fluid was drained from a large number of culture tubes which had been seeded 24 h previously from a pool of McCoy cells. TT virus (0·1 ml. of stock diluted 1 : 4 in nutrient fluid) was added to each monolayer of cells. This dilution normally infects 90 per cent of the cells. Virus was incubated with cells for 1 h at room temperature, and then cells in a set of 4 culture tubes were irradiated. Nutrient fluid (1·0 ml.) was added to all the inoculated tubes, and cultures were incubated at 37° C. At intervals, nutrient fluid was decanted from a new set of 4 infected cultures, cells were irradiated, fresh medium was added to each, and incubation was resumed. Sets of infected cultures were thus irradiated at 3, 5, 7, 9, 12 and 15 h after onset of infection. At 24 h after onset of infection, all the cell preparations were fixed, stained with acridine orange, and examined for 'red-ball' inclusions.

Sets of cultures were irradiated at 1 and at 7 h after onset of infection with single dosages of 1,000, 2,000, 4,000, and 6,000 r. of X-rays. In order to determine the significance of viral asynchrony on survival, other sets of cultures were exposed to a single dosage each of 12,000 r. of X-rays at 3, 5 and 7 h after onset of infection. For comparison, one set of cultures was treated three times with 4,000 r. of X-rays at 3, 5, and 7 h after onset of infection to give a cumulative dose of 12,000 r.

Control preparations included: (*a*) infected cells which were not irradiated; (*b*) cells which were irradiated and then infected; (*c*) cells which were infected with irradiated virus. For the latter preparations, 0·1 ml. of stock virus was spread on a cell-free coverslip in a Leighton tube. The virus was irradiated, diluted in nutrient fluid (1 : 4) and added to fresh cell cultures (0·1 ml. plus 1·0 ml. of nutrient fluid per tube).

The X-ray controlling factors were 280 kV, 20 m.amp, filter 1 mm aluminium, focal distance 17 cm, dose rate 3,800 r./min at room temperature (22° C).

Irradiated cells were enlarged, and mitotic figures were not observed among them. Intracellular virus was more sensitive to X-rays at all times during the initial 3–9 h of replication than were the control cultures (Table 1); irradiation of infected cells during this time interval with 4,000 r. of X-rays resulted in inactivation of 80–90 per cent of the virus. Virus inclusions which survived the effects of irradiation proceeded normally through stages of maturation to infectivity. Progeny of virus which survived exposure to 4,000 r. of X-rays was as sensitive to the same dose as the parent stock of virus. Virus inactivation was more marked following treatment at 7 h with 4,000 r. of X-rays than at lower doses (Fig. 1). The cumulative virus-inactivating effect of 3 doses of 4,000 r. each was slightly greater (99·9 per cent) than that from a single dose of 12,000 r. (98 per cent). Despite the cells being in better condition and more numerous after 3 × 4,000 r. than after the single 12,000 r. dose, this difference may not be a significant one.

Table 1. Response of Intracellular Psittacosis Virus to 4,000 R. X-rays

Irradiation h after infection	Virus particles (× 10⁶)/ml. at 24 h	Percentage of survival
Control	18·0	100·0
1	10·0	55·0
3	3·0	16·6
5	2·9	16·1
7	2·8	15·0
9	2·8	15·0
12	4·2	23·0
15	10·0	55·0

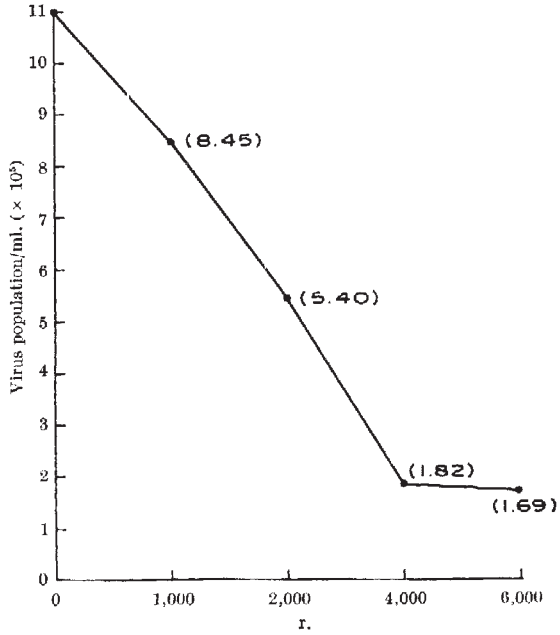

Fig. 1. Survival of psittacosis virus in McCoy cells following exposure to X-rays

The observation that virus maturation was slower in untreated cells than in cells which were inoculated either immediately or at 24 h after they had been irradiated indicates that capacity of irradiated cells to support virus replication was intact or improved.

