A reciprocal translocation, $t(6p+; 14q-)$, in the pig

Kamlesh Madan*, C. E. Ford† and C. Polge‡

§ *MRC Population Genetics Unit, Old Road, Headington, Oxford*; †*Sir William Dunn School of Pathology, South Parks Road, Oxford OX1 3RE*; and ‡*A.R.C. Institute of Animal Physiology, Animal Research Station, 307 Huntingdon Road, Cambridge CB3 0JQ, U.K.*

Summary. A reciprocal translocation, identified as $t(6p+; 14q-)$, is described in a 38,XX intersex pig. It is the fourth reciprocal translocation to be reported for this species, whereas Robertsonian translocations, of frequent occurrence in cattle and sheep, are so far unknown in domestic pig breeds.

Introduction

Partial sterility brought about by irregular segregation of chromosomes at meiosis is a well understood consequence of heterozygosity for a reciprocal translocation. The condition may be particularly prevalent in pigs. A boar heterozygous for a translocation was first reported by Henricson & Bäckström (1964). Hageltorn, Gustavsson & Zech (1973), using Q- and C-banding techniques, later characterized this rearrangement as a reciprocal translocation between chromosomes 11 and 15, i.e. $t(11p+; 15q-)$. Subsequently, Locniskar, Gustavsson, Hageltorn & Zech (1976) and Hageltorn *et al.* (1976) have reported two more boars with reciprocal translocations defined as $t(1p-; 6q+)$ and $t(13q-; 14q+)$ respectively. All 3 of these boars were selected for study because of reduced fertility. We now give details of a fourth reciprocal translocation found in an intersex pig and identified as $t(6p+; 14q-)$.

Materials and Methods

The boar was known from previous conventional karyotype analysis to be heterozygous for a translocation between a large submetacentric chromosome and a large acrocentric chromosome. It was a crossbred (Large White $\times$ Essex), about 1 year old, and was one of 15 pigs with intersexual features and 6 normal males whose chromosomes have been examined in preparations from blood cultures at Cambridge. The intersexes all had 38,XX karyotypes except for one 38,XX/38,XY presumptive chimaera (Booth & Polge, 1976). In no animal other than the one reported here were structural rearrangements of the chromosomes identified or suspected.

The pig had received attention because of ambiguity of the external genitalia. A laparotomy was performed and bilateral ovotestes were identified. The oviducts on both sides were blind. At one time the pig showed cyclic activity and oestrus. At laparotomy the presence of corpora lutea indicated that follicles in the right ovotestis had ovulated.

Further blood cultures were set up at Oxford. Chromosome preparations were made by a standard technique and stained with quinacrine dihydrochloride to obtain Q-bands, or with Giemsa after trypsin treatment (Seabright, 1971) for G-bands.

Results

A G-banded karyotype (Pl. 1, Fig. 1) is set out according to the arrangement and system of chromosome numbering adopted by Hageltorn & Gustavsson (1973). Plate 1, Fig. 2, shows the chromosomes involved in the translocation from four different cells. It demonstrates that the translocation is

* Present address: Cytogenetics Laboratory, ZP009, Free University, De Boelelaan 1117, Amsterdam, The Netherlands.

§ Now closed.

reciprocal and that most of the long arm of one chromosome 14 has been exchanged for most of the short arm of a chromosome 6. The remaining chromosomes appear to be normal. The sex chromosomes were identified as XX and the karyotype may therefore be written 38, XX, t(6p+; 14q-).

Discussion

The reciprocal translocation described is the fourth to be reported in the pig, although only two Robertsonian translocations have been identified in this species (McFee, Banner & Rary, 1966; Gustavsson, Hageltorn, Zech & Reiland, 1973; Tikhonov & Troshina, 1975) and they have been found only in wild populations or in recent descendants of wild animals. The XX chromosome constitution is common among intersex pigs (see Melander, Hansen-Melander, Holm & Somlev, 1971; Booth & Polge, 1976) and there is no reason to suppose that the association between intersexuality and reciprocal translocation in the present animal was other than fortuitous. No relatives of the animal were traced.

