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Report of the committee on the genetic constitution of chromosomes 9 and 10

M. Smith and N.E. Simpson

CHROMOSOME 9

Currently there are 100 loci mapped to human chromosome 9, including 58 genes and 42 random DNA fragments. New genes added to the chromosome 9 map since HGM9.5 include the gene encoding the L form cathepsin CTSL, (Fan et al., HGM10), a gene encoding the RNA portion of the mitochondrial RNA endonuclease (Hsieh et al., HGM10 A2575), a cytokeratin 18 like gene (Romano et al., 1988), and DYT1, a gene determining the dominantly inherited form of torsion dystonia (Ozelius et al., HGM10).

Cathepsin L is a lysosomal cysteine proteinase involved in intracellular protein degradation. A cDNA clone for this protein was mapped by in situ hybridization to the 9q21-q22 region; further confirmation of this assignment was obtained through PCR amplification of a 234 bp fragment of cathepsin L DNA followed by hybridization of this PCR product to somatic cell hybrids (Fan et al., HGM10).

Studies by Hsieh et al. (HGM10 A2575), established that the gene encoding the RNA component of the mitochondrial RNA processing endonuclease (RMRP) maps to human chromosome 9p21-p12. These authors also note that the 9p genes ACO1, GALT, and RMRP constitute a conserved linkage group which maps to mouse chromosome 4.

Linkage maps of chromosome 9

Since HGM 9.5, a linkage map of chromosome 9 has been reported by Lathrop et al. (1988 H7451). This map included linkage information on the genes GALT, ORM, AK1, ABL, ABO, the ASSP3 pseudogene, and 13 random DNA probes. Keats et al. (HGM10) have constructed a linkage map based on published data on chromosome 9 and two-point lod scores. Information on gene order on chromosome 9 could also be obtained from data presented at HGM10 by Sampson et al. (HGM10), Ozelius et al. (HGM10), and Chamberlain et al. (HGM10). We have used information from these five sources to construct a tentative linear map of 31 genes on chromosome 9 (see Figure 1).

Development of DNA libraries of chromosome 9 regions

The assignment of the gene for FPGS to chromosome 9 (Jones et al., 1980, 1984) was confirmed at HGM10 by studies reported by Florian et al. (HGM10). These investigators used the single human chromosome GAT CHO hybrids produced by Jones et al. (1980) to derive irradiation fragment gene transfer hybrids. Fragments present in these hybrids were used to construct a genomic library in EMBL3a. Clones isolated from this library were found to hybridize to DNA probes for chromosome 9 genes.

Raimondi et al. (HGM10) isolated a supernumerary mini-chromosome from a female with multiple malformations. A library of EcoR1 fragments was established in the vector λ gt wes. Three clones derived from this library were mapped to chromosome 9p13-cen.

Friedreich's ataxia

Chamberlain et al. (1989) reported the mapping of Friedreich's ataxia to human chromosome 9 on the basis of linkage to two probes, D9S15 (MCT 112) and IFNB1. A number of investigators have confirmed this linkage. In addition they have determined that several clinically distinct forms of FRDA map to human chromosome 9 (Fujita et al., HGM10; Ross et al., HGM10). Fujita et al. (1989), confirmed this linkage and identified another closely linked marker D9S5 (DR47). Studies carried out by Richter et al. (HGM10) report findings on 16 FRDA families in Quebec. Included are 122 individuals and 43 patients. Lod scores between FRDA and D9S15 (MCT 112), reported in this study are 10.77 at $\hat{\theta}=0$, and between FRDA and D9S27 (HHH220) were 7.75 at $\hat{\theta}=.05$. Chamberlain et al. (HGM10) report linkage analysis between FRDA and five probes on human chromosome 9. These investigators have determined that the D9S15/FRDA/D9S5 linkage group is flanked on one side by the 9p markers D9S18 at a distance of 13 cM and INFB1 at 35 cM. Chamberlain et al. (HGM10) reported that ALDH1 currently represents the distal flanking marker for FRDA. ALDH1 was assigned to 9q21.1 by Raghunathan et al. (1988). Fujita et al. (HGM10) reported that D9S5 maps to chromosome 9q12-q13 by in situ hybridization. Unfortunately, there is currently no in situ mapping data of D9S15. Chamberlain et al. (HGM10) and Fujita et al. (HGM10) concurred on a regional assignment of FRDA to the region 9q13-21.1. Results of linkage analysis of 9p markers and the 9q markers D9S15, D9S5 and ALDH1 by Chamberlain et al. (HGM10) provided evidence for suppression of recombination across the centromere of the chromosome.

