Chromosome pairing and germ cell loss in male and female mice carrying a reciprocal translocation

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Summary. Female carriers of the T(5;12)31H reciprocal translocation had an average reduction of 73% in oocyte numbers compared with normal litter mates, which was of a magnitude similar to the reduction in sperm counts of male carriers. Analysis of synaptonemal complexes showed that the translocated chromosomes appeared as quadrivalents, or trivalents and univalents, or bivalents in both sexes. Quadrivalents were of three types: fully synapsed, with asynapsis confined to breakpoints, and with unsynapsed ends. There was more pairing in spermatocytes than in oocytes: 37% of spermatocytes, but only 14% of oocytes, contained a fully synapsed quadrivalent, and trivalents were also more frequently fully synapsed in spermatocytes. When these results are compared with those previously obtained for other chromosome anomalies, it becomes evident that there are considerable differences in chromosome pairing between males and females, and that different chromosome rearrangements differ in the relative amount of pairing failure occurring in male and female carriers.

Keywords: Spermatogenic impairment; oogenic impairment; synaptonemal complex; reciprocal translocation; chromosomal asynapsis.

Introduction

Chromosome rearrangements can lead to breakdown of gametogenesis and infertility in mice and men. Although the underlying biological events linking cause and effect have not so far been completely elucidated, the opinion is widely held that the inability of full pairing between homologous chromosomes has a damaging effect on developing germ cells.

Since the discovery by Lyon & Meredith (1966) that heterozygosity for certain reciprocal autosomal translocations in the mouse was associated with sterility in males, many other examples of such translocations have been reported (Searle, 1982). Sterility is due to impairment of spermatogenesis, the severity of which varies between different translocations, and sometimes also in the same translocation according to genetic background.

Male-sterile translocations typically have one breakpoint near the centromere, while the other chromosome is broken near the opposite, distal end, and this often gives rise to two marker chromosomes, one long and one short one. The latter, because of its small size, may be compatible with viability even if present in addition to the normal chromosome complement, and the majority of such tertiary trisomic mice are also male-sterile.

Although female translocation carriers and tertiary trisomics can reproduce, it is now known that oogenesis, too, is impaired. A reduction in ovary size in carriers of a reciprocal translocation (Mittwoch *et al.*, 1981), and of two other autosomal anomalies (Mittwoch *et al.*, 1984) suggested a reduction in the number of oocytes, and this was confirmed by oocyte counts (Burgoyne *et al.*, 1985; Setterfield & Mittwoch, 1986) in the reciprocal translocation T(11;19)42H and the tertiary trisomic Ts(5¹²)31H (these will subsequently be referred to as T42H and Ts31H respectively). Both

anomalies are male-sterile, T42H giving rise to azoospermia (all germ cells dying in pachytene) and Ts31H to severe oligospermia, while average reductions in oocyte numbers amounted to 65% and 71% respectively. We now wish to describe a translocation in which the degree of gametogenic impairment in males and females is very similar.

The T(5;12)31H reciprocal translocation (henceforth referred to as T31H) was described by Beechey *et al.* (1980). One of the breakpoints is in chromosome 5, in band B, and the other is near the distal end of chromosome 12, in band F1. This gives rise to a short marker chromosome, 5¹², and a long one, 12⁵. Beechey *et al.* (1980) found, on average, a 90% reduction in sperm count and a high frequency of abnormal spermatozoa, leading to sterility in most heterozygous male carriers. The degree of spermatogenic impairment was subject to considerable variation.

In an attempt to elucidate the impairment of gametogenesis in both sexes, we shall be giving a comparative account of chromosome pairing at the level of synaptonemal complexes in spermatocytes and oocytes. These results will be preceded by data on numbers of spermatozoa and oocytes in translocation carriers.

In view of the variation in the degree of spermatogenic breakdown observed by Beechey *et al.* (1980), we have obtained data on sperm counts and breeding ability in the males in which we examined chromosome pairing at meiotic prophase, and in a few others. Quantitative studies on oogenesis in T31H translocation carriers have not previously been carried out and we therefore present data on oocyte numbers in 10 translocation carriers and their normal litter mates.

Materials and Methods

Mice. Female mice carrying the T31H translocation were obtained from the MRC Radiobiology Unit, Chilton, and the stock was maintained by mating them to C3H males. The presence or absence of the long and short marker chromosomes was assessed in post-natal animals from fibroblast cultures obtained from tail tips, and in fetuses to be used for pachytene analysis of oocytes from preparations of liver and spleen (Eicher & Washburn, 1978).

