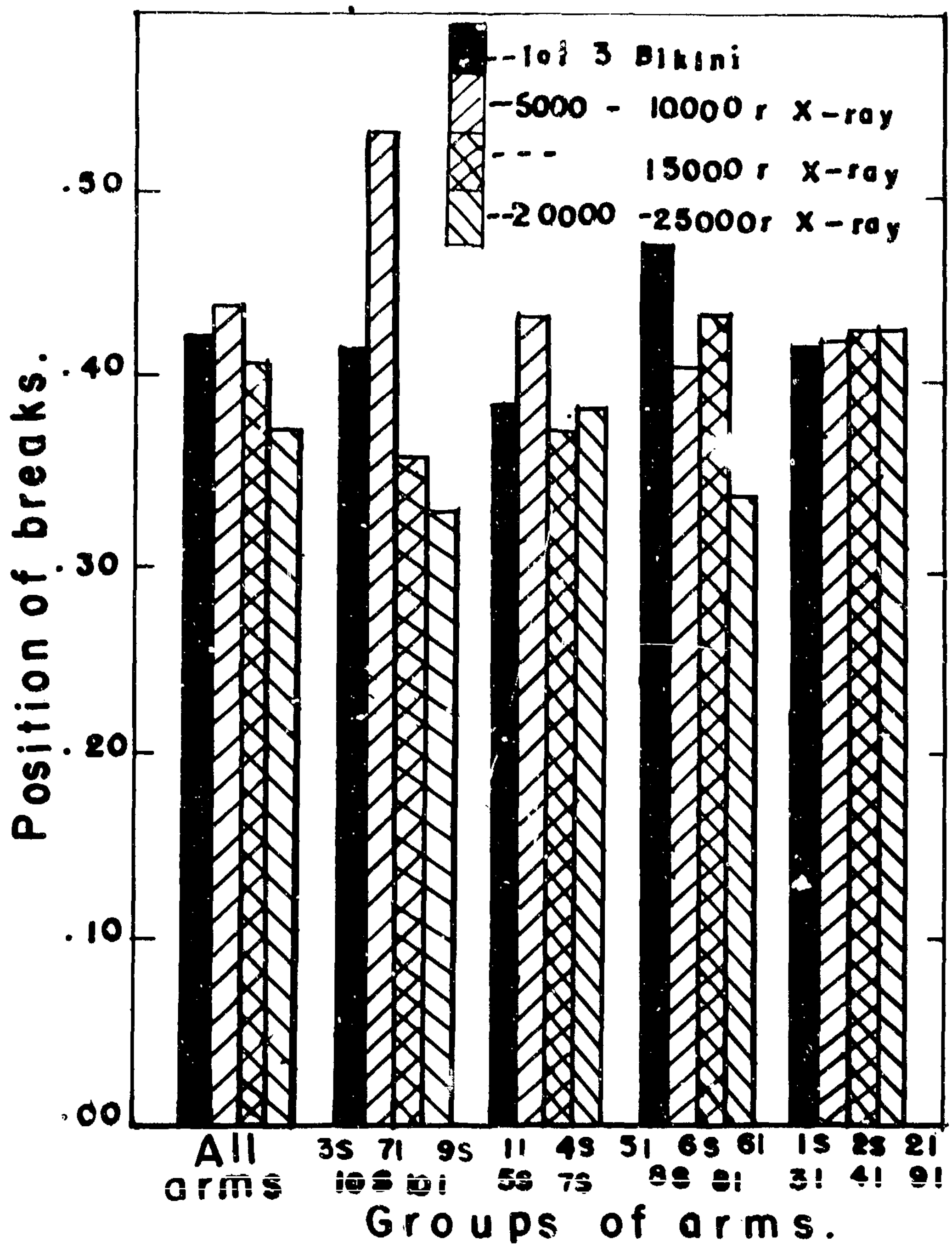

Fig. 6. Average position of the breaks (distance from the fibre attachment) in all chromosome arms and in four groups of arms.

The relationship between breaks of associated chromosomes

The possibility that there is a preferential association of certain chromosomes in the formation of translocations was tested by comparing the observed and the expected number of combinations of each chromosome with each of the other chromosomes. The chi-square test, although not altogether satisfactory due to the small numbers in each comparison, shows that only 7.3% of the associations are outside the normal curve.

The data for the association between chromosome arms are so meagre that a chi-square test seems unwarranted. Of the 180 possible combinations, 17 were not obtained from the population of 588 translocations. There were 12 combinations that occurred with a frequency above 7.15, the number expected for the association of the two longest arms.

An impression received during the cytological analyses of these translocations suggests that the two breaks which unite to form a translocation have a tendency to be the same distance from the fibre attachments. This possible relationship is tested in Table 12 and shown graphically in Figure 7.

The distribution of the 1176 breaks among the various sections of the chromosome arms is shown in the left-hand column. The distribution of these breaks as they are associated with breaks in each of the successive sections is given in the body of the table. For a comparison of the distribution of breaks as a whole with the distribution of the associate breaks a parallel tabulation is given.