Tuberous sclerosis (TSC)

Fryer et al. (1987) linked TSC to ABO ($\hat{z}_{max}=3.85$, $\hat{\theta}=0$). Further support for the assignment of TSC to chromosome 9q34 was obtained by Connor et al. (1987), who reported evidence for linkage of TSC and ABL ($\hat{z}_{max}=3.9$ at $\hat{\theta}=0$). Other investigators have not been able to support this assignment (Smith et al., 1987 A0912; Northrup et al., 1987; Renwick 1987; Kandt et al., HGM10).

Results of data analysis in 90 TSC families, by an international TSC collaborative study group, were reported at this conference. Data were most complete for loci on chromosome 9: ABO, AK1 (protein and DNA polymorphisms), and RFLPs for ASS (Northrup et al., 1989) and D9S10 (Mct 136). Approximately 60% of the families were typed for at least one chromosome 11q marker. There is evidence for a linkage of TSC to ABO with a total lod score of 3.8 at 20 cM. Linkage analysis on the cumulative data on the chromosome 11 (MCT

128.1, D11S144) showed a $\hat{z}_{max}$ of 1.46 at 30 cM. Results of heterogeneity analysis using the HOMOG program provided strong support for linkage heterogeneity. The maximum likelihood estimate of the proportion of chromosome 9 linked families was 0.4, with a maximum likelihood position of the TSC gene near the ABL and AK1 loci. In view of the evidence for genetic heterogeneity in tuberous sclerosis, the symbol TSC1 is used to describe the chromosome 9 locus.

Torsion dystonia (dystonia musculorum deformans) (DYT1)

Ozelius et al. (HGM10) described the assignment of the gene responsible for the dominant form of hereditary torsion dystonia to chromosome 9. In a pairwise analysis the dystonia gene shows tight linkage with the gelsolin gene (GSN). Gelsolin could not be used in the multipoint linkage analysis since it has not been placed on a linkage map. Multipoint linkage analysis was carried out with DYT1 and the loci D9S26, ABO, and D9S10. Based on this analysis, Ozelius et al. suggest that the most likely position of dystonia is 9.5 cM centromeric to ABO. The authors have assigned DYT1 to the region 9q32-9q34.

The GSN gene was mapped to the 9q32-9q34 region (Kwiatkowski et al., 1988). In situ hybridization experiments reported by this group support a localization to the 9q34 region. Results of pulse field gel analysis by Kwiatkowski et al. (1988) of the 9/22 chromosomal translocation in chronic myelogenous leukemia cell lines, indicated that gelsolin maps more than 40 kb centromeric to ABL and is not translocated to chromosome 22 along with ABL.

Since DYT1 shows tight linkage with gelsolin, it is therefore possible that the DYT1 gene maps in the 9q34 region. The dopamine β hydroxylase gene (DBH), which has been assigned to the chromosome 9q34 region on the basis of in situ hybridization (Craig et al., 1988), is considered to be a possible candidate gene (Ozelius et al., HGM10). Earlier studies (McKusick, 1986) reported abnormal elevations of the plasma levels of catecholamines and DBH in certain patients with torsion dystonia. It is furthermore of interest to note that drug-induced phenocopies of torsion dystonia occur (McKusick, 1986).

Type 1 Waardenburg syndrome

Possible loose linkage of type 1 Waardenburg syndrome was previously reported (Cook et al., 1978). Read et al. (HGM10) reported linkage data on seven families with this syndrome. Results of their analyses allowed them to exclude close linkage of type 1 Waardenburg and ABO ($\hat{z}_{max}$=0.19 at $\hat{\theta}$ =0.3, $\hat{z}$ <-2 for $\hat{\theta}$ <.05).

Possible role of genes on chromosome 9pter-9p22 in testis determination

There is some evidence that genes on chromosome 9p22-9pter may represent autosomal testis determining genes. Affara et al. (HGM10) reported on the isolation of DNA probes representing transcribed gene sequences from the testis, which hybridized to chromosome 9p22-9pter. One of these sequences hybridized to X and Y chromosomes in addition to chromosome 9, while the second sequence hybridized only to the Y chromosome and to chromosome 9. Crocker et al. (1988)