Assessment of male fertility. Each male to be tested was put together with a female of proven fertility for up to 8 weeks. Subsequently the male was killed by cervical dislocation following ether anaesthesia, and both testes were weighed. Sperm counts were obtained from the heads of each epididymis, which were dissected out, minced in 1% trisodium citrate and, after diluting to 2 ml and thorough mixing, were counted in a haemocytometer.

To assess motility, caudal spermatozoa were flushed out with warm culture medium, and examined under a microscope. The spermatozoa were checked to see whether a majority exhibited vigorous directional movement, markedly reduced movement, or none at all. These classes were given scores of 2, 1 and 0, respectively.

Ovarian volumes and oocyte counts were obtained from 8 litters aged 3–6 days containing 10 T31H/+ females and 10 chromosomally normal litter mates. The mice were killed by decapitation after anaesthesia, ovaries were dissected out, fixed in Bouin's fluid, sectioned at 7 µm, and stained with haematoxylin and eosin. Measurements were carried out using the distributed point counting method by Burgoyne & Baker (1985; see also Setterfield & Mittwoch, 1986). Essentially the method consists of sampling evenly distributed points over the entire section areas of the ovary while the sections themselves are not in focus by focussing on a squared grid attached to the bottom of the slide, while an eye piece graticule with central cross bar is also in focus. Subsequently, the section is examined under oil immersion, and it is recorded whether an oocyte or somatic cell was hit by the cross bar. The relative numbers of points in the two categories determine the proportion of germinal and somatic tissue in the ovary. Absolute values are obtained from area measurements of oocytes, with a correction made for the fact that large oocytes are more likely to be hit than small ones. For statistical analysis a weighted *t* test was used, as described by Mittwoch *et al.* (1984).

Synaptonemal complexes. Spermatocytes were obtained from 4 heterozygous translocation carriers (Nos 360, 424, 432 and 436, see Table 1), and oocytes from 3 translocation-carrying fetuses (Nos 303E2, 422E2 and 422E3) aged 19 days (day of vaginal plug being counted as Day 1). Gametocytes were prepared for analysis in the electron microscope using the method of Moses & Poorman (1984) with minor modifications by Mahadevaiah & Mittwoch (1986). Spermatocytes and oocytes were processed in identical ways. Silver staining was carried out by the method of Howell & Black (1980).

Suitable fields of cells were selected in the light microscope under a ×12.5 objective, and were cut with a Leitz diamond marker. The cut-out discs were floated onto water, and picked up on G100 grids for examination in a Philips 300, or a Jeol 1200, electron microscope at 80 kV. All complete pachytene cells were photographed and analysed. Incomplete cells, including those partly obscured by the grid, were excluded, as were all cells in meiotic stages other than pachytene.

Fig. 1. Histological appearance of the ovary of (a) a 4-day-old T31H/+ mouse and (b) a 4-day-old normal mouse. Bar = 50 μ m.

Results

Gametogenic impairment

Table 1 gives information on sperm output and male fertility. In spite of reduced testis weights and sperm counts, 6 out of 7 males were able to impregnate females. One male which failed to do so had totally immotile spermatozoa. A quantitative analysis of ovaries and their components is given in Table 2. It is evident that, although the two classes of mice did not differ in ovarian volume, the germinal volume was reduced in translocation carriers, and there was an even more marked reduction in oocyte numbers amounting to 74%. By contrast, the mean oocyte size was larger in translocation carriers than in their normal sisters. This was because the small oocyte pool of translocation carriers was reduced by a relatively massive 80%, whereas the number of growing oocytes was very slightly increased. The average number ($\pm$ standard error) of small oocytes in translocation carriers was 2438 ($\pm$ 363) compared with 11 946 ($\pm$ 808) in normal litter mates, and that of large oocytes was 886 ($\pm$ 97) in translocation carriers, and 648 ($\pm$ 94) in normals. The difference in histology between the two types of ovary is illustrated in Fig. 1.

