Translocations of D Chromosomes in Two Families: t(13q14q) and t(13q14q)+(13p14p)

CATHERINE G. PALMER, PATRICK M. CONNEALLY, and JOE C. CHRISTIAN

From the Department of Medical Genetics, Indiana University Medical Center, Indianapolis, Indiana, U.S.A.

Translocations involving two members of the D group of chromosomes appear to be a relatively common chromosomal polymorphism. Several of these translocations are familial (Chaptal, Jean, and Emberger, 1965; Dekaban, 1966; Dill and Miller, 1963; de Grouchy *et al.*, 1963, 1964; Hamerton, Giannelli, and Carter, 1963; Hamerton, 1966; D. Hayman, unpublished, cited by Hamerton, 1966; Hustinx, 1963; Jacobsen *et al.*, 1966; Jagiello, 1963; Marsden *et al.*, 1966; Nuzzo, Marini, and Flauto, 1966; Oikawa *et al.*, 1962; Orye and Delire, 1967; Pitt, Ferguson, and Baikie, 1964; Richards and Stewart, 1965; Stahl *et al.*, 1966; Walker and Harris, 1962; Zergollern *et al.*, 1964; J. Wahrman, unpublished, cited by Hamerton, 1966), and a number are sporadic (Antonuis *et al.*, 1965; Bühler *et al.*, 1963; Cohen, Takagi, and Harrod, 1968; Conen, Erkman, and Metaxoutou, 1966; Cooper and Hirschhorn, 1961; Court Brown, Jacobs, and Brunton, 1965; Ferguson and Pitt, 1962; Haas and Lewis, 1965; Court Brown *et al.*, 1966; Hemet *et al.*, 1967; Jacobs *et al.*, 1968; Jongbloet *et al.*, 1964; Kjessler, 1964; Pinkerton and Cohen, 1967; Summitt and Atnip, 1966; Therman *et al.*, 1962; Tiepolo *et al.*, 1967; Tolksdorf *et al.*, 1965; Van Hemel and Van Brink, 1966; Yarema *et al.*, 1965; Ying, 1966; Yunis *et al.*, 1964). Such translocations have been encountered in surveys of the normal population (Court Brown *et al.*, 1965; Court Brown, 1967; Jacobs, 1964), in individuals with trisomy-D syndrome (Cohen *et al.*, 1968; Conen *et al.*, 1966; Dill and Miller, 1963; de Grouchy *et al.*, 1963; Haas and Lewis, 1965; Jacobsen *et al.*, 1966; Jongbloet *et al.*, 1964; Oikawa *et al.*, 1962; Summitt and Atnip, 1966; Therman *et al.*, 1962; Tolksdorf *et al.*, 1965; Yunis *et al.*, 1964), and in families of patients with other aneuploidies (Chaptal *et al.*, 1965; Hamerton *et al.*, 1963; Hustinx, 1963; Marsden *et al.*, 1966; Orye and Delire, 1967; Stahl *et al.*, 1966; Tiepolo *et al.*,

1967; Yunis *et al.*, 1964; Zergollern *et al.* (1964). It is of interest to note that of the D trisomies with a t(DqDq)* only 4 of 18 reported occur in families bearing the translocation (Dill and Miller, 1963; de Grouchy *et al.*, 1963; Jacobsen *et al.*, 1966; Oikawa *et al.*, 1962). The other 14 cases represent sporadically occurring translocations with trisomy-D.

In the past year we have seen two separate families bearing D-D-,t(DqDq) in multiple individuals. In each case the family was ascertained through a propositus with Down's syndrome. One of the families carried the reciprocal t(DpDp) as well as t(DqDq). Transmission of the translocations has been studied in both families, and autoradiographic studies indicate that both translocations involve chromosomes 13 and 14.