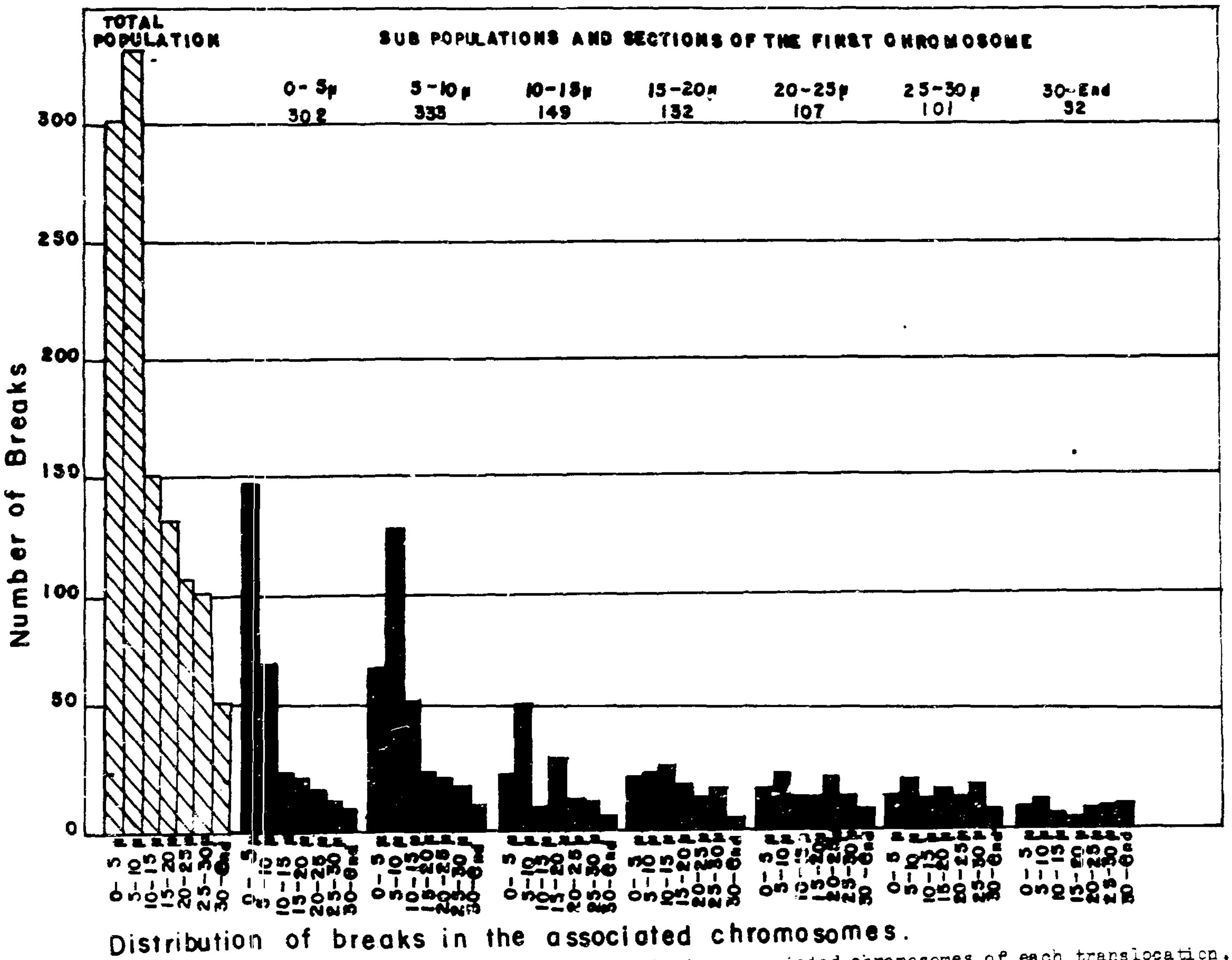

Fig. 7. Distribution of breaks by chromosome sections of the two associated chromosomes of each translocation.

Table 12. The distribution of associated breaks in each 5 micron section of the chromosome arms.

Breaks No.	Position	Observed, associated break position and number: 0-5 u No.	5-10 u No.	10-15 u No.	15-20 u No.	20-25 u No.	25-30 u No.	30 u-end No.	mean
302	0-5 u	146	68	26	23	17	13	9	8.76 u
333	5-10 u	68	132	62	25	24	21	11	11.19 u
149	10-15 u	26	52	10	31	13	12	5	13.00 u
132	15-20 u	23	25	31	20	13	16	4	13.83 u
107	20-25 u	17	24	13	13	20	13	7	15.40 u
101	25-30 u	13	21	12	16	13	18	8	16.71 u
52	30 u to end	9	11	5	4	7	8	8	17.75 u

Breaks No.	Position	Calculated, associated break position and number: 0-5 u C No.	0-5 u X^2	5-10 u C No.	5-10 u X^2	10-15 u C No.	10-15 u X^2	15-20 u C No.	15-20 u X^2	20-25 u C No.	20-25 u X^2	25-30u C No.	25-30u X^2	30u-end C No.	30u-end X^2	Mean	X^2
302	0-5u	77.6	60.29	85.6	3.62	58.4	3.95	33.8	3.45	27.5	4.01	26.0	6.40	13.3	1.39	12.24u	83.21
333	5-10u	85.[illegible]	3.62	94.3	15.07	42.3	2.22	37.3	4.06	30.6	1.42	28.6	2.02	14.7	.93	"	29.34
149	10-15 u	38.3	3.95	42.3	2.22	18.9	4.19	16.7	12.24	13.5	.02	12.8	.05	6.7	.35	"	23.02
132	15-20 u	33.8	3.45	37.3	4.06	16.7	12.24	14.8	1.83	12.0	.08	11.4	1.86	5.9	.61	"	24.13
107	20-25 u	27.5	4.01	30.6	1.42	13.5	.02	12.0	.08	9.7	10.94	9.2	1.57	4.7	1.13	"	19.17
101	25-30 u	26.0	6.50	28.6	2.02	12.8	.05	11.4	1.86	9.2	1.57	8.7	9.94	4.4	2.95	"	24.89
52	30u-end	13.3	1.39	14.7	.93	6.7	.35	5.9	.61	4.7	1.13	4.4	2.95	2.2	10.47	"	17.83

The chi-square tests show that the observed distribution of the associated breaks does not fit the distribution of breaks as a whole in any of the comparisons.

The mean position of the associate breaks shows that when the breaks in the primary chromosomes are more distal, the breaks in the associated chromosomes are also more distal. Thus, the impression that breaks at similar distances from the fibre attachment are associated more frequently than expected is confirmed.

Discussion

The distribution of breaks in the chromosomes of corn, resulting from the exposure of seed to X-rays or to the Bikini explosion, show many significant departures from the expected random distribution of breaks based upon the length of the chromosome arms. The non-random distribution of breaks resulting from the X-ray treatments is most apparent in the long chromosomes with their long lightly-staining sections. In them the number of breaks is below that expected. A comparison of differences in the number of breaks found in long and short chromosomes and differences observed in material from different radiation treatments indicates that non-random distribution of breaks is general.

This general non-random distribution is also apparent whenever the relative frequencies of breaks in certain chromosome arms and sections of arms are compared. They show that the Bikini exposures gave a distribution of breaks among the twenty chromosome arms quite different from that caused by X-ray treatments, and that heavily-staining sections adjacent to fibre attachments had well above the expected number of breaks in all radiation treatments.

Kaufmann (25) in his analysis of breaks following X-ray treatment of Drosophila melanogaster found that one-fourth of the breaks were in the proximal heterochromatic regions. The corn chromosome is not usually divided into heterochromatic and euchromatic regions, but the association of a high frequency of breaks with a high chromosome density seems very similar to the association between break frequencies and chromatic differences in D. melanogaster chromosomes.

The correlation of chromosome morphology and break frequency suggests that in all radiation treatments there is an association between the intensity of staining and the frequency of breaks. This association is most apparent in the more deeply staining chromosomes, chromosome arms and sections of chromosome arms, since the total frequency of breaks in them is outstandingly high.

A comparison of different radiation treatments indicates that as the dosage increases, the number of breaks increases in the heavily-staining sections, and decreases in the lightly-staining sections. The Bikini treatments produced effects that would suggest a dosage intensity below 15000 r.

The chromosome arms that stain heavily adjacent to the fibre attachment have served best to indicate the differences in break frequency resulting from different radiation treatments. The data on the positions of breaks in translocation complexes indicate that breaks equidistant from fibre attachment tend to be associated.

Summary

Analysis of the 588 translocations resulting from the exposure of corn seed to different radiation treatments, including the ionizing radiations of the Bikini Test ABLE atomic bomb has led to the following conclusions:

The breaks produced by the various radiation treatments are not distributed at random, among the 10 chromosomes, the 20 chromosome arms, or the different sections of the chromosome arms.

The non-random distribution of the Bikini induced translocations is different from that of the X-ray treated controls.

Chromosome arms with mixed heavily and lightly staining areas have more than the expected number of breaks, regardless of the radiation treatment.

Chromosome arms with heavily staining distal regions have less than the expected numbers of breaks following all types of radiation exposures.

Chromosome arms staining heavily adjacent to the fibre attachment have more breaks than expected when treated with X-ray and fewer breaks than expected when exposed to the Bikini radiations.

Chromosome arms staining lightly throughout their length have fewer breaks than expected when treated with X-ray and more than expected when exposed to the Bikini radiations.

A comparison of the position of breaks resulting from low, medium, and high dosages of X-rays indicates that the proportion of breaks in heavily staining areas is greatest when the dosage is highest, and in lightly staining areas is greatest after low dosages.

The position of the breaks in Bikini-treated material indicates that the dosage intensity was intermediate between the low and medium X-ray dosages studied.

Among the whole population of translocations there is a tendency for breaks the same distance from the fibre attachment to be associated more frequently than expected on a random basis.