Chromosome pairing in pachytene gametocytes

The pair of translocated chromosomes and their normal homologues paired as a quadrivalent, or as a trivalent and univalent, or as bivalents, in spermatocytes and oocytes (Figs 2–4). However, the relative proportion of the different configurations varied in male and female gametocytes: whereas quadrivalents were the most common configuration seen in spermatocytes, trivalents, bivalents, and univalents were relatively more frequent in oocytes than in spermatocytes (Table 3). The proportion of doubtful configurations scored in oocytes was greater than that in spermatocytes because of the more frequent presence of synaptic errors and unpaired chromosomes in oocytes (see below).

For pairing between homologous chromosomes, quadrivalents formed between the translocated 5¹² and 12⁵ and their nontranslocated homologues, 5 and 12, could be fully synapsed or have

Table 1. Fertility data of T31H/+ and chromosomally normal male mice

Mouse no.	Chromosomes	Mean testis wt (mg)	Mean caput wt (mg)	Sperm count (caput) ($\times 10^{-6}$)	Motility score	No. of young in test litter	Time until birth of litter (days)
T31H 360	T31H/+	64.5	9.8	0.5	1	4	51
T31H 368	T31H/+	74.8	12.5	0.51	1	1	43
T31H 424	T31H/+	57.4	11.7	1.31	1	3	26
T31H 432	T31H/+	64.0	6.9	0.7	1	0†	
T31H 436	T31H/+	54.2	12.0	1.86	1	4	35
T31H 465	T31H/+	59.8	12.3	0.83	1	3	27
T31H 392	T31H/+	59.4	12.4	0.22	0	0	
T31H 391*	+/+	105.9	17.2	2.73	2	5	28
C3H 365	+/+	88.6	14.2	2.47	2	7	24
C3H 366	+/+	87.4	14.4	2.53	2	2	40

*Litter mate of T31H 392.

†Two embryos found 60 days after pairing.

Table 2. Quantitative analysis of ovarian components* in T31H/+ and normal littermate mice

Mouse No.	Age (days)	Chromosomes	Body wt (g)	Ovarian vol. (mm ³)	Volume of tissue		Mean oocyte vol. (mm ³ $\times 10^{-6}$)	No. of oocytes
					Somatic (mm ³)	Germinal (mm ³)		
56	4	+/+	4.96	0.066	0.045	0.021	1.456	14 726
57		T31H/+	4.96	0.026	0.019	0.007	3.286	2 130
71	4	+/+	4.05	0.051	0.034	0.018	1.771	9 883
72		T31H/+	3.77	0.045	0.030	0.014	2.981	4 843
222	3	+/+	3.96	0.041	0.026	0.015	1.586	9 380
224		+/+	3.54	0.048	0.030	0.018	1.388	12 606
223†		T31H/+	3.52	0.059	0.039	0.012	2.493	4 913
260	5	+/+	2.57	0.044	0.024	0.020	1.688	11 925
259		T31H/+	3.35	0.046	0.034	0.011	6.266	1 815
275	4	+/+	3.03	0.035	0.019	0.016	1.480	10 643
277		+/+	3.25	0.049	0.028	0.021	1.493	14 360
276		T31H/+	3.53	0.042	0.032	0.009	5.426	1 693
326	5	+/+	2.32	0.058	0.035	0.024	1.652	14 298
325		T31H/+	2.57	0.048	0.035	0.014	3.121	4 346
338	4	+/+	2.12	0.030	0.017	0.013	1.576	8 327
336		T31H/+	3.51	0.042	0.033	0.009	3.715	2 473
337		T31H/+	3.44	0.030	0.023	0.007	3.679	2 022
395	6	+/+	5.49	0.080	0.048	0.032	1.997	15 990
393		T31H/+	5.07	0.098	0.080	0.018	4.830	3 623
394		T31H/+	4.76	0.090	0.074	0.016	3.317	4 880
Normal mean			3.53	0.050	0.031	0.020	1.609	12 214
T31H/+ mean			3.85	0.052	0.040	0.012	3.912	3274
Weighted d			-0.22	1.12×10^{-3}	-6.39×10^{-3}	8.65×10^{-3}	-2.28	8997
Standard error			0.23	6.04×10^{-3}	5.49×10^{-3}	1.62×10^{-3}	0.45	1019
t ₇			-0.93	0.186	-1.17	5.34	-5.07	8.83
P			N.S.	N.S.	N.S.	<0.01	<0.01	<0.001

*Left ovaries were measured throughout except for Mice 56, 57, 259 and 260 for which right ovaries were used.