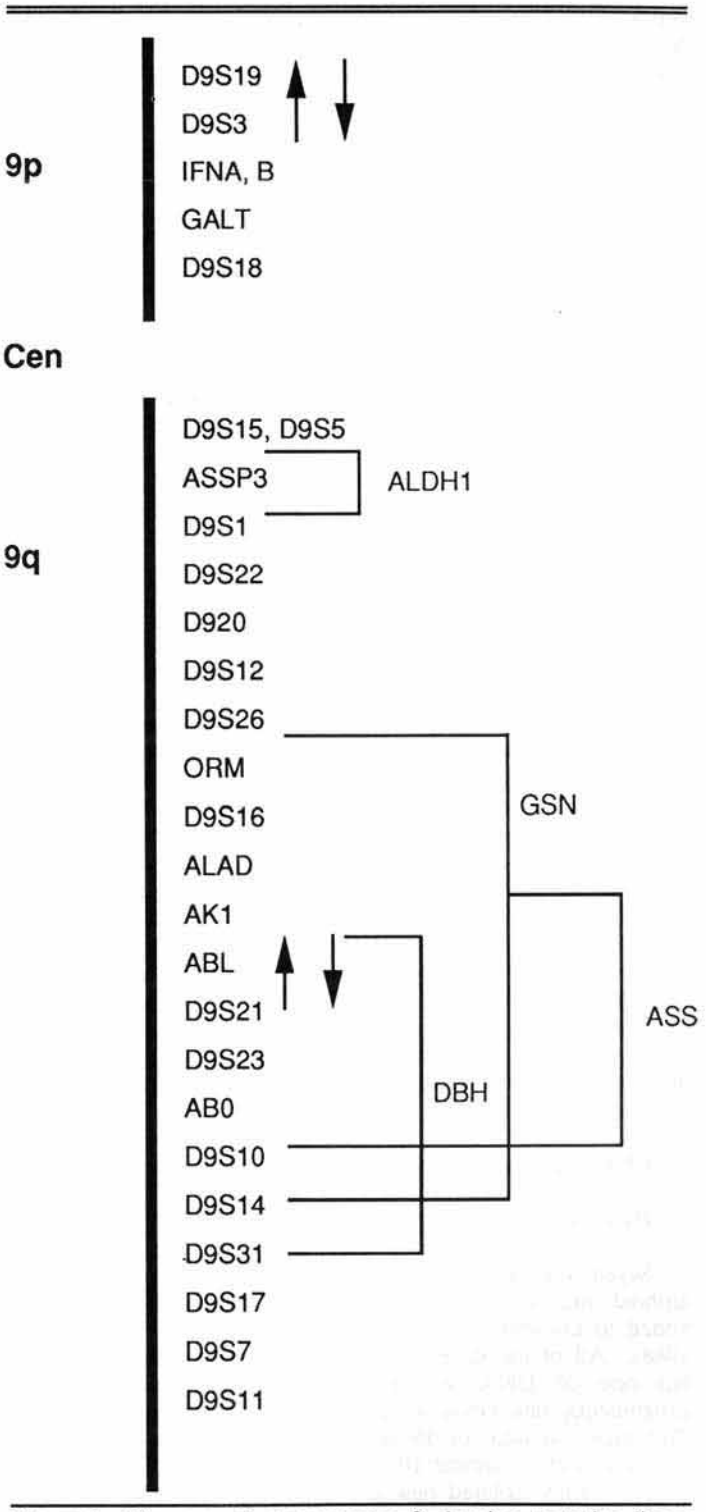

Figure 1. Diagram of chromosome 9 showing tentative linear order of genes based on maps of Lathrop et al. (1988), Keats et al. (HGM10), and data presented at HGM10 by Sampson et al. and Ozelius et al.

reported a case of monosomy for 9p23-pter associated with feminization. A review of the literature by Crocker et al. (1988) noted that ambiguous genitalia have been reported in cases of 9p- syndrome, and sex reversal has been reported in cases of partial 9p monosomy.

Structural chromosome 9 changes in malignancy

Chromosome 9p deletions have been found in a variety of different leukemias (for summary see Trent et al., 1988). Deletions occur most frequently in the 9p13-p21 region. Secker-Walker et al. (HGM10) described two cases of acute lymphoblastic leukemia with translocation-dicentric chromosomes, with breakpoints in 9p11 and 9p13: t dic(9;12), t(dic 9;16).

Cowan et al. (1988) analyzed cultured melanocytes from dysplastic nevi and melanomas. They noted that the only chromosome change in common between nevi and melanomas involved chromosome 9. One copy of chromosome 9 was lost in two out of four nevi and in four out of eleven melanomas. In three additional melanomas there was loss of chromosome 9p, most commonly the 9pter-p22 region. Based on these findings, Cowan et al. (1988), suggested that loss of genes on chromosome 9p constitutes an initial step in malignant transformation.

The occurrence of chromosome 9p deletions has been reported in gliomas by a number of investigators, (Bigner et al., 1988; Shen et al., HGM10).