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Addendum

The two following tables are the uncondensed data on chromosome translocations and inversions analyzed in these studies. These details are given to make it possible for readers to reanalyze the data and to acquaint other investigators with the different translocations and inversions being maintained by Dr. Anderson of the California Institute of Technology.

The following key shows the sources of the various progenies.

Progenies	Types of treatment
21, 22	5000 r X-ray
23, 24	10000 r "
25, 26, 36, 37, 38, 43	15000 r "
27, 28	20000 r "
70	25000 r "
01, 02, 03	Lot 1 Bikini bomb
04, 05, 06	" 2 " "
29, 30, 31, 32, 33, 34, 39, 40	" 3 " "
07, 08, 09	" 6 " "
10, 11, 12	" 7 " "
58, 59, 65, 66	Miscellaneous
All others	Calif. Inst. of Tech. collection

The cross bars, subdividing the column of position of breaks, separate the divisions of the chromosome arms into 5 micron sections, beginning at the fibre attachment.

Table A. List of Translocations

Progeny	Position of breaks				
X22-61	1S.96	4L.65	B-89	1S.42	7S.36
30-146	1S.90	8L.03	70-44	1S.40	6L.59
28-23	1S.85	4L.38	38-37	1S.33	5L.08
28-3	1S.81	3L.50	30-106	1S.31	6L.25
30-73	1S.79	2S.54	A-80	1S.30	6 .00
B-49	1S.79	7S.37	b	1S.29	5L.18
29-87	1S.78	5S.28	30-80	1S.29	6L.15
(2-7a)	1S.77	2S.24	26-12	1S.29	8L.46
37-154	1S.77	3S.65	34-109	1S.28	5S.16
38-30	1S.75	3L.66	30-64	1S.28	8S.82
30-173	1S.75	9S.78	B-75	1S.26	2 L.49
X23-2	1S.72	5S.71	I-17	1S.26	7L.24
30-36	1S.72	7L.14	c	1S.26	3L.12
C-47	1S.72	10L.10	27-52	1S.25	6S.79o
29-32	1S.71	10S.70	27-59	1S.24	4L.31
A-69	1S.70	7L.72	38-4	1S.22	2S.40
39-36	1S.69	4L.71	26-28	1S.21	2S.25
31-16	1S.69	7L.53	31-13	1S.20	5L.12
c	1S.66	2L.22	37-77	1S.20	6S.77o
30-126	1S.65	7L.41	a	1S.19	3L.15
c	1S.61	9L.32	A-61	1S.18	5S.73
29-4	1S.52	7S.60	c	1S.17	6L.39
25-11	1S.54	2L.38	21-63	1S.17	6L.21
34-24	1S.45	7S.36	a	1S.17	9L.17

21-60	1S.16 - - -	6L.45	D-5	1L.11	4L.14
33-53	1S.14	2L.34	30-108	1L.11	6L.26
34-101	1S.13	2S.74	X1-37	1L.12	5S.51
C-15	1S.12	3L.11	30-118	1L.13	2S.66
30-66	1S.11	5L.67	34-95	1L.13	3L.11
A-69	1S.09	7S.67	32-66	1L.13	4S.11
66-op	1S.09	7L.65	26-4	1L.13	8S.08
27-74	1S.09	8S.53	26-83	1L.14	8L.56
C-36	1S.09	10L.27	26-40	1L.16	10L.69
33-160	1S.08	9L.49	B-104	1L.17	3L.13
37-41	1S.08	10S.10	39-149	1L.17	8L.21
24-14	1S.06	5L.02	30-102	1L.17	9L.17
			B-98	1L.17	10L.30
o	1 .00	5.00	26-74	1L.18	4S.37
C-46	1L.01	4S.01	36-137	1L.18	8S.42
30-106	1L.02	4S.06	37-45	1L.19	7L.82
39-35	1L.03	5S.02	30-150	1L.19	8L.14
A-90	1L.03	5L.09	30-81	1L.20	8S.44
30-100	1L.03	8L.13	32-160	1L.21	5S.96
34-77	1L.04	3L.65	a	1L.21	6L.59
X41-13	1L.06	6L.15	30-129	1L.21	8S.80
31-51	1L.07	2S.11	37-83	1L.21	9S.14
30-80	1L.07	2S.11	B-89	1L.22	4S.50
30-155	1L.09	3L.04	30-19	1L.22 - - - -	7L.13
30-109	1L.09	8S.28	X55-16	1L.23	7L.59
F-10	1L.10	2L.28	B-2	1L.27	3L.07

a	1L.29	7L.03	B-42	1L.60	8L.82
B-92	1L.30	6L.35	29-136	1L.61	6L.73
30-5	1L.31	5L.47	A-33	1L.62	3L.49
34-102	1L.32	2L.39	34-3	1L.62	8L.79
A-57	1L.33	4S.16	34-94	1L.63	2L.52
A-37	1L.33	5S.47	d	1L.63	3S.75
30-71	1L.34	2L.71	33-6	1L.66	8L.35
c	1L.34	7L.14	26-36	1L.68	3L.71
I-9	1L.36	9L.35	d	1L.79	7S.38
30-84	1L.36	9L.32	32-37	1L.79	9L.40
A-50	1L.36	10L.67	40-40	1L.81	3L.89
a	1L.38	10L.21	24-45	1L.85	8L.45
B-94	1L.42	7L.15	29-146	1L.86	3L.64
37-87	1L.42	8L.31	28-32	1L.86	7L.11
b	1L.42	9L.54	29-130	1L.90	3L.92
42	1L.43	7L.08	37-89	1L.91	2L.70
26-19	1L.44	4L.08	33-31	1L.95	8L.73
29-16	1L.47	7L.90			
a	1L.49	4S.66	26-44	2S.94	7L.31
25-64	1L.50	5S.40	22-48	2S.93	4L.08
43-26	1L.51	9S.19	43-9	2S.85	6L.10
a	1L.52	5S.35	X14-122	2S.79	5S.28
b	1L.54	7L.16	26-92	2S.76	6L.71
I-24	1L.56	5S.93	34-101	2S.74	1S.13
27-27	1L.60	3L.81	28-6	2S.72	8L.62
29-136	1L.60	3L.76	37-120	2S.70	3S.89

b	2S.69	6L.49
70-4	2S.68	9L.61
29-154	2S.67	3L.39
30-118	2S.66	1L.13
e	2S.64	3L.34
c	2S.59	3S.66
10-26/117	2S.59	4L.95
37-146	2S.57	5L.28
a	2S.56	9L.72
30-73	2S.54	1S.79
22-46/48	2S.51	4L.71
38-4	2S.40	1S.22
33-74	2S.40	8L.55
F-2	2S.38	10L.76
39-128	2S.37	6S.81s
27-31	2S.35	8S.60
34-78	2S.34	3L.16
(2-8a)	2S.34	9L.80
25-24	2S.33	10L.23
30-76	2S.32	1S.21
30-145	2S.30	5L.26
26-28	2S.25	1S.21
27-55	2S.22	10S.12

39-122	2S.20	3S.27
d	2S.20	4L.25

K-10	2S.19	4L.30
22-27	2S.19	5L.14
33-28	2S.19	6L.21
A-36	2S.17	8S.13
36-51	2S.13	7L.19
B-69	2S.12	5S.23
b	2S.12	9L.12
31-51	2S.11	1L.07
30-80	2S.11	1L.07
X47-4	2S.08	4S.16
b	2S.05	3S.10