†This ovary contained heteropycnotic cells which were not counted as somatic or germinal cells but which are included in the total ovarian volume estimates.

Table 3. Types of translocation configurations in pachytene of spermatocytes and oocytes of T31H/+ mice

	No. of mice or embryos	Mean no. of cells with				Total
		Quadrivalents	Trivalents + univalents	2 Bivalents, 1 bivalent + 2 univalents, or 4 univalents	Doubtful configurations	
Spermatocytes	4	102 (0.75)	25 (0.18)	3 (0.02)	6 (0.04)	136
Oocytes	3	38 (0.36)	40 (0.37)	12 (0.11)	17 (0.16)	107

asynapsed regions confined to the breakpoints, or have unsynapsed ends (Figs 2a & 2c). Trivalents were fully synapsed or had asynapsed ends (Figs 2d & 3a); however, gametocytes containing a trivalent also included a small univalent chromosome, 5¹² (Figs 2d, 3a & 3c). It is evident from Fig. 5 that full synapsis of quadrivalents and trivalents was more likely to be achieved in spermatocytes than in oocytes. This fact, added to the different distribution of translocation configurations in male and female gametocytes, resulted in 37% of the spermatocytes having fully synapsed chromosomes, compared with 14% of oocytes; an additional third of oocytes contained trivalents with asynapsed ends. Table 4 shows that in spermatocytes association of the translocated chromosomes with the XY bivalent occurred most frequently in trivalent plus univalent configurations (Fig. 2d), and least often in quadrivalents with synapsed ends.

Errors of pairing could also occur in chromosomes that were not involved in the translocation, and the results in Table 5 show that oocytes were more prone to such errors than were spermatocytes. If univalent X and Y chromosomes were excluded, there were only 5 spermatocytes (4%) with autosomal pairing errors. The corresponding figure for oocytes must be many times greater, for although the proportion of synaptic errors involving the X chromosomes is unknown, there was no reason to believe that the two X chromosomes in oocytes were more liable to such errors than were autosomes.

A significant proportion of unsynapsed or partly synapsed bivalents in oocytes was closely associated with the translocation configuration (Fig. 3c). The rather large number of cells in which such an association remained uncertain was due to the fact that oocytes not infrequently contained a great many synaptic errors within the same cell.

Discussion

The fact that 6 out of 7 males were successful in impregnating females, whereas Beechey *et al.* (1980) found that 19 out of 24 T31H-carrying males were sterile, suggests that the reproductive performance of these males might have improved somewhat since they were first described, although different criteria of assessing fertility need to be taken into account. An improvement in the level of spermatogenesis achieved by the males in our data is also suggested by the fact that the average testis weight was 62 mg, compared with 55.4 mg reported by Beechey *et al.* (1980). Nevertheless, all the males tested by us had reduced (compared with C3H normal mice) weights of testes and of epididymides, sperm counts, and sperm motilities, indicating spermatogenic impairment and possible subfertility. Litter size cannot be directly compared with that of chromosomally normal males, since the translocation would be expected to give rise to a proportion of chromosomally unbalanced spermatozoa and inviable conceptuses. This is known to occur in females (Beechey *et al.*, 1980), but there are no data as yet for males.

Fig. 2. Synaptonemal complexes of translocation configurations in T31H/+ spermatocytes. (a) Complete cell containing a fully paired quadrivalent. No association between quadrivalent (long arrow) and XY bivalent (short arrow). $\times 4000$. (b) Diagram of configuration in (a). (c) Terminally asynapsed quadrivalent associated with univalent X chromosome. Univalent Y (arrow) folded back. $\times 4000$. (d) Fully synapsed trivalent (long arrow) plus ring-shaped univalent (short arrow) associated with XY. $\times 3400$.

The average reduction in sperm count of T31H-carrying males was about 70%, while the reduction in oocyte numbers of translocation-carrying females was 74%, a figure similar to that obtained for tertiary trisomic females, Ts31H, which carry the 5^{12} marker chromosome in addition to an otherwise normal diploid karyotype, and for females carrying the reciprocal translocation, T42H (Burgoyne *et al.*, 1985; Setterfield & Mittwoch, 1986). However, this translocation causes complete breakdown of spermatogenesis during pachytene, leading to azoospermia, whereas tertiary trisomic

Fig. 3. Translocation configurations in T31H/+ oocytes. (a) Terminally asynapsed trivalent (long arrow) + univalent (short arrow) $\times 7800$. (b) Diagram of trivalent in (a). (c) Terminally asynapsed trivalent (long arrow) + univalent (short arrow). Trivalent is associated with univalent chromosomes (arrowheads) not involved in the translocation. $\times 4000$. (d) Diagram of trivalent in (c).

males have very severe oligospermia. The fact that in T31H mice breakdown of gametogenesis is of similar order of magnitude in both sexes makes a comparison of chromosome pairing of particular interest.