Materials and Methods

Chromosome studies were carried out on peripheral blood cultures of all available members of both families. Leucocytes were grown in spinner medium (BME-suspension medium without calcium, 2X vitamins and amino acids) and laboratory prepared phytohaemagglutinin. At 71 hours of growth, colcemid (0.025 µg./ml.) was added to the cultures which were then fixed one hour later. Hypotonic treatment in 0.95% sodium citrate for 30 minutes preceded fixation in 1:1 methanol acetic acid. Air-dry preparations were made and stained with acetic acid, and others were stained with aceto orcein. For autoradiographic studies, tritiated thymidine (Schwartz Bioresearch, specific activity 1.9 Ci/mM) was added 4½ to 5 hours before fixation. The final concentration of labelled thymidine was 1 µCi/ml. The cells were fixed as above, and the prepared slides were dipped in Kodak NTB2 emulsion. The slides were exposed for 10 days, developed, and stained with Giemsa. After photographing suitably labelled cells, the grain and emulsion were removed (Bianchi, Lima-De-Faria, and Jaworska, 1964); the slides were restained with orcein and rephotographed.

Received October 21, 1968.

* Nomenclature recommended by the Chicago Conference on Standardization in Human Cytogenetics, 1966.

Family History and Chromosome Findings

Family 926 was ascertained through a 6-week-old male infant with Down's syndrome. The father was 44 years old and the mother 37. There were 4 normal sibs in the family, and the mother had had 10 additional pregnancies ending in early abortions. This fact and the occurrence of 4 abortions in her sister made us consider the possibility that the patient might be a translocation mongol.

Leucocyte cultures showed that the proband had a $(46,XX,D-D-,t(DqDq)+,21+)$ chromosome complement, and that the mother was a translocation heterozygote $(45,XX,D-D-,t(DqDq)+)$ (Fig. 1). Among other members of the mother's family who were studied, the sister (who had 4 miscarriages), 3 of her children, 1 brother, and the father were also translocation heterozygotes (Table I). The pedigree is shown in Fig. 2. Thus the translocation is present in 9 members in 3 generations, and is transmitted by males and females. The family shows multiple instances of spontaneous abortion.

Family 1156 was ascertained through an 18-month-old boy with the diagnosis of Down's syndrome and severe congenital heart defect who died before chromo-

some cultures could be obtained. The mother was 21 years of age at the child's birth.

Leucocyte cultures were established from peripheral blood of the mother, and proved to have cells with a translocation involving two D chromosomes $(45,XX,D-D-,t(DqDq)+)$. Thereafter, only maternal sibs and relatives were studied. Her mother and one brother had normal chromosomes. The second brother had 46 chromosomes with four D's, a large metacentric, and a small metacentric bearing satellites on both ends $(46,XY,D-D-,t(DqDq)+,t(DpDp)+)$ (Fig. 3). This was interpreted to be the reciprocal translocation involving the two short arms of the translocated chromosomes. The family pedigree is shown in Fig. 4.

Subsequently cells were cultured from peripheral blood of the grandfather and 4 additional half-sibs of the mother (see Fig. 4). The grandfather had two populations of cells $45,XY,D-D-,t(DqDq)+/46,XY,D-D-,t(DqDq)+,t(DpDp)+$. Two of the half-brothers had normal chromosomes and one half-brother and one half-sister also carried the balanced translocation in mosaic form. Thus, of 6 translocation heterozygotes found in this family, 4 individuals have been shown to carry both parts of the reciprocal translocation involving two D chromosomes in at least part of their peripheral blood cells. Three of the four had loss of the short arm translocation in some cells, and thus were

FIG. 1. Chromosomes of mongol child of family 926, with trisomy 21 and a $t(13q14q)$ translocation.

45/46 chromosome mosaics. The chromosome counts and karyotypic findings are summarized in Table I.

Autoradiography

When tritiated thymidine is added approximately 4½ hours before fixation it is possible to differentiate among the D chromosomes by the pattern of termination of DNA synthesis.