Deletions in the region 9q32-9q34 region have been found in a number of different forms of leukemia. (Trent et al., 1988). Tycko et al. (1989) isolated and sequenced DNA from the breakpoint regions in human T cell neoplasms carrying the t(7;9)(q34;q32). Results of these analyses revealed that the breakpoint on chromosome 9 frequently leads to the interruption of DNA between two palindromic heptamer sequences CAC(A/T)GTG. Tycko et al. (1989) point out that such palindromic heptamers are recognized by the lymphocyte recombinase mechanism, suggesting that aberrant recombinase function may be related to the generation of the t(7;9)(q34;q32).

Morris et al. (1988) presented additional evidence that the Ph chromosomal translocation which leads to the association of abl and bcr, is frequently a complex event involving three different chromosomes.

CHROMOSOME 10

New assignments

Seven new genes, one locus for a disease, one centromeric alphoid and 36 single copy anonymous sequences have been added to chromosome 10 since HGM9.5 (Smith and Simpson, 1988). All of the genes, the disease locus for MEN2B and all but one of DNA sequences have been given provisional assignments; one DNA sequence was only tentatively mapped. This makes a total of 55 genes and 73 anonymous sequences mapped to chromosome 10.

A recently isolated new gene for excision repair, as shown by its correction of the excision deficiency in a CHO mutant of the complementation group 6, has been mapped to chromosome 10. The gene, known as ERCC6, (excision repair cross complementing rodent repair deficiency) was mapped to 10q11 by in situ hybridization using biotin labelled cDNA and a centromeric alphoid probe at D10Z1 to identify the chromosome (Hoeijmakers et al., HGM10). Other ERCC genes map to chromosomes 2, 13, 16, and 19.

A new gene, G10P2, inducible by α interferon has been mapped to chromosome 10. Wathelet et al. (1988) have isolated a cDNA clone (also independently isolated by Levy et al., 1986) that corresponds to a gene that codes for a 54 kD protein induced by α interferon. It was shown to be syntenic on chromosome 10 using a somatic cell panel to another α interferon inducible gene which codes for a 56 kD protein. The latter gene was listed in HGM9 as IFNAI1, now designated as G10P1 and was assigned to 10q25-q26 by Kusari et al. (1987). Thereby, Wathelet et al. have probably confirmed the assignment of G10P1. This is the first example of syntenic interferon inducible genes.

A gene coding for one of the three heavy chains (H2) of inter-α-trypsin inhibitor (ITIH2) has been mapped to 10p15 by in situ hybridization (Diarra-Mehrpour et al., 1989).

The neutrophil cytosol factor known as NCF1 has been assigned to chromosome 10 using a somatic cell hybrid panel (Hsieh et al., HGM10 A2573) and a cDNA that codes for a 47 kD protein that is essential for phagocytic cell superoxide production. Deficiency of the protein appears to be responsible for the most common form of autosomal chronic granulomatous disease (Nunoi et al., 1989; Volpp et al., 1989), recessive in most cases, but it has been shown to be deficient in one dominantly inherited case (Nunoi et al. 1989). The autosomal forms of the disease resulting from a deficiency of a cytosol protein have a different biochemical basis from that of the X-linked form that is characterized by an absence of cytochrome b (Segal et al., 1983; Ohno et al., 1986).

DNA from the putative oncogene (PTC), isolated from human thyroid papillary carcinomas by Fusco et al. (1987), has been mapped to chromosome 10 in somatic cell hybrids and more specifically the 5' end was mapped to 10q11-q12 using the probe p1.2 (Donghi et al., 1989; Radice et al., HGM10). The locus has been designated TST1 for the transforming sequence thyroid 1. It is thought that the transforming activity is somatically activated and may be the result of accidental or therapeutic radiation (Fusco et al., 1987). Furthermore, the probe detects a TaqI polymorphism. Activation of the TST1 oncogene is due to a rearrangement that links the tyrosine-kinase domain of the RET proto-oncogene to the 3' end of the TST1 gene (Radice et al., HGM10). It is of interest that the TST1 gene maps to the same region as the loci for MEN2A and 2B but recombinants have been observed between TST1 and MEN2A loci (Mathew, personal communication).

The new disease locus that has been provisionally mapped to chromosome 10 is that for multiple endocrine neoplasia type 2B (MEN2B) by Jackson et al. (1988). The lod score between MEN2B and RBP3 was over 3 at a small recombination and between the disease locus and D10S5 it was positive (Jackson et al., 1988; Jackson, personal communication). These linkages define the limit of the region on the q arm of the chromosome (the new position of RBP3 is 10q11.2, see below) but not the p arm and therefore we have given the regional assignment of pter-q11.2. However, the locus for this disease is likely to be the same as that for MEN2A, which was assigned to chromosome 10 (Mathew et al., 1987; Simpson et al., 1987) because of the close linkage to RBP3 and the similarities between the endocrine

neoplasias, despite their distinctive phenotypes.