C-24	2L.01	8L.01
b	2L.02	5S.02
K-7	2L.05	3L.08
F-30	2L.05	6L.90
36-159	2L.06	7S.45
28-39	2L.07	8L.11
C-31	2L.09	4S.19
XI-1	2L.12	4L.18
27-11	2L.12	8S.47
a	2L.14	6S.09
26-76	2L.14	10S.07
34-133	2L.15	4L.23
I-10	2L.16	3S.48
37-145	2L.16	3L.18

a	2L.16	5S.18	38-48	2L.36	9S.32
a	2L.16	8L.81	25-11	2L.38	1S.54
B-108	2L.16	7L.16	34-102	2L.39	1L.32
a	2L.17	10L.53	b	2L.41	7L.12
38-6	2L.20	4S.28	A-16	2L.42	5S.41
27-24	2L.20	6L.28	C-57	2L.43	8S.50
X42-32	2L.20	8L.22	36-13	2L.45	4L.21
c	2L.22	1S.66	c	2L.48	7S.50
38-60	2L.22	6L.29	B-75	2L.49	1S.26
A-1	2L.22	8L.19	34-94	2L.52	1L.63
P-51	2L.23	7L.25	d	2L.52	6L.57
(2-7a)	2L.24	1S.77	30-89	2L.53	5S.65
34-131	2L.24	6L.24	X2-64	2L.56	4S.51
30-118	2L.24	6L.16	30-116	2L.59	5S.86
32-124	2L.24	9L.23	I-3	2L.59	7L.24
26-30	2L.26	9S.42	24-71	2L.61	3L.64
F-10	2L.28	1L.10	34-96	2L.61	5S.68
F-35	2L.28	4S.05	24-65	2L.62	6S.72o
e	2L.28	6L.22	29-51	2L.64	7L.63
a	2L.29	4L.15	37-106	2L.66	7L.07
c	2L.32	6L.20	37-89	2L.70	1L.91
25-76	2L.33	7L.22	30-71	2L.71	1L.34
33-53	2L.34	1S.14	G-2	2L.71	8S.42
F-29	2L.34	7L.67	59-op	2L.73	3L.68
30-44	2L.34	8L.84	d	2L.73	3L.63
30-81	2L.34	8S.18	84-84$_2$	2L.73	6L.84

30-129	2L.73	6L.35
30-89	2L.74	5L.82
25-51	2L.76	5S.88
33-15	2L.77	3S.51
c	2L.77	4S.09
C-4[illegible]	2L.77	7L.57
[illegible] 2	2L.78	4L.14
30-40	2L.78	6S.75a
A-84	2L.79	10L.39
34-72	2L.83	10L.92
36-13	2L.85	6S.80
b	2L.88	4L.54
A-74	2L.89	5L.86
K-3	2L.90	5L.08
F-7	2L.92	9L.32
C-49	2L.94	4L.23
b	3S.90	7L.03
36-25	3S.90	7L.44
37-120	3S.89	2S.70
02-3/134	3S.89	5L.45
b	3S.82	6S.75
d	3S.75	1L.63
c	3S.66	2S.59
37-154	3S.65	1S.77
A-22	3S.64	8L.23
58-op	3S.61	8L.54

33-123	3S.60	9S.67
30-115	3S.54	9L.60
33-151	3S.51	2L.77
24-68	3S.50	9L.63
I-10	3S.48	2L.16
29-104	3S.45	5S.49
[illegible]-52	3S.45	8L.57
36-142	3S.41	7L.16
36-159	3S.33	7L.16
33-37	3S.30	4L.74
29-95	3S.30	8L.31
37-142	3S.29	7L.13
32-132	3S.28	7S.26
29-122	3S.27	2S.20
36-39	3S.25	5S.27
37-37	3S.25	5L.18
36-82	3S.25	5L.45
Bur.	3S.25	8L.85
F-25	3S.25	10S.40
25-76	3S.24	4S.78
A-101	3S.24	5S.12
33-13	3S.24	8S.38
a	3S.23	7L.17
29-152	3S.20	8L.49
30-136	3S.18	4L.11
25-80	3S.18	7L.71
24-4	3S.17	6L.06

37-160	38.19	10L.19	B-104	3L.13	1L.27
36-158	38.12	7L.07	37-49	3L.14	8 .00
b	38.10	28.05	26-78	3L.14	7L.63
37-159	38.04	4L.01	a	3L.15	18.19
			b	3L.15	8L.29
X4-108	3 .00	58.99	c	3L.15	98.20
A-94	3L.02	9L.29	34-78	3 .16	28.34
58-op	3L.04	58.04	37-145	3L.18	2L.16
30-155	3L.04	1L.09	29-116	3L.18	6L.24
27-75	3L.05	8L.05	a	3L.19	9L.40
X23-158	3L.05	9L.44	30-126	3L.21	48.59
36-115	3L.06	78.60	a	3L.22	2L.63
30-140	3L.06	8L.67	c	3L.27	10L.31
a	3L.07	6L.19	29-105	3L.28	5L.52
B-2	3L.07	1L.27	37-34	3L.28	8L.32
A-104	3L.07	8L.03	a	3L.28	10L.12
K-7	3L.08	2L.05	c	3L.34	28.64
59-op	3L.09	82.39	c	3L.36	7L.29
37-33	3L.09	8L.17	24-41	3L.37	10L.75
32-51	3L.10	6L.11	29-154	3L.39	28.67
C-13	3L.11	18.12	a	3L.40	5L.60
34-95	3L.11	1L.13	36-121	3L.41	6L.35
38-9	3L.11	7L.54	36-85	3L.41	7L.15
c	3L.12	18.26	B-37	3L.41	8L.14
Li	3L.12	48.14	30-137	3L.42	9L.26
30-70	3L.12	58.44	A-53	3L.44	6L.73
24-43	3L.12	8L.06	36-9	3L.45	8L.38

B-103	3L.46	9L.69
F-24	3L.46	9L.18
26-47	3L.47	9L.47
b	3L.48	9L.53
A-[illegible]3	3L.49	1L.62
X23-[illegible]	3L.49	8S.32
32-105	3L.50	4L.91
28-3	3L.50	1S.81
A-21	3L.51	8S.45
b	3L.54	5L.49
70-72	3L.54	6L.48
D-25	3L.59	9L.17
b	3L.61	10S.25
27-23	3L.62	7L.57
d	3L.63	2L.73
29-146	3L.64	1L.86
24-71	3L.64	2L.61
37-77	3L.65	1L.04
X7-38	3L.65	5L.23
38-30	3L.66	1S.75
25-6	3L.66	6L.26
59-op	3L.68	2L.73
29-12	3L.68	9L.24
26-36	3L.71	1L.68
29-136	3L.76	1L.60
37-60	3L.80	9L.56

27-27	3L.81	1L.60
40-40	3L.89	1L.81
29-130	3L.92	1L.90
B-29	3L.92	10L.23
32-49	3L.95	5L.82
25-9	4S.85	6L.22
30-68	4S.82	7S.37
25-76	4S.78	3S.24
b	3S.71	6L.25
B-45	4S.70	10L.11
a	4S.66	1L.49
X57-36	4S.60	6L.51
A-52	4S.60	9L.24
30-126	4S.59	3L.21
39-52	4S.58	6S.83
a	4S.54	8L.48
X2-64	4S.51	2L.56
29-136	4S.51	6S.80a
B-89	4S.50	1L.22
X17-108	4S.50	8L.23
c	4S.45	5L.38
67-op	4S.43	9L.64
39-9[illegible]	4S.40	8L.14
33-35	4S.39	9L.30
39-74	4S.38	6L.92