Giannelli and Howlett (1966) have established the following replication pattern among the D chromosomes;

TABLE I
SUMMARY OF CHROMOSOME FINDINGS IN FAMILIES 926 AND 1156

Pedigree No.	No. of Cells Counted		Karyotypic Findings*
	45	46	
Family 926			
II.5	28		45,XX,13-14-,t(13q14q) +
III.14		24	46,XY,13-14-,t(13q14q),21 +
III.10		10	46,XY
III.11		10	46,XX
III.12	10		45,XY,13-14-,t(13q14q) +
III.13		10	46,XY
III.15		25	46,XX
I.2	10		45,XY,13-14-,t(13q14q) +
I.3		11	46,XX
II.2		11	46,XX
II.3		10	46,XY
II.8		26	45,XX,13-14-,t(13q14q) +
III.17		10	46,XY
III.18	10		45,XX,13-14-,t(13q14q) +
III.19	10		45,XX,13-14-,t(13q14q) +
III.20	10		45,XY,13-14-,t(13q14q) +
II.10		10	46,XX
II.11	10		45,XY,13-14-,t(13q14q) +
III.24		11	46,XY
Family 1156			
I.2	6	13	45,XY,13-14-,t(13q14q) + /46,XY,13-14-,t(13q14q) + ,13p14p +
II.6	31		45,XX,13-14-,t(13q14q) +
II.8	25		45,XX,13-14-,t(13q14q) +
II.9	26		46,XY,13-14-,t(13q14q) + t(13p14p) +
II.1	9		46,XY
II.2	7	14	45,XX,13-14-,t(13q14q) + /46,XX,13-14-,t(13q14q) + t(13p14p) +
II.3	18		46,XY
II.4	12	10	45,XY,13-14-,t(13q14q) + /46,XX,13-14-,t(13q14q) + t(13p14p) +
I.3	28		46,XX
II.10	11		46,XY

* Nomenclature recommended by the Chicago Conference on Standardization in Human Cytogenetics, 1966.

one pair which completes its replication early is also the shortest and may be identified as chromosome 15 (D₃); one pair, No. 13 (D₁), continues synthesis relatively late in the distal segments of the long arms; one pair, No. 14 (D₂), continues synthesis relatively late in the area proximal to the centromere.

Autoradiographic studies of cells of five translocation carriers of family 926 were carried out. In 34 informatively labelled cells one pair of D chromosomes was unlabelled. Of the two remaining D chromosomes, 26 cells showed, in addition, one proximally and one distally labelled chromosome. Of the three chromosomes resembling chromosome 3, two differ in their labelling pattern from the third which is labelled proximally in one arm and distally in the other. Thus, the data indicate that in this family chromosomes 13 and 14 are most likely involved in the translocation.

In family 1156, 33 cells from four translocation carriers were informatively labelled. Of these cells, 30 had two unlabelled early-replicating chromosomes appearing in the D group, and, of these, 17 also showed differential labelling in the remaining two D's, one labelling proximally, the other distally. This then suggests the involvement of the homologues of 13 and 14 in the translocation present in this family.

Both families, therefore, appear to carry translocations of chromosomes 13 and 14, t(13q14q) (Fig. 5).

Linkage Data

A summary of blood group, Gm, Inv, haptoglobin, phosphoglucomutase, and acid phosphatase markers in these families is given in the Appendix.

Discussion

There have been frequent reports of t(DqDq) translocations, but none have reported the reciprocal translocation t(DpDp) as seen in family 1156.

The unusual occurrence of the t(DpDp) reciprocal in this family might be indicative of its recent origin. The t(13p14p) chromosome is transmitted less frequently than the t(13q14q) chromosome (see Table III), and is subject to frequent loss in the

FIG. 2. Pedigree chart of family 926.

FIG. 3. Chromosomes of male member of family 1156 bearing the reciprocal translocation of two D chromosomes $46,XY,13-14-t(13q14q)+(13p14p)+$.

FIG. 4. Pedigree chart for family 1156 showing blood group data for Rh locus.

cells of carriers of this chromosome (Table I). The $t(13q14q)$ chromosome is transmitted equally by males and females.