By contrast, Robertsonian translocations are relatively common in cattle and sheep. Six distinct types have been reported in cattle (Gustavsson & Rockborn, 1964; Bruère & Chapman, 1973; Pollock & Bowman, 1974; Eldridge, 1974; Darré, Berland & Quéinnec, 1974; Stranzinger & Forster, 1976) and three in sheep (Bruère, Chapman, Jaine & Morris, 1976). Yet despite the extensive cytogenetic studies of animals of these two species we are aware of only one decisive instance of reciprocal translocation: banding studies have revealed that an abnormal karyotype in the sheep, previously thought to represent a deletion (Luft & Wassmuth, 1974) is, in fact, due to reciprocal translocation (B. Luft, personal communication). An abnormal X chromosome found in a cow by Gustavsson, Fraccaro, Tiepolo & Lindsten (1968) may also have originated by reciprocal translocation but other explanations are not excluded. It is true that few (acrocentric) chromosomes are available for Robertsonian translocation in the pig (6 pairs) compared with cattle (29 pairs) and sheep (23 pairs). On the other hand, although the human karyotype includes only 5 pairs of acrocentric chromosomes, reciprocal translocation and Robertsonian translocation are about equally frequent according to surveys of the karyotypes of unselected newborn children (Hamerton, Canning, Ray & Smith, 1975).

Heterozygosity for a Robertsonian translocation may have a negligible effect on relative fertility, but heterozygosity for a reciprocal translocation is invariably associated with severe reduction of fertility in both sexes. Carrier animals are therefore likely to be selected for cytogenetic study. This makes the low ratio of reciprocal to Robertsonian translocations identified in cattle and sheep the more remarkable and perhaps indicates a substantial difference between species in relative risks of occurrence.

Of the eight break points in the four reciprocal translocations now known in the pig, two were in chromosome 14 and two in chromosome 6, and all four translocations involve the exchange of a very short segment for a long one (Text-fig. 1). Four of the eight break points lie close to the centromere and three close to the end of the chromosome, the eighth being located in the tiny short arm of chromosome 11 and therefore close to both centromere and chromosome end. Although these data are limited they are sufficient to suggest non-random distribution of break points in spontaneous rearrangements in the pig, both between and within chromosomes. Jacobs, Buckton, Cunningham & Newton (1974) report a significant excess of break points in the centromeric and terminal regions of human chromosomes involved in reciprocal translocations ascertained through balanced carriers.

Pig and man resemble one another in the morphological diversity of their karyotypes. Study of the meiotic properties of reciprocal translocations in heterozygous pigs and their relationship to reproductive performance may therefore help to illuminate the behaviour of reciprocal translocations in man. The translocation first reported by Henricson & Bäckström (1964) is ideal for this purpose because both rearranged chromosomes are sufficiently distinctive to allow identification of all ten potential products of 2:2 disjunctions of the translocation complex (Ford, 1969; Paris Conference, 1971) by chromosome morphology alone, without recourse to banding. Åkesson & Henricson (1972) have defined the karyotypes of fetuses originating from matings of normal sows by a boar heterozygous for this translocation and have identified five different abnormal fetal karyotypes. Their total

PLATE 1

Fig. 1. G-banded karyotype of the pig heterozygous for a reciprocal translocation between chromosomes 6 and 14.

Fig. 2. Normal and translocation chromosomes from four cells showing the presumptive points of breakage and rejoining.

(Facing p. 396)

Text-fig 1. Diagrams of anticipated chromosome pairing at pachytene in the four types of translocation heterozygote discussed, based on measurement of banded chromosomes at mitotic metaphase: (a) $t(11p+; 15q-)$ (Hageltorn *et al.*, 1973); (b) $t(1p-; 6q+)$ (Lockniskar *et al.*, 1977); (c) $t(13q-; 14q+)$ (Hageltorn *et al.*, 1977); (d) $t(6p+; 14q-)$ (present results).

evidence strongly suggests, but does not quite prove, a marked excess of alternate disjunctions (McClintock, 1945) over adjacent disjunctions at first meiotic anaphase, with adjacent-2 predominant over adjacent-1. Such behaviour appears to be without parallel at present in mammals and it would be of great interest if confirmed by direct study of meiosis in heterozygotes. Comparative studies of other reciprocal translocations in the pig could be equally rewarding.

The translocation was first identified by J. J. Weiser in 1971 when a visiting worker at the A.R.C. Institute of Animal Physiology, Cambridge. The present investigation was carried out at the former Population Genetics Unit of the M.R.C. at Headington, Oxford. We are grateful to the Technical Staff of this Unit for their assistance.