One of the striking results emerging from our data is that the degree of pairing achieved by spermatocytes was markedly higher than that in oocytes. Although the range of translocation configurations was the same in male and female germ cells, quadrivalents with fully paired ends were more than twice as common in spermatocytes than in oocytes (Table 3). In oocytes, most

Fig. 4. A bivalent and two univalents in a T31H/+ oocyte. × 6300.

Table 4. Position of different types of translocation configurations in relation to the XY bivalent

Type of configuration	No. of cells in which translocation configuration and XY are		Total
	Associated	Not associated	
Quadrivalents with synapsed ends	26 (0.39)	40 (0.61)	66
Quadrivalents with asynapsed ends	23 (0.63)	13 (0.36)	36
Trivalents + univalents	23 (0.92)	2 (0.08)	25
Total	72 (0.57)	55 (0.43)	127

Table 5. Synaptic errors in chromosomes other than 5 and 12 and their position in the cell in relation to translocation configurations

	Total	No. of cells with synaptic errors*			Total no. of cells analysed
		Associated with translocation configuration	Not associated with translocation configuration	Association not known	
Spermatocytes	19†	1	18†	0	136
Oocytes	31	8	11	12	107

*Includes pairing failure and non-homologous pairing.
†Of these cells, 16 contained X, Y univalents and 5 cells contained autosomal errors.

Fig. 5. Proportion of translocation configurations seen in spermatocytes (solid bars) and oocytes (open bars): (a) fully synapsed quadrivalents; (b) quadrivalents with synapsed ends but asynapsed around breakpoints; (c) quadrivalents with asynapsed ends; (d) fully synapsed trivalent + univalent; (e) trivalent with asynapsed end + univalent; (f) 2 bivalents, fully synapsed; (g) bivalents and/or univalents (asynapsed).

quadrivalents and trivalents were unsynapsed. Our data relating to the proximity of translocation configurations to the XY bivalent confirm the finding by de Boer *et al.* (1986) that configurations with synapsed ends are least likely to be associated with the XY bivalent, and that univalents are most likely to show such an association (Table 5). De Boer *et al.* (1986) also found a similar relationship with breakdown of spermatogenesis.

It is widely believed today that spermatogenic breakdown in carriers of reciprocal chromosomal translocations is a consequence of pairing failure at meiosis (Searle, 1982). Miklos (1974) proposed that saturation of pairing sites between homologous chromosomes is a prerequisite for meiotic and post-meiotic development of male germ cells, so that any pairing difficulty would be expected to lead to spermatogenic breakdown, whereas Forejt (1984) postulated that the adverse effect on spermatogenesis is not a direct effect of unpaired chromosomes but results from the association of unpaired autosomes with the X chromosome and consequent interference with its inactivation in primary spermatocytes. When it became apparent that oogenesis, too, is affected in karyotypes with an inability of chromosomes to pair during meiosis, Burgoyne & Baker (1984) extended the hypothesis by Miklos (1974) to apply also to female germ cells, although interference with X chromosome inactivation could cause additional damage to male germ cells (Burgoyne *et al.*, 1985).

We previously showed that in trisomic Ts31H mice, in which the amount of unpaired chromosomal material originating from the translocation configuration is similar in males and females, being confined to the small marker chromosome, the number of oocytes was reduced by about 70% (Setterfield & Mittwoch, 1986), which compares with sperm counts of barely 1% of normal (Beechey *et al.*, 1980). In conjunction with the data on T31H, this might suggest that the same amount of unpaired chromosomal material is associated with more severe breakdown of spermatogenesis than of oogenesis, whereas similar degrees of gametogenic breakdown in males and females are associated with additional asynapsis in females. This supposition is supported by results on the insertion, Is(7;1)40H, in which there is complete spermatogenic breakdown during early pachytene. Oocyte numbers were reduced by only 55% (S. Parry, L. A. Setterfield & U. Mittwoch, unpublished data),

and terminal asynapsis was observed more frequently in males than in females (S. Mahadevaiah, unpublished data).