Three possible combinations of D chromosomes in the translocations 13-14, 13-15, and 14-15 may be expected. Identification of the chromosomes involved has been made by measurements of relative lengths of the chromosomes and, more recently, by autoradiography. Earlier workers, using the measuring technique, identified all the expected translocations (Table II). However, those using autoradiography have identified the translocations only of 13 and 14. In one instance (Cohen *et al.*, 1968), the patient had both 13-14 and 13-15 translocations.

FIG. 5. Autoradiography: labelling pattern of group A, translocation chromosome, D group chromosomes of t(13q14q)+ translocation heterozygotes of families 926 and 1156.

TABLE II
IDENTIFICATION OF D CHROMOSOMES IN
TRANSLOCATIONS D-D-, $t(DqDq)$

Chromosomes Involved	Criteria for Identification	Reference
13/15	Chromosome lengths	Walker and Harris (1962)
13/15	'Arm ratio'	Kjessler (1964)
13/14	Chromosome length	Oikawa <i>et al.</i> (1962)
13/15	"	Hamerton <i>et al.</i> (1963)
14/15	"	Zergollern <i>et al.</i> (1964)
D ₁ /D ₂	Autoradiography	Yunis <i>et al.</i> (1964)
D ₁ /D ₂	"	Dekaban (1966)
D ₁ /D ₂	"	Giannelli and Howlett (1966)
D ₁ /D ₂	"	Van Hemel and Van Braink (1966)
D ₁ /D ₂ ,D ₁ /D ₃	"	Cohen <i>et al.</i> (1968)
D ₁ /D ₂	"	Jacobsen <i>et al.</i> (1966)
D ₁ /D ₂ probably	"	Tiepolo <i>et al.</i> (1967)
13/14	"	L. Reisman (personal communication)
13/14	"	This paper
13/14	"	This paper

TABLE III
TRANSMISSION OF D TRANSLOCATIONS

	Sex of Heterozygous Parents	Total Children	Carrier Children	Percentage
Family 926 (13q14q)	2 Males	7	4	60
	2 Females	10	5	50
Family 1156 (13q14q) (13p14p)	1 Male	8	5	62
	1 Male	8	3	38

The frequent occurrence of $t(13q14q)$ translocation may result from similarity of replication time. Both 13 and 14 chromosomes have regions continuing to replicate relatively late in the cycle, while 15 completes its replication at an earlier period. Hence breakage and reunion occurring during replication might occur more frequently between 13 and 14. Chromosomes 13 and 14, but not 15, have also been shown to have induced secondary constrictions after treatment with 5-bromodeoxyuridine (BUdR) (Palmer and Funderburk, 1965; unpublished data). Since secondary constrictions show greater breakability to a variety of agents (Engel, Krone, and Wolf, 1967), there may be a relation of these constrictions to the involvement of 13 and 14 chromosomes on translocation. Non-randomness of translocations involving a D chromosome has also been reported in $t(DqGq)$ translocations, where 14 occurs in the translocation more frequently than 15. Chromosome 13 was not involved in any case (Hecht *et al.*, 1968). In this case the difference in frequency of chromosomes 13 and 14 might be related to the positioning of the constriction close to the centromere in 14, and medial in 13. The association of aneuploidy of chromosomes other than D's in families with $t(DqDq)$ trans-