The effect of X-rays on intracellular virus suggests that it was an irreversible reaction. During the sensitive stage of replication (hours 3–9), the logarithm of the survival ratio was proportional to the dose of X-rays, except for the deviation shown at 6,000 r. (Fig. 1). Response of the virus to irradiation was more decisive than that of the host cell. In normal circumstances, viral stages beyond the initial DNA particle were visible as a mass of RNA-staining material ('red-ball') which eventually matured to infectious DNA-staining virus[1]. Since neither stage was visible in irradiated cultures, except for the few that survived treatment, it is postulated that the effect of X-ray treatment was on the initial viral DNA.

The procedure described herein provides a method for examining radiation-effects on a dynamic, intracellular, cytochemical, indicator system, with which quantitative dose–response relationships can be studied.

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GENETICS

Correlations between Relatives arising from Sex-linked Genes

In a recent communication, Garn and Rohmann[1] report observations on the correlations between sibs in respect of three characters which they consider may be taken as reflecting developmental timing in man. The methods they used in calculating the correlation coefficients are

not completely clear from their account; but the values which they obtained and which are reproduced in Table 1, are consistent over the three characters in showing that the correlation between pairs of sisters is markedly higher than that between pairs of unlike sex, which in turn is slightly higher than that between pairs of brothers. This the authors interpret as indicative of control by sex-linked genes.

Table 1. GARN AND ROHMANN'S CORRELATION COEFFICIENTS

Characters	Sister–Sister (r_{SS})	Sister–Brother (r_{SB})	Brother–Brother (r_{BB})
Ossification-rate	0·62	0·40	0·39
Ossification timing	0·54	0·47	0·40
Tooth calcification	0·41	0·24	0·22

Consider two alleles (A and a) at a locus on the X chromosome. The population will contain females of three genotypes (AA, Aa and aa) and males of two genotypes (A and a) with the respective frequencies u^2, $2uv$, v^2 and u, v, where u is the frequency of gene A and $v\,(=1-u)$ that of a, mating being at random. Using Mather's[2] notation, let the mean expression of the character associated with these genotypes be:

Females			Males	
AA	Aa	aa	A	a
d_f	h	$-d_f$	d_m	$-d_m$

d_f and d_m being distinguished to accommodate any difference in effect of the genes in the two sexes.

It is then not difficult to show that the contributions made by this gene pair to the three covariances and the two variances are:

Covariance of sisters (W_{SS}) — $\frac{3}{2}uv[d_f+h(v-u)]^2+2u^2v^2h^2$

Covariance of sister and brother (W_{SB}) — $uvd_m[d_f+h(v-u)]$

Covariance of brothers (W_{BB}) — $2uvd_m^2$

Variance of females (V_S) — $2uv[d_f+h(v-u)]^2+4u^2v^2h^2$

Variance of males (V_B) — $4uvd_m^2$

Summing over all such genes gives:

$W_{SS}=\frac{3}{8}D_S+\frac{1}{8}H$ where $D_S=S\{4uv[d_f+h(v-u)]^2\}$ and $H=S\{16u^2v^2h^2\}$

$W_{SB}=\frac{1}{4}D_U$ where $D_U=S\{4uvd_m[d_f+h(v-u)]\}$

$W_{BB}=\frac{1}{2}D_B$ where $D_B=S\{4uvd_m^2\}$

$V_S=\frac{1}{2}D_S+\frac{1}{4}H+E$
$V_B=D_B+E$
} with D_S, H and D_B as above and E indicating the non-heritable component of variation.