References

- ÅKESSON, A. & HENRICSON, B. (1972) Embryonic death in pigs caused by unbalanced karyotype. *Acta vet. scand.* **13**, 151–160.
- BOOTH, W.D. & POLGE, C. (1976) The occurrence of C_{19} steroids in testicular tissue and submaxillary glands of intersex pigs in relation to morphological characteristics. *J. Reprod. Fert.* **46**, 115–121.
- BRUÈRE, A.N. & CHAPMAN, H.M. (1973) Autosomal translocations in two exotic breeds of cattle in New Zealand. *Vet. Rec.* **92**, 615–618.
- BRUÈRE, A.N., CHAPMAN, H.M., JAINE, P.M. & MORRIS, R.M. (1976) Origin and significance of centric fusions in domestic sheep. *J. Hered.* **67**, 149–154.
- DARRÉ, R., BERLAND, H.M. & QUIÉNNÉC, G. (1974) Une nouvelle translocation Robertsonienne chez les Bovins. *Annls Génét. Sel. anim.* **6**, 297–304.
- ELDRIDGE, F.E. (1974) A dicentric Robertsonian translocation in a Dexter cow. *J. Hered.* **65**, 353–355.
- FORD, C.E. (1969) Meiosis in mammals. In *Comparative Mammalian Cytogenetics*, pp. 91–106. Ed. K. Benirschke. Springer-Verlag, New York.
- GUSTAVSSON, I. & ROCKBORN, G. (1964) Chromosome abnormality in three cases of lymphatic leukaemia in cattle. *Nature, Lond.* **203**, 990.
- GUSTAVSSON, I., FRACCARO, M., TIEPOLO, L. & LINDSTEN, J. (1968) Presumptive X-autosome trans-

- location in a cow: preferential inactivation of the normal X chromosome. *Nature, Lond.* **218**, 183–184.
- GUSTAVSSON, I., HAGELTORN, M., ZECH, L. & REILAND, S. (1973) Identification of the chromosomes in a centric fusion/fission polymorphic system of the pig. *Hereditas* **75**, 153–155.
- HAGLETORN, M. & GUSTAVSSON, I. (1973) Giemsa staining patterns for identification of the pig mitotic chromosomes. *Hereditas* **75**, 144–146.
- HAGELTORN, M., GUSTAVSSON, I. & ZECH, L. (1973) The Q- and G-banding patterns of a t(11p+; 15q-) in the domestic pig. *Hereditas* **75**, 147–151.
- HAGELTORN, M., GUSTAVSSON, I. & ZECH, L. (1976) Detailed analysis of a reciprocal translocation (13q-; 14q+) in the domestic pig by C- and G-staining techniques. *Hereditas* **83**, 268–272.
- HAMERTON, J.L., CANNING, N., RAY, M. & SMITH, S. (1975) A cytogenetic survey of 14,069 newborn infants. 1. Incidence of chromosome abnormalities. *Clin. Genet.* **8** 223–243.
- HENRICSON, B. & BÄCKSTRÖM, L. (1964) Translocation heterozygosity in a boar. *Hereditas* **52**, 166–170.
- JACOBS, P.A., BUCKTON, K.E., CUNNINGHAM, C. & NEWTON, M. (1974) An analysis of the break points of structural rearrangements in man. *J. med. Genet.* **11**, 50–64.
- LOCNISKAR, F., GUSTAVSSON, I., HAGELTORN, M. & ZECH, L. (1976) Cytological origin and points of exchange of a reciprocal chromosome translocation (1p-; 6q+) in the domestic pig. *Hereditas* **83**, 272–275.
- LUFT, B. & WASSMUTH, R. (1974) Die Vererbung der Deletion des A₁-Chromosomes eines Schafbockes in der F₁-Generation. In *Proc. 1st World Congress on Genetics Applied to Livestock Production*, pp. 153–158. Graficas Orbe, Madrid.
- McCLINTOCK, B. (1945) *Neurospora* I. Preliminary observations of the chromosomes of *Neurospora crassa*. *Am. J. Bot.* **32**, 671–678.
- McFEE, A.F., BANNER, M.W. & RARY, J.M. (1966) Variation in chromosome number among European wild pigs. *Cytogenetics* **5**, 75–81.
- MELANDER, Y., HANSEN-MELANDER, E., HOLM, L. & SOMLEV, B. (1971) Seven swine intersexes with XX chromosome constitution. *Hereditas* **63**, 51–58.
- PARIS CONFERENCE (1971) Standardization in Human Cytogenetics, Birth Defects Original Article Series, VIII: 7, 1972. The National Foundation, New York.
- POLLOCK, D.L. & BOWMAN, J.C. (1974) A Robertsonian translocation in British Friesian cattle. *J. Reprod. Fert.* **40**, 423–432.
- SEABRIGHT, M. (1971) A rapid banding technique for human chromosomes. *Lancet* **ii**, 971–972.
- STRANZINGER, G.F. & FORSTER, M. (1976) Autosomal translocations in German Simmental and German brown cattle. *Experientia* **32**, 24–27.
- TIKHONOV, V.N. & TROSHINA, A.I. (1975) Chromosome translocations in the karyotypes of wild boar *Sus scrofa* L. of the European and Asian areas of the U.S.S.R. *Theoret. appl. Genetics* **45**, 304–308.

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