locations has been noted (Hamerton *et al.*, 1963; Yunis *et al.*, 1964). Some investigators (Grell and Valencia, 1964; Grell, 1967; Hamerton *et al.*, 1963; Yunis *et al.*, 1964) have considered the possibility that 'distributive pairing' brings about the non-disjunction of autosomes other than those involved in the translocation in such families. However, the similar frequencies of the $DqDq$ translocations in the general population, 1:1000 (Hamerton, 1968), and in unselected surveys of mongols, 1:900 (Richards and Stewart, 1965), argue against the functioning of this mechanism of non-disjunction in $DqDq$ translocation heterozygotes. In considering the possibility of linkage of serum proteins or erythrocyte enzymes and blood groups, all translocation heterozygotes in the two families were tested for the possibility of a deleted gene. No evidence for such a deletion was found in the systems studied (Appendix). Furthermore, the possibility of linkage of a marker gene with the translocated chromosome segments $t(13q14q)$ or $t(13p14p)$ was examined. All informative matings (translocation heterozygote parent heterozygous for a known marker) and their offspring were tested. No evidence for linkage was found, with the possible exception of Rh. In family 1156 (Fig. 4), I.2 is a carrier of the reciprocal translocation $(45,XY,13-14-,t(13q14q)+/46,XY,13-14-,t(13q14q)+,t(13p14p)+$ and is heterozygous at Rh locus (R_1r). If we assume the $r(cde)$ allele is on the $t(13q14q)$ portion of the translocation, then among his 5 informative offspring no cross-overs occurred. Since II.6 does not carry the $t(13p14p)$ portion and is heterozygous R_1r , the gene cannot be on the short arm translocation ($13p14p$). Though the data are suggestive of linkage of Rh with 13q or 14q in our family 1156, Dekaban has also reported a family with a $t(13q14q)$ translocation, informative for Rh, in which no evidence for linkage could be demonstrated. Further studies of this system in $t(DqDq)$ translocation-bearing families, in which definitive chromosome identification has been made, are needed to resolve this question.

Summary

Two families with D-,D-, $t(DqDq)$ translocations in multiple individuals are described. Members of one family also carried the reciprocal translocation $t(DpDp)$. Transmission of the translocations has been studied in both families. Autoradiographic studies indicate that the translocations in both families involve chromosomes 13 and 14.

Research for this paper was supported by a grant from the U.S. Public Health Service HD 00358 and a Career Development Award to Dr. C. G. Palmer (5-K3-GM-16).

The authors wish to thank Dr. A. D. Merritt, Dr. N. Fareed, and Dr. C. E. Fenlon for examinations of family members, and Dagnija Grins, Judy Morris, Rosalie Armstrong, and Brien Hughes for excellent technical assistance.

The Gm and Inv typing of the subjects was carried out in the laboratories of Dr. Hugh Fudenberg (San Francisco Medical Center, University of California, San Francisco, California) to whom we express our sincere appreciation.

This paper is dedicated to Dr. Ralph E. Cleland on the occasion of his 75th birthday.