Where only sex-linked genes are involved, the three correlation coefficients will be:

$$r_{SS}=W_{SS}/V_S,\quad r_{SB}=W_{SB}/\sqrt{V_S\cdot V_B},\quad r_{BB}=W_{BB}/V_B$$

Setting $d_f=d_m$ for ease of calculation, in the absence of dominance (that is, $h=0$) we find as maximal values attained in the absence of non-heritable variation, $r_{SS}=0{\cdot}75$, $r_{SB}=0{\cdot}35$ and $r_{BB}=0{\cdot}5$ for all values of u. With dominance the values of the correlations change with u. Considering only a single gene pair, and assuming complete dominance ($h=d$), the maximal correlations obtained in the absence of non-heritable variation are plotted against u in Fig. 1. The correlation between sisters, r_{SS}, ranges from 0·75 to 0·5, that for brothers is constant at 0·5, and that between sibs of unlike sex varies from 0·35 to 0·0, though it falls below 0·1 only for extreme values of u.

If there is some sex-limitation of the variation, so that d_f and d_m are not equal, the relative values of the contributions made by the gene pair to W_{SS}, W_{SB} and W_{BB} may be greatly changed. The contributions to the value of V_S and V_B will, however, be changed correspondingly. Thus, provided that the sex difference in the expression of variation affects the action of all sources of variation, gene differences and non-heritable agencies alike, in much the same way, the relative values of the correlation coefficients will be little affected by the sex-limitation.

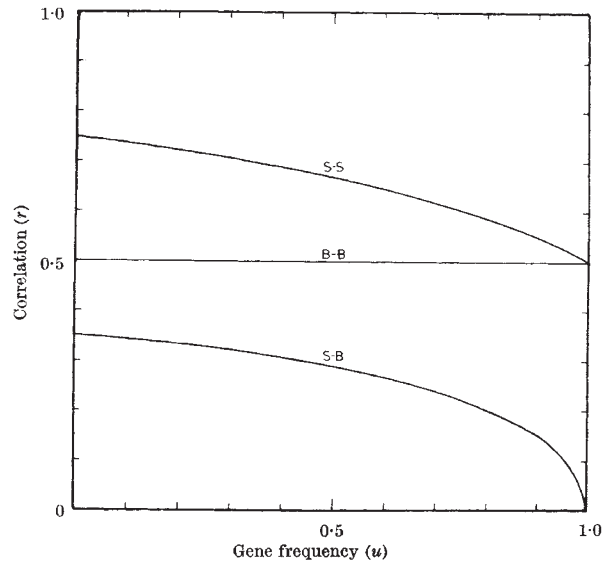

Fig. 1. Variation of the correlation coefficient r with gene frequency u, assuming one sex-linked locus, complete dominance and no non-heritable variation

It is characteristic of sex-linked inheritance, therefore, that the sister–sister correlation is higher than that between brothers (and may be much greater than 0·5, which is the maximum value for autosomal gene pairs); but the cross-sex correlation is lower than either. The actual values of the correlation coefficients will of course vary with the effects of autosomal genes and non-heritable agencies affecting the characters; but assuming these to be the same in both sexes, the relations $r_{SS}>r_{BB}>r_{SB}$ will hold. Thus although Garn and Rohmann's finding that r_{SS} is larger than either r_{BB} or r_{SB}, and may even exceed 0·5, can be held to support the postulation of sex-linked inheritance, their further finding that r_{SB} is not less than r_{BB} is in conflict with this view.

Garn and Rohmann refer to as yet incomplete investigations of the correlations between parents and children, saying that on the basis of sex-linked inheritance the greatest degree of similarity might be expected in father–daughter pairs. Using the same notation as here the contributions of sex-linked genes to the four parent–offspring covariances are: Mother–daughter, $\frac{1}{4}D_S$; Mother–son, $\frac{1}{2}D_U$; Father–daughter, $\frac{1}{2}D_U$; Father–son, 0: so that in fact the correlation between mothers and sons will be as high as that between fathers and daughters.

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THE correlations given in our communication[1] were summarized from sex-specific and age or centre-specific correlations previously published by us[2–4] or distributed in photo-offset form and at present in the press[5]. Whether pooled weighted values of r were used (using Z transforms of r) or whether sister–sister, sister–brother and brother–brother correlations were compared, using a sign test, r_{SS} is larger than r_{BB} but not r_{SB} in osseous and dental developmental timing.

Since both bones and teeth were involved in the investigations, including both the time of appearance of individual post-natal centres of ossification and the age at attainment of specific stages of tooth calcification, we