Chandley *et al.* (1986) have described a reciprocal translocation in an infertile man, whose sperm count was reduced by 90%, and in whom only 20% of pachytene configurations were associated with the XY bivalent. Although the large majority of translocation configurations showed pairing failures, terminal asynapsis was present in only a minority of cells, which could account for the low level of XY association. While there is good evidence that terminal asynapsis in an autosomal configuration increases the chance of association with the XY bivalent, the effect of this association on spermatogenesis remains uncertain. The patient described by Chandley *et al.* (1986) had inherited the translocation from his mother but nothing seems to be known for man about the effect of male-sterile translocations on oogenesis in female carriers.

While there is now abundant evidence of an association between failure of chromosome pairing in meiosis and germ cell death, the exact relationship between cause and effect is not always apparent. There have been a number of reports on germ cell impairment before meiosis, particularly in human trisomy syndromes. For instance, Mikamo *et al.* (1968) found germ cell numbers in three infants with Klinefelter's syndrome to be below normal, and Coerdts *et al.* (1985) reported germ cell numbers to be reduced in fetuses with trisomy syndromes 13, 18 and 21, as well as XXY. In the patient with a 9;20 reciprocal translocation described by Chandley *et al.* (1986), the authors detected germ cell degeneration from early prophase onwards, while Speed (1986) concluded that the atresia seen in human XO fetuses originates mainly in very early meiosis before the start of pairing. On the other hand, testicular volumes, protein and DNA contents of T42H/+ mice were indistinguishable from normal during the first post-natal week (Mittwoch, 1982), and similar results were obtained for Is40H/+ and Ts31H males (L. A. Setterfield, unpublished data), suggesting that large-scale losses of germ cells do not occur long before the onset of meiosis in these male-sterile stocks.

Irrespective of whether germ cell death is initiated before zygotene of meiosis, our data on mice show that pairing failure is not merely a function of the structure and contents of the chromosomes involved, but that the degree of synapsis can differ between spermatocytes and oocytes. What is perhaps more surprising is that different rearrangements differ as to whether male or female germ cells exhibit the greater degree of asynapsis and so there appears to be no simple relationship between the degree of gametogenic impairment in males and females.

The data in Table 2 show that there was no reduction in the somatic component of the ovaries of T31H-carrying females. In Ts31H females, somatic ovarian tissue was reduced, although the difference was less than that of germinal tissue (Setterfield & Mittwoch, 1986), while in T42H females a reduction in somatic tissue did not reach statistical significance (Burgoyne *et al.*, 1985). The most likely conclusion is that pairing failure at meiosis in females is connected with impairment of oogenesis, and that any reduction in the somatic tissue of the ovary is a secondary effect.

Impairment of oogenesis is not expected to affect ovulation rates, since these are not dependent on the oocyte pool (Burgoyne & Baker, 1984). Normal ovulation rates in the presence of reduced oocyte numbers are undoubtedly an important reason for the earlier assumption that male-sterile chromosome anomalies have no effect on oogenesis. A smaller than normal oocyte pool would, however, be expected to result in a reduction in reproductive life span, and Searle *et al.* (1983) reported evidence for this in female carriers of the Is40H insertion.

The rather large number of synaptic errors in oocytes of chromosomes not involved in the translocation is in agreement with findings for Ts31H and chromosomally normal female mice (Mahadevaiah & Mittwoch, 1986), as well as in human oocytes (Speed, 1985). The high proportion of pairing anomalies seen in chromosomally normal oocytes, but not in spermatocytes, is likely to reflect the wave of degeneration that occurs during female meiosis (Weir & Rowlands, 1977), and is probably the result, rather than the cause, of oocytes that are moribund. Nevertheless, the proportion of such cells may be increased in the presence of a systemic chromosomal error, as was found by Speed (1986) in XO fetuses of humans and mice.

Our results show that oocytes that would normally be destined to proceed through oogenesis react to pairing difficulties due to chromosome rearrangements by synaptic failure, the amount of which may be higher or lower than that exhibited by spermatocytes. For mice with the T31H translocation it is higher, and is associated with oogenic impairment which is of a magnitude similar to the spermatogenic impairment seen in male carriers.

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