REFERENCES

- Antonuis, J. I., Dion, R. F., Taylor, D., McGuire, P. A., and Hecht, F. (1965). Male with D/D translocation. *Hum. Chromos. Newsl.*, **15**, 1.
- Bianchi, N., Lima-De-Faria, A., and Jaworska, H. (1964). A technique for removing silver grains and gelatin from Tritium autoradiographs of human chromosomes. *Hereditas (Lund)*, **51**, 207.
- Bühler, E. M., Rossier, R., Bodis, I., Vulliet, V., Bühler, U. K., and Stalder, G. (1963). Chromosomal translocation in a mentally deficient child with cryptorchidism. *Acta paediat. (Uppsala)*, **52**, 177.
- Chaptal, J., Jean, R., and Emberger, J. M. (1965). Translocation entre deux chromosomes du groupe 13-15 chez la mère d'un mongolien par trisomie 21 régulière. *Arch. franç. Pédiat.*, **22**, 35.
- Cohen, M. M., Takagi, N., and Harrod, E. K. (1968). Trisomy D₁ with 2 D/D translocation chromosomes. Report of a case. *Amer. J. Dis. Child.*, **115**, 185.
- Conen, P. E., Erkman, B., and Metaxoutou, C. (1966). The 'D' syndrome. Report of four trisomic and one D/D translocation case. *ibid.*, **111**, 236.
- Cooper, H. L., and Hirschhorn, K. (1961). Chromosomal anomaly in a phenotypically normal male. *Hum. Chromos. Newsl.*, **4**, 12.
- Court Brown, W. M. (1967). *Human Population Cytogenetics*. *Frontiers of Biology* Vol. 5. North Holland Publishing Company, Amsterdam.
- , Buckton, K. E., Jacobs, P. A., Tough, I. M., Kuenssberg, E. V., and Knox, J. D. E. (1966). *Chromosome Studies on Adults*. Cambridge University Press, London.
- , Jacobs, P. A., and Brunton, M. (1965). Chromosome studies on randomly chosen men and women. *Lancet*, **2**, 561.
- Dekaban, A. S. (1966). Transmission of a D/D reciprocal translocation in a family with high incidence of mental retardation. *Amer. J. hum. Genet.*, **18**, 288.
- Dill, F. J., and Miller, J. R. (1963). Pathological conditions with apparently normal chromosomes. *Hum. Chromos. Newsl.*, **9**, 3.
- Engel, W., Krone, W., and Wolf, U. (1967). Die Wirkung von Thioguanin Hydroxylamin und 5-Bromodesoxyuridin auf menschliche Chromosomen in Vitro. *Mutation Res.*, **4**, 353.
- Ferguson, J., and Pitt, D. (1962). Congenital anomalies with chromosome abnormality. *Hum. Chromos. Newsl.*, **7**, 6.
- Giannelli, F., and Howlett, R. M. (1966). The identification of the D group (13-15) Denver: An autoradiographic and measurement study. *Cytogenetics*, **5**, 186.
- Grell, R. F. (1967). Pairing at the chromosomal level. *J. cell. Physiol.*, **70**, Suppl. 1, 119.
- , and Valencia, J. I. (1964). Distributive pairing and aneuploidy in man. *Science*, **145**, 66.
- Grouchy, J. de, Brissaud, H. E., Repessé, G., and Lamy, M. (1964). Anencéphalie familiale et remaniement de deux chromosomes 13-15. *C.R. Acad. Sci. (Paris)*, **259**, 691.
- , Mlynarski, J. C., Maroteaux, P., Lamy, M., Deshaies, G., Benichou, C., and Salmon, C. (1963). Syndrome polydyspondylique par translocation 14-15 et dyschondrostéose chez un même sujet. *Ségrégation familiale. ibid.*, **256**, 1614.
- Haas, L., and Lewis, F. (1965). Presumptive D/D translocation trisomy in a female infant. *Hum. Chromos. Newsl.*, **17**, 12.
- Hamerton, J. L. (1966). Chromosome segregation in three human interchanges. *Chromosomes Today*, **1**, 237.
- (1968) Robertsonian translocations in man: evidence for prezygotic selection. *Cytogenetics*, **7**, 260.
- , Giannelli, G., and Carter, C. O. (1963). A family showing transmission of a D/D reciprocal translocation and a case of regular 21-trisomic Down's syndrome. *ibid.*, **2**, 194.