26-74	4S.37	1L.18	26-70	4S.04	6L.15
F-22	4S.35	9L.42	C-46	4S.01	1L.01
30-19	4S.30	8L.69			
29-11	4S.30	8S.38	37-1[illegible]9	4L.01	3S.04
36-118	4S.29	5S.24	59-op	4L.01	9L.13
38-6	4S.28	2L.20	38-52	4L.01	10L.02
a	4S.27	7L.07	23-24	4L.03	8L.02
65-op	4S.24	5L.27	31-79	4L.03	9S.69
30-76	4S.21	2S.32	33-31	4L.04	8L.06
X19-5	4S.21	5L.18	K-17	4L.04	10L.01
d	4S.21	5L.19	26-24	4L.05	7L.68
C-31	4S.19	2L.09	28-51	4L.06	5S.14
L1	4S.19	3L.12	32-86	4L.06	9S.88
36-126	4S.18	7S.07	26-19	4L.08	1L.44
34-52	4S.17	5S.62	22-48	4L.08	2[illegible].93
30-71	4S.17	10L.08	B-74	4L.10	5S.13
A-57	4S.16	1L.33	30-136	4L.11	3S.18
X47-4	4S.16	2S.08	A-29	4L.13	2L.78
25-16	4S.16	5S.15	D-5	4L.14	1L.11
70-20	4S.14	7S.44	A-26	4L.14	9L.15
c	4S.13	6S.86	a	4L.15	2L.29
32-66	4S.11	1L.13	33-82	4L.15	6L.17
e	4S.09	2L.77	X1-1	4L.18	2L.12
21-61	4S.08	5S.07	a	4L.18	9L.50
30-106	4S.06	1L.02	b	4L.18	10L.57
F-35	4S.05	2L.28	a	4L.19	5S.29

30-83	4L.20	7S.12	b	4L.66	5S.66
36-13	4L.21	2L.45	36-43	4L.66	8L.23
28-7	4L.21	6L.30	37-112	4L.66	9L.81
28-38	4L.21	7S.67	39-[illegible]	4L.71	1S.69
C-49	4L.23	2L.94	22-46/48	4L.71	2S.51
39-133	4L.23	2L.15	33-37	4L.74	3S.30
d	4L.25	2S.20	bp	4L.81	9L.27
X6-77	4L.25	5L.43	27-66	4L.83	9L.83
30-153	4L.28	8L.11	32-105	4L.91	3L.50
K-10	4L.30	2S.19	X12-57	4L.92	10L.14
B-2	4L.30	5L.08	10-26/117	4L.95	2S.59
29-131	4L.30	9L.35			
28-9	4L.30	9S.14	X4-108	5S.99	3 .00
27-59	4L.31	1S.24	32-160	5S.96	1L.21
a	4L.33	6L.44	30-102	5S.96	6L.50
25-23	4L.34	8L.54	I-24	5S.93	1L.56
28-23	4L.38	1S.85	25-51	5S.88	2L.76
39-36	4L.41	9L.93	32-96	5S.88	6L.74
37-154	4L.48	9L.58	30-116	5S.86	2L.59
33-145	4L.52	5S.51	X27-44	5S.84	7L.83
70-47	4L.53	5L.19	33-158	5S.78	10S.44
36-134	4L.53	10L.51	25-51	5S.76	6L.12
b	4L.54	2L.88	A-61	5S.73	1S.18
34-128	4L.54	8L.74	X23-2	5S.71	1S.72
30-35	4L.63	8L.95	34-96	5S.68	2L.61
X22-61	4L.65	1S.96	01-92/86	5S.67	8L.61

b	5S.66	9L.66
30-89	5S.65	2L.53
22.83	5S.64	7L.68
34-52	5S.62	4S.17
23-22	5S.62	10L.56
d	5S.61	7S.27
A-75	5S.54	6S.91
X1-37	5S.51	1L.12
33-145	5S.51	4L.52
29-104	5S.49	3S.45
B-18	5S.49	8L.07
A-37	5S.47	1L.33
30-70	5S.44	3L.12
A-16	5S.41	2L.42
27-28	5S.41	8L.22
25-64	5S.40	1L.50
a	5S.35	1L.52
66-op	5S.35	7L.31
40-31	5S.34	10L.38
40-34	5S.33	10L.30
B-10	5S.32	8L.40
30-136	5S.31	8S.60
30-151	5S.31	7S.25
a	5S.29	4L.19
X23-41	5S.29	6S.70
29-87	5S.28	1S.78
X14-122	5S.28	2S.79
84_5	5S.28	8L.24
23-19	5S.28	9S.51
36-89	5S.27	3S.25
30-96	5S.25	9S.25
32-77	5S.25	8L.16
36-118	5S.24	4S.29
B-69	5S.23	2S.12
36-96	5S.22	6S.780
X10-6	5S.21	9L.26
27-66	5S.20	8S.25
a	5S.18	2L.16
28-38	5S.18	8L.18
28-22	5S.18	10L.17
25-79	5S.17	6L.30
34-109	5S.16	1S.28
40-38	5S.16	10L.74
25-16	5S.15	4S.16
28-51	5S.14	4L.06
B-74	5S.13	4L.10
A-101	5S.12	3S.24
37-103	5S.10	8S.22
21-61	5S.07	4S.08
34-51	5S.06	10L.07
58-op	5S.04	3L.04
32-53	5S.04	8L.03

39-35	5S.02	1L.03
b	5S.02	2L.02
c	5S.00	1 .00
24-14	5L.02	1S.06
58-op	5L.06	8S.11
C-52	5L.07	8S.36
36-28	5L.07	8L.53
31-4	5L.07	9S.08
29-124	5L.07	10L.27
38-37	5L.08	1S.33
K-3	5L.08	2L.90
B-2	5L.08	4L.30
A-90	5L.09	1L.03
26-62	5L.10	10L.80
31-13	5L.12	1S.20
22-27	5L.14	2S.19
A-49	5L.14	10S.68
b	5L.17	7S.33
b	5L.18	1S.29
37-37	5L.18	3S.25
X19-5	5L.18	4S.21
37-95	5L.18	6L.30
d	5L.19	4S.21
70-47	5L.19	4L.53
23-23	5L.20	6L.79

58-op	5L.21	7L.20
B-91	5L.21	8L.28
X11-73	5L.22	9L.15
X7-38	5L.23	3L.65
28-27	5L.23	6L.20
31-49	5L.25	6L.88
36-30	5L.25	7L.52
28-29	5L.25	10L.46
30-145	5L.26	2S.30
65-op	5L.27	4S.24
32-55	5L.27	8S.75
37-146	5L.28	2S.57
29-105	5L.28	8L.89
37-84	5L.28	9S.36
A-77	5L.29	6L.64
31-50	5L.30	6L.89
37-139	5L.31	8L.82
26-92	5L.31	10L.47
a	5L.32	6L.45
23-1	5L.37	8S.66
X27-37	5L.37	8S.61
c	5L.38	4S.45
c	5L.38	7L.71
65-op	5L.41	9L.64
X6-77	5L.43	4L.25
02-3/134	5L.45	3S.89

36-82	5L.45	3S.25
25-78	5L.46	6L.84
30-5	5L.47	1L.31
70-101	5L.48	8S.10
b	5L.49	3L.54
01-27/03-59	5L.50	7 .00
39-81	5L.51	9L.63
29-105	5L.52	3L.28
X14-111	5L.56	9S.68
B-21	5L.59	7S.39
30-125	5L.62	8L.79
a	5L.63	3L.22
70-53	5L.66	10L.13
30-66	5L.67	1S.11
37-32	5L.67	9S.46
B-70	5L.68	10L.60
X7-39	5L.70	[illegible].40
26-60	5L.70	10L.93
b	5L.71	6L.29
C-61	5L.71	7L.60
39-51	5L.73	8L.90
(3-5a)	5L.76	8S.48
a	5L.77	7L.71
a	5L.80	9S.21
c	5L.81	6S.11
26-50	5L.81	10S.38