- Hecht, F., Case, M. P., Lovrien, E. W., Higgins, J. V., Thuline, H. C., and Melnyk, J. (1968). Non-randomness of translocations in man: Preferential entry of chromosomes into 13-15/21 translocations. *Science*, **161**, 371.
- Hemert, J., Lamachère, D., Forthomme, J., and Ensel, J. (1967). Trisomie 13 par aberration de structure. *Ann. Anat. path.*, **12**, 101.
- Hustinx, T. J. (1963). Two cases of Down's syndrome with a translocation. *Hum. Chromos. Newsl.*, **9**, 17.
- Jacobs, P. A. (1964). Chromosome studies in the general population. Symposium of the International Society for Cell Biology, **3**, 111.
- , Price, W. H., Court Brown, W. M., Brittain, R. P., and Whatmore, P. B. (1968). Chromosome studies on men in a maximum security hospital. *Ann. hum. Genet.*, **31**, 339.
- Jacobsen, P., Mikkelsen, M., Frøland, A., and Dupont, A. (1966). Familial transmission of a translocation between two non-homologous large acrocentric chromosomes. Clinical cytogenetic and autoradiographic studies. *Ann. hum. Genet.*, **29**, 391.
- Jagiello, G. M. (1963). Familial 13-15 translocation abnormality (Denver classification) associated with one case of cerebral palsy. Preliminary report. *New Engl. J. Med.*, **269**, 66.
- Jongbloet, P., Winckel, H. van, Adriaenssens, K., and Hooft, C. (1964). Sporadic trisomy D₁ with translocation D/D. *Helv. paediat. Acta*, **19**, 121.
- Kjessler, B. (1964). Meiosis in a man with a D/D translocation and clinical sterility. *Lancet*, **1**, 1421.
- Marsden, H. B., Mackay, R. I., Murray, A., and Ward, H. E. (1966). Down's syndrome with a familial D/D reciprocal translocation and a G/G chromosome. *J. med. Genet.*, **3**, 56.
- Nuzzo, F., Marini, A., and Flauto, U. (1966). Studies on a D/D translocation family. *Associazione Genetica Italiana*, **11**, 411.
- Oikawa, K., Gromults, J. M. Jr., Hirschhorn, K., and Novins, J. (1962). 13-15 trisomy with translocation. *Hum. Chromos. Newsl.*, **7**, 11.
- Orye, E., and Delire, C. (1967). Familial D/D and D/G₁ translocation. *Helv. paediat. Acta*, **22**, 36.
- Palmer, C. G., and Funderburk, S. (1965). Secondary constrictions in human chromosomes. *Cytogenetics*, **4**, 261.
- Pinkerton, P. H., and Cohen, M. M. (1967). Persistence of hemoglobin F in D/D translocation with trisomy 13-15 (D). *J. Amer. med. Ass.*, **200**, 647.
- Pitt, D., Ferguson, J., and Baikie, A. G. (1964). Normal and abnormal sibs with a familial chromosome translocation. *Aust. Ann. Med.*, **13**, 178.
- Richards, B. W., and Stewart, A. (1965). D/D translocation. *Lancet*, **1**, 1076.
- Stahl, A., Aubert, L., Arroyo, H., and Luciani, J. M. (1966). Translocation familiale D/D. Association à un syndrome de Turner XO/XX. *Ann. Endocr. (Paris)*, **27**, 847.
- Summitt, R. L., and Atnip, R. L. (1966). Chromosomal aberrations with normal phenotype. Four examples. *Ala. J. med. Sci.*, **3**, 483.
- Therman, E., Patau, K., Demars, R. I., and Smith, D. W. (1962). Mosaicism for a presumed D₁ isochromosome. (Abs.) The American Society of Human Genetics.
- Tiepolo, L., Fraccaro, M., Hultén, M., and Lindsten, J. (1967). Double aneuploidy (46,XXY,D-,(DqDq)+). *Ann. Génét.*, **10**, 114.
- Tolksdorf, M., Wiedemann, H. R., Hansen, H. G., Lehmann, W., Fidderssen, A., and Carstensen, F. (1965). Patau-Syndrom mit Trisomie D₁ und D/D Translokation. *Med. Welt (Stuttg.)*, **41**, 2304.
- Van Hemel, J. O., and Van Braink, J. M. (1966). D/D translocation in a patient with Louisbar syndrome. *Hum. Chromos. Newsl.*, **18**, 26.
- Walker, S., and Harris, R. (1962). Familial transmission of a translocation between two chromosomes of 13-15 group (Denver classification). *Ann. hum. Genet.*, **26**, 151.