30-89	5L.82	2L.74
32-49	5L.82	3L.95
29-21	5L.82	10S.81
29-122	5L.84	8L.39
A-74	5L.86	2L.89
24-17	5L.86	9L.76
30-152	5L.92	10L.33
07-13/05-25	5L.97	8L.73
24-65	6S.97	7L.82
I-22	6S.95	10S.20
A-75	6S.95	5S.54
c	6S.86	4S.13
39-52	6S.83	4S.58
39-128	6S.81	2S.37
36-13	6S.80	2L.85
29-137	6S.80s	4S.51
37-1	6S.800	9L.30
27-52	6S.790	1S.25
a	6S.79	9L.40
36-96	6S.780	5S.22
26-87	6S.780	8S.83
26-27	6S.780	10L.49
37-77	6S.770	1S.20
30-40	6S.75s	1L.78
b	6S.75	3S.82

22-91/86	6S.750	7L.84
24-65	6S.720	2L.62
X23-41	6S.70	5S.29
37-61	6S.670	8L.72
30-125	6S.65	8S.54
C-23	6S.54	9L.76
27-11	6S.31	9S.66
30-69	6S.30	10L.12
c	6S.11	5L.81
a	6S.09	2L.14
A-80	6S.00	1S.30
39-45	6L.01	7L.01
25-49	6L.03	7L.16
24-4	6L.06	3S.17
43-9	6L.10	2S.85
32-51	6L.11	3L.10
36-117	6L.12	5S.76
29-39	6L.12	9S.16
36-109	6L.13	7S.41
b	6L.13	9S.42
30-80	6L.15	1S.29
X41-13	6L.15	1L.06
26-70	6L.15	4S.04
C-27	6L.15	10L.06
30-118	6L.16	2L.24
34-87	6L.16	8L.27

33-82	6L.17	4L.15
X25-78	6L.17	9L.22
b	6L.17	10L.14
a	6L.19	3L.07
c	6L.20	2L.32
28-27	6L.20	5L.23
A-66	6L.20	9L.17
21-63	6L.21	1S.17
33-28	6L.21	2S.19
D-13	6L.21	10S.62
e	6L.22	2L.28
25-9	6L.22	4S.85
01-153/140	6L.23	7L.29
34-131	6L.24	2L.24
29-116	6L.24	3L.18
30-106	6L.25	1S.31
b	6L.25	4S.71
24-3	6L.25	7L.39
33-13	6L.25	9L.17
30-108	6L.26	1L.11
25-6	6L.26	3L.66
04-48/46	6L.27	9L.15
27-24	6L.28	2L.20
38-60	6L.29	2L.22
b	6L.29	5L.71
29-72	6L.29	7S.75
37-95	6L.30	5L.18

25-79	6L.30	5S.17	A-77	6L.64	5L.29
28-7	6L.30	4L.21	a	6L.68	10L.
34-96	6L.33	7S.67	26-92	6L.71	2S.76
B-92	6L.35	1L.30	29-136	6L.73	1L.61
30-129	6L.35	2L.73	A-53	6L.73	3L.44
36-121	6L.35	3L.41	B-83	6L.73	8S.72
30-91	6L.36	8L.22	32-96	6L.74	5S.88
C-59	6L.37	8L.42	X1-31	6L.74	7L.61
c	6L.39	1S.17	23-23	6L.79	5L.20
36-142	6L.41	7L.52	25-51	6L.79	8L.93
L1	6L.43	8S.36	84&84$_2$	6L.84	2L.73
a	6L.44	4L.33	25-78	6L.84	5L.46
21-60	6L.45	1S.16	X17-15	6L.84	10L.17
a	6L.45	5L.32	31-49	6L.88	5L.25
70-72	6L.48	3L.54	31-50	6L.89	5L.30
b	6L.49	2S.69	F-30	6L.90	2L.05
38-16	6L.49	9L.90	37-106	6L.91	10L.04
30-102	6L.50	5S.96	39-74	6L.92	4S.38
a	6L.50	8L.83			
X57-36	6L.51	4S.60	F-11	7S.92	9S.24
D-1	6L.51	8L.78	29-72	7S.75	6L.29
A-23	6L.51	10S.40	29-17	7S.73	10S.44
d	6L.57	2L.52	A-69	7S.67	1S.09
X46-13	6L.58	8L.90	28-38	7S.67	4L.21
70-4	6L.59	1S.40	34-96	7S.67	6L.33
a	6L.59	1L.21	25-62	7S.62	6L.62
25-62	6L.62	7S.62	29-4	7S.60	1S.59

36-115	7S.60	3L.06	36-158	7L.07	3S.12
c	7S.50	2L.48	a	7L.07	4S.27
21-61	7S.49	9L.58	31.81	7L.07	9L.33
36-139	7S.45	2L.06	42	7L.08	1L.43
70-20	7S.44	4S.14	27-45	7L.08	8L.17
36-109	7S.41	6L.13	03-59	7L.09	8S.40
B-21	7S.39	5L.59	08-129	7L.09	8S.41
d	7S.38	1L.79	39-112	7L.09	[illegible]S.11
B-49	7S.37	1S.79	23 32	7L.11	1L.86
30-68	7S.37	4S.82	b	7L.12	2L.41
34-24	7S.36	1S.45	30-19	7L.13	1L.22
33-10	7S.35	10L.14	37-142	7L.13	3S.29
b	7S.33	5L.17	30-36	7L.14	1S.7[illegible]
d	7S.27	5S.61	c	7L.14	1L.34
32-132	7S.26	3S.28	B-94	7L.15	1L.42
30-15	7S.25	5S.31	36-85	7L.15	3L.41
30-83	7S.12	4L.20	B-108	7L.16	2L.16
36-126	7S.07	4S.18	b	7L.16	1L.54
01-27	7S.00	5L.50	36-142	7L.16	3S.41
			36-159	7L.16	3S.33
39-45	7L.01	6L.01	25-49	7L.16	5L.03
a	7L.03	1L.29	X56-86	7L.16	9L.18
b	7L.03	3S.90	a	7L.17	3S.23
28-42	7L.03	9S.84	36-51	7L.19	2S.13
L1	7L.05	8S.08	58-op	7L.20	5L.21
37-108	7L.07	2L.66	25-76	7L.22	2L.33