Yarema, W. A., Elizabeth, Sr. M., Serbin, R. A., Kadotani, T., and Pergament, E. (1965). Multiple familial chromosome aberrations—A D/D translocation mother with a B/D translocation child. *Hum. Chromos. Newsl.*, 17, 24.

Ying, K. L. (1966). Anomalies of the human chromosomes. *ibid.*, 18, 28.

Yunis, J. J., Alter, M., Hook, E. B., and Mayer, M. (1964). Familial D/D translocation. Report of a pedigree and DNA replication analysis. *New Engl. J. Med.*, 271, 1133.

Zergollern, J., Hoefnagel, D., Benirschke, K., and Corcoran, P. A. (1964). A patient with trisomy 21 and a reciprocal translocation in the 13-15 group. *Cytogenetics*, 3, 148.

APPENDIX

GENOTYPING DATA

Pedigree No.	ABO	Rhesus	MNS	Duffy	Kidd	Kell	P	Hp*	P G M†	A P‡	Gm	Inv
<i>Family 1156</i>												
I.2	O	R ₁ r	MNs	—	NT	—	NT	2-2	1-1	BA	a b f	—
I.3	A ₁ B	R ₁ R ₂	MSs	+	NT	—	NT	1-1	2-2	BA	+++	—
II.1	O	R ₁ r	MNs	+	NT	—	NT	2-1	2-1	AA	+++	+
II.2	O	R ₁ r	NSs	+	NT	—	NT	2-1	2-1	BA	+++	+
II.3	O	R ₁ R ₁	NSs	+	NT	—	NT	2-1	2-1	BA	+++	+
II.4	O	rr	MNSs	+	NT	—	NT	2-2	2-1	BA	+++	+
II.6	B	R ₁ r	MSs	+	NT	—	NT	2-1	2-1	BB	+++	—
II.8	B	R ₁ r	MS	+	NT	—	NT	2-1	2-2	BA	+++	—
II.9	B	R ₂ r	MNs	+	NT	—	NT	2-1	2-2	BA	+++	?
<i>Family 926</i>												
I.2	O	rr	Ns	—	—	—	+	2-2	2-1	BB	+++	—
I.3	O	R ₂ r	MS	+	—	—	+	2-1	1-1	BA	+++	—
II.2	O	R ₂ r	MNSs	—	—	—	+	2-2	2-1	BB	+++	—
II.3	O	R ₂ r	MNSs	—	—	—	+	2-1	2-1	BB	+++	—
II.5	A ₁	R ₁ R ₂	MNS	+	+	—	+	2-2	2-1	BB	+++	—
II.6	O	rr	MNSs	—	—	—	+	2-1	2-1	BA	+++	—
II.7	B	R ₁ R ₁	Ns	—	+	—	+	2-2	2-1	BA	+++	—
II.8	O	rr	MNSs	—	—	—	+	2-1	2-1	BB	+++	—
II.10	O	rr	MNSs	—	—	—	+	2-1	2-1	BB	+++	—
II.11	O	rr	MNSs	+	—	—	+	2-2	1-1	BA	+++	?
II.12	B	rr	MS	+	+	—	+	2-1	2-1	BB	+++	—
III.10	O	R ₂ r	MNSs	—	+	—	+	2-2	2-1	BB	+++	—
III.12	O	R ₂ r	MNSs	+	—	—	+	2-2	2-1	BA	+++	—
III.13	A ₁	R ₂ r	NSs	—	+	—	+	2-1	2-1	BA	+++	—
III.14	A ₁	R ₂ r	MNS	—	—	—	+	2-2	2-1	BA	+++	—
III.15	A ₁	R ₁ r	MNSs	+	NT	—	NT	2-1	2-2	BA	+++	—
III.17	O	R ₁ r	MNSs	—	+	—	—	2-1	2-1	BB	+++	—
III.18	O	R ₁ r	MNSs	—	+	—	+	2-1	2-1	BB	+++	—
III.19	B	R ₁ r	MNSs	—	+	—	+	2-2	2-1	BB	+++	—
III.20	O	R ₁ r	MNSs	—	+	—	+	2-2	2-1	BB	+++	—
III.24	B	rr	MSs	+	+	—	+	2-1	1-1	BA	+++	—

* Haptoglobin.

† Phosphoglucumutase.

‡ Red cell acid phosphatase.

? = Agglutinator.