I-17	7L.24	1S.26
I-3	7L.24	2L.59
D-36	7L.24	10L.04
P-51	7L.25	2L.23
A-76	7L.27	9L.20
a	7L.29	3L.36
01-153/140	7L.29	6L.23
66-op	7L.31	5S.35
26-44	7L.31	2S.94
29-65	7L.35	8L.44
24-3	7L.39	6L.25
30-126	7L.41	1S.65
36-25	7L.44	3S.90
36-30	7L.52	5L.25
31-16	7L.53	1S.69
38-9	7L.54	3L.11
C-44	7L.57	2L.77
27-23	7L.57	3L.62
X55-16	7L.59	1L.23
36-142	7L.59	6L.41
C-61	7L.60	5L.71
X1-31	7L.61	6L.74
70-59	7L.61	8L.64
29-50	7L.63	2L.64
26-78	7L.63	3L.14
67-op	7L.65	1S.09
09 28/08-119	7L.65	9S.96
[illegible]	7L.67	[illegible]
26-24	7L.68	4L.05
22-83	7L.68	5S.64
25-60	7L.7	3S.19
a	7L.71	5L.77
c	7L.71	5L.38
A-69	7L.72	1S.70
C-75	7L.75	8L.60
37-45	7L.82	1L.19
24-65	7L.82	6S.97
X27-44	7L.83	5S.84
31-8	7L.83	8L.25
22-91/86	7L.84	6S.75o
26-81	7L.84	9L.74
29-129	7L.86	8S.63
29-16	7L.90	1L.47
32-68	7L.96	8L.28
26-87	8S.83	6S.780
30-64	8S.82	1S.28
30-129	8S.80	1L.21
b	8S.76	9L.88
X57-15	8S.76	10L.67
32-55	8S.75	5L.27
B-83	8S.72	6L.73
23-1	8S.66	5L.37
29-110	8S.65	9L.13
29-129	8S.63	7L.86
X27-87	8S.[illegible]	[illegible]

27-31	8S.60	2S.35	X26-8	8S.11	9L.24
30-136	8S.60	5S.31	7-101	8S.10	5L.48
30-125	8S.54	6S.65	26-4	8S.08	1L.13
27-74	8S.53	1S.09	Li	8S.08	7L.05
C-57	8S.50	2L.43	37-49	8S.00	3L.14
(3-5a)	8S.48	5L.76	27-76	8S.00	10 .00
27-11	8S.47	2L.12			
A-21	8S.45	3L.51	C-24	8L.01	2L.01
30-81	8S.44	1L.20	23-24	8L.02	4L.03
36-137	8S.42	1L.18	30-146	8L.03	1S.90
G-2	8S.42	2L.71	A-104	8L.03	3L.07
08-129	8S.41	7L.09	32-53	8L.03	5S.04
03-59	8S.40	7L.09	38-46	8L.03	10L.05
59-op	8S.39	3L.09	27-74	8L.05	3L.05
33-13	8S.38	3S.24	24-43	8L.06	3L.12
29-11	8S.38	4S.30	33-31	8L.06	4L.04
C-52	8S.36	5L.07	27-1	8L.06	9S.27
Li	8S.36	6L.43	B-18	8L.07	5S.49
X23-36	8S.32	3L.49	36-101	8L.09	10S.29
30-109	8S.28	1L.09	28-39	8L.11	2L.07
b	8S.27	10L.14	30-153	8L.11	4L.28
27-66	8S.25	5S.20	30-100	8L.13	1L.03
37-103	8S.22	5S.10	30-150	8L.14	1L.19
30-81	8S.18	2L.34	B-37	8L.14	3L.41
A-36	8S.13	2S.17	39-93	8L.14	4S.40
58-op	8S.11	5L.06	32-77	8L.16	5S.25

37-33	8L.17	3L.09	B-18	8L.40	5S.32
27-45	8L.17	7L.08	06-22/12	8L.40	10S.61
26-49	8L.17	10S.37	C-59	8L.42	6L.37
28-38	8L.18	5S.18	c	8L.43	10S.51
A-1	8L.19	2L.22	29-65	8L.44	7L.35
39-149	8L.21	1L.17	24-45	8L.45	1L.85
X42-32	8L.22	2L.20	26-12	8L.46	1S.29
30-91	8L.22	6L.36	a	8L.48	4S.54
27-28	8L.22	5S.41	29-152	8L.49	3S.20
A-22	8L.23	3S.84	36-159	8L.49	9L.70
X17-108	8L.23	4S.50	36-16	8L.51	10S.37
36-43	8L.23	4L.66	36-26	8L.53	5L.07
84_5	8L.24	5S.28	58-op	8L.54	3S.61
b	8L.25	3L.15	25-23	8L.54	4L.34
31-8	8L.25	7L.83	33-74	8L.55	2S.40
34-87	8L.27	6L.16	26-83	8L.56	1L.14
B-91	8L.28	5L.21	36-52	8L.57	3S.45
32-68	8L.28	7L.96	a	8L.60	3L.40
24-20	8L.30	9S.15	C-75	8L.60	7L.75
C-12	8L.30	9L.36	01-92/86	8L.61	5S.67
37-87	8L.31	1L.42	28-6	8L.62	2S.72
29-95	8L.31	3S.30	70-59	8L.64	7L.61
37-34	8L.32	3L.28	30-140	8L.67	3L.06
33-6	8L.35	1L.66	a	8L.68	10L.83
F-1	8L.37	10L.18	30-19	8L.69	4S.30
36-9	8L.38	3L.45	B-89	8L.70	1S.42
29-122	8L.39	5L.84	33-60	8L.70	10L.40

37-61	8L.72	6S.67o	X14-111	9S.68	5L.56
33-31	8L.73	1L.95	33-123	9S.67	3S.60
07-13/05-25	8L.73	5L.97	27-11	9S.66	6S.31
25-61	8L.73	9L.63	25-2	9S.64	10L.83
34-128	8L.74	4L.54	23-19	9S.51	5S.28
D-1	8L.78	6L.31	37-32	9S.46	5L.67
34-3	8L.79	1L.62	26-30	9S.42	2L.26
30-125	8L.79	5L.62	b	9S.42	6L.13
a	8L.81	2L.16	26-57	9S.41	8L.86
B-42	8L.82	1L.60	37-84	9S.36	5L.28
37-139	8L.82	5L.31	38-48	9S.32	2L.36
a	8L.83	6L.50	27-1	9S.27	8L.06
30-44	8L.84	2L.34	30-96	9S.25	5S.25
Bur.	8L.85	3S.25	F-11	9S.24	7S.92
26-57	8L.86	9S.41	a	9S.21	5L.80
34-125	8L.88	9L.15	c	9S.20	3L.15
29-105	8L.89	5L.28	43-26	9S.19	1L.51
39-51	8L.90	5L.73	29-39	9S.16	6L.12
X46-13	8L.90	6L.58	24-20	9S.15	8L.30
25-51	8L.93	6L.79	37-83	9S.14	1L.21
30-35	8L.95	4L.63	28-9	9S.14	4L.30
			39-112	9S.11	7L.09
09-28/08-119	9S.96	7L.65	b	9S.11	10S.28
32-86	9S.88	4L.06	31-4	9S.08	5L.07
28-42	9S.84	7L.03			
30-73	9S.78	1S.75	b	9L.12	2S.12
31-79	9S.69	4L.03	59-op	9L.13	4L.01

31-81	9L.13	7L.07	30-84	9L.32	1L.36
29-110	9L.13	8S.65	N-7	9L.32	2L.92
A-26	9L.15	4L.14	I-9	9L.35	1L.36
X11-73	9L.15	5L.22	39-131	9L.35	4L.30
04-48/46	9L.15	6L.27	C-12	9L.36	8L.30
34-125	9L.15	8L.88	32-37	9L.40	1L.79
a	9L.17	1S.17	a	9L.40	3L.19
30-102	9L.17	1L.17	X7-39	9L.40	5L.70
D-25	9L.17	3L.59	a	9L.40	6S.79
33-13	9L.17	6L.25	F-22	9L.42	4S.35
A-66	9L.17	6L.20	X23-158	9L.44	3L.05
F-24	9L.18	3L.46	26-47	9L.47	3L.47
X56-86	9L.18	7L.16	33-160	9L.49	1S.08
A-76	9L.20	7L.27	a	9L.50	4L.18
X25-78	9L.22	6L.17	b	9L.53	3L.48
32-124	9L.23	2L.24	b	9L.54	1L.42
29-12	9L.24	3L.68	27-36	9L.55	10L.73
A-52	9L.24	4S.60	37-60	9L.56	3L.80
X26-8	9L.24	8S.11	37-154	9L.58	4L.48
30-137	9L.26	3L.42	21-61	9L.58	7S.49
X10-6	9L.26	5S.21	30-115	9L.60	3S.54
59-op	9L.26	10S.49	70-4	9L.61	2S.68
bp	9L.27	4L.81	24-68	9L.63	3S.50
A-94	9L.29	3L.02	39-81	9L.63	5L.51
33-35	9L 30	4S.39	25-61	9L.63	8L.73
37-1	9L.30	6S.80o	67-op	9L.64	4S.43
C	9L.32	1S.61	65-op	9L.64	5L.41

B-103	9L.69	3L.46
36-159	9L.70	8L.49
a	9L.72	2S.56
26-81	9L.74	7L.84
24-17	9L.76	5L.86
C-23	9L.76	6S.54
(2-7a)	9L.80	2S.34
37-112	9L.81	4L.66
27-66	9L.83	4L.83
b	9L.88	8S.76
38-16	9L.90	6L.49
39-36	9L.93	4L.41
29.21	10S.81	5L.82
29-32	10S.70	1S.71
A-49	10S.68	5L.14
D-13	10S.62	6L.21
06-22/12	10S.61	8L.40
c	10S.51	8L.43
59-op	10S.49	9L.26
33-158	10S.44	5S.78
29-17	10S.44	7S.73
F-25	10S.40	3S.25
A-23	10S.40	6L.51
26-50	10S.38	5L.81
36-16	10S.37	8L.51

26-49	10S.37	8L.17
36-101	10S.29	8L.09
b	10S.28	9L.11
b	10S.25	3L.61
I-22	10S.20	6S.95
27-55	10S.12	2S.22
37-41	10S.10	1S.08
26-76	10S.07	2L.14
27-76	10S.00	8 .00
K-17	10L.01	4L.04
38-52	10L.02	4I.01
37-106	10L.04	6L.91
D-36	10L.04	7L.24
38-46	10L.05	8L.03
C-27	10L.06	6L.15
34-51	10L.07	5S.06
30-71	10L.08	4S.17
C-47	10L.10	1S.72
B-45	10L.11	4S.70
a	10L.12	7L.28
30-69	10L.12	6S.30
70-53	10L.13	5L.66
X12-57	10L.14	4L.92
b	10L.14	6L.17
33-10	10L.14	7S.35

b	10L.14	8S.27
28-22	10L.17	5S.18
X17-15	10L.17	6L.84
F-1	10L.18	8L.37
37-160	10L.19	3S.15
a	10L.19	6L.68
a	10L.21	1L.38
25-24	10L.23	2S.33
B-29	10L.23	3L.92
C-36	10L.27	1S.09
29-24	10L.27	5L.07
B-98	10L.30	1L.17
40-34	10L.30	5S.33
c	10L.31	3L.27
30-150	10L.33	5L.92
40-31	10L.38	5S.34
A-84	10L.39	2L.79
30-60	10L.40	8L.70
28-29	10L.46	5L.25
26-92	10L.47	5L.31
26-27	10L.49	6S.680
36-134	10L.51.	4L.53
a	10L.53	2L.17
23-22	10L.56	5S.62
b	10L.57	4L.18
B-70	10L.60	5L.68

A-50	10L.67	1L.36
X57-16	10L.67	8S.78
[illegible]-40	10L.69	1L.16
27-36	10L.73	9L.52
40-38	10L.74	5S.16
24-41	10L.75	3L.37
F-2	10L.76	2S.38
26-62	10L.80	5L.10
a	10L.83	8L.60
25-2	10L.83	9S.64
34-72	10L.92	2L.83
26-60	10L.93	5L.70

Table B. <u>List of Inversions</u>

Progeny	Position of inversion	
33-158	1S.88	L.67
33-101	1S.72	L.40
39-61	1S.61	L.44
31-49	1S.39	L.90
30-115	1S.30	L.30
30-68	1S.20	L.08
32-119	1S.18	S.09
26-62	1S.15	L.08
30-98	1S.06	L.05
30-71	1L.07	L.17
29-92	1L.25	L.63
03-14/17	1L.46	L.82
21-77/88	1L.56	L.93
30-32	2S.82	L.41
09-42	2S.81	L.85
30-23	2S.76	L.86
30-15	2S.64	L.96
30-52	2S.38	L.43
27-2	2L.13	L.64
33-62	2L.18	L.58
04-66	2L.24	L.76
26-60	2L.35	L.79
34-59	3S.73	L.69
06-18	3S.26	L.09
33-13	3S.09	L.25
26-92	3L.08	L.39
34-16	3L.21	L.78
26-39	3L.29	L.89
37.12	4S.89	L.72
30-153	4S.30	S.09
32-34	4S.29	L.53
38-17	4L.13	L.60
33-160	4L.15	L.44
33-149	4L.16	L.77
37-156	4L.19	L.55
37-146	4L.32	L.59
30-52	4L.43	L.62
30-47	5S.78	L.86
30-100	5S.67	L.30
27-75	5S.61	L.09
28-65	5S.45	L.55
30-3	5S.41	S.04
32-24	5S.41	L.84
37-112	5S.33	L.39

65-op	51.26	1.81
38-58	68.09	1.87
29-119	61.55	1.70
29-152	78.62	1.74
30-107	78.37	1.57
25-62	71.06	1.70
26-33	71.15	1.74
32-152	71.17	1.69
33-62	81.27	1.37
30-124	81.28	1.54
30-76	81.51	1.86
29-21	81.65	1.81
25-40	98.67	1.78
27-62	108.55	1.86
30-25	101.12	1.50

Defense Special Weapons Agency
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TRC

10 April 1997

MEMORANDUM FOR DEFENSE TECHNICAL INFORMATION CENTER
ATTENTION: OMI/Mr. William Bush

SUBJECT: Declassification of Reports

The Defense Special Weapons Agency (formerly Defense Nuclear Agency) Security Office has reviewed and declassified the following reports:

AD-366718	XRD-32-Volume 3	
AD-366726	XRD-12-Volume 2	
AD-366703	XRD-16-Volume 1	
AD-366702	XRD-14-Volume 2	
AD-376819L	XRD-17-Volume 2	
AD-366704	XRD-18	
AD-367451	XRD-19-Volume 1	
AD-366700 05	XRD-20-Volume 2	AD-366705
AD-376028L	XRD-4	
AD-366694	XRD-1	
AD-473912	XRD-193	
AD-473891	XRD-171	
AD-473899	XRD-163	
AD-473887	XRD-166	
AD-473888	XRD-167	ST-A 28 JAN 80 made target
AD-473889	XRD-168	

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AD-B197749	XRD-174
AD-473905	XRD-182
AD-366719	XRD-33 Volume 4
AD-366700	XRD-10
AD-366712	XRD-25 Volume 1
AD-376827L	XRD-75
AD-366756	XRD-73
AD-366757	XRD-74
AD-366755	XRD-72
AD-366754	XRD-71
AD-366710	XRD-23 Volume 1
AD-366711	XRD-24 Volume 2
AD-366753	XRD-70
AD-366749	XRD-66
AD-366701	XRD-11
AD-366745	XRD-62.

All of the cited reports are now **approved for public release; distribution statement "A" applies.**

Ardith Jarrett
ARDITH JARRETT
Chief, Technical Resource Center

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