Using the cDNA clone for procathepsin L, a "zinc finger binding" structure isolated by Joseph et al. (1988), Fan et al. (HGM10) have mapped a cathepsin L-like gene (CTSLL) to chromosome 10 using a somatic cell hybrid panel. Cathepsin is a lysosomal cysteine proteinase with collagenolytic and elastinolytic activity and increased activity of the proteinase has also been associated with some transformed cells (Joseph et al., 1988). The functional gene has been mapped to chromosome 9 in the same study (Fan et al., HGM10).

A nonfunctional gene (LDHAL5) for lactate dehydrogenase A-like 5 hybridized with a medium signal to chromosome 10 in dot blot analysis of flow sorted chromosomes (Li et al., 1988). The strong signal was seen for chromosomes 9 and 11 for this skeletal muscle enzyme.

The 36 new single copy anonymous sequences mapped to chromosome 10 since HGM9.5 begin at D10S36 in the locus table index. All of the DNA sequences have provisional assignments except D10S37 which has been mapped by in situ hybridization (Warnich et al., 1989) and by linkage (Nakamura et al., 1988 H6953) and thereby confirmed. The α satellite repetitive sequences pYAM11-19 and pPD10-1 at D10Z1 were added and confirmed at this meeting (Devilee et al., 1988; Yurov et al., HGM10; Kouri et al., HGM10).

Genes and DNA sequences removed

Two gene loci, MDF2 and MSK12, were removed. The MDF2 locus codes for the monoclonal antibody A-1A5 and the MSK2 for the AJS monoclonal antibody which both recognized cell surface antigens. MDF2 and MSK2 had been mapped to chromosome 10 (Messer Peters et al., 1984; Rettig et al., 1984, 1988) but it is now clear that both these antibodies recognize the β subunit of the fibronectin receptor (for details see Goodfellow et al., 1989) and therefore can be considered at the FNRB locus. The D10F9S2 locus was removed for lack of documentation and one anonymous sequence (D10S38) was lost to chromosome 7 and is now D7S422.

Changes in localizations

There have been some interesting subregionalizations since HGM9.5 (Smith and Simpson, 1989):

The SRO of RBP3 has been reduced from 10p11.2-q11.2 to 10cen-q11.2 in view of the report by Lathrop et al. (1988 H6361) using the cell line 64034p61c10 in which the only human chromosomes are 10q and Y, the in situ data localizing it to 10cen-q24 by Mathew et al. (HGM10) and the dosage studies in various cell lines by Carson and Simpson (HGM10). Although the probe IRBP.H4 for this gene does not have a high PIC value (.22) it has been widely used in mapping studies because of its early availability. The more recent probe cTBIRBP-9 at the RBP3 locus (Nakamura, 1988 H6953) detects a TaqI polymorphism with a PIC value of 0.36 and will prove to be more useful for linkage studies particularly when haplotypes are used from the two probes.

A second interstitial retinol binding protein (RBP4) that was assigned to chromosome 10 at HGM9 (the first was RBP3) has been regionally mapped using a cDNA clone in a somatic cell mapping panel and by in situ hybridization (Rocchi et al., 1989). It is of interest that the two intracellular proteins (RBP3 and RBP4) are on the same chromosome and the other two retinol binding proteins which are extracellular are on chromosome 3 and are conserved in syntenic form suggesting that the intra- and extra-cellular types evolved from two common ancestors. When the cDNA for RBP4 was localized by hybridization to 10q23-q24 a second peak of grains appeared over 10p11-q11, the site of RBP3. A similar result in reverse had occurred during the hybridization of RBP3 by Liou et al. (1987), suggesting some cross-hybridization occurred between the two DNAs. The cross-hybridization did not occur in Southerns under the higher than in situ stringency of the washing conditions.

The regional position of the locus for the enzyme hexokinase 1 (HK1), an important enzyme in the glycolytic pathway, has likely been resolved after years of conflicting dosage studies of the enzyme activity (reviewed in Magnani and Dallapiccola, 1979) since HGM1, when it was assigned to chromosome 10 (Shows, 1974). A cDNA clone of HK1 has been isolated (Nishi et al., 1988). Shows et al. (HGM10) have mapped the gene to 10q22 by in situ hybridization. This localization is consistent with the regional assignments of Gitelman and Simpson (1982) and Chern (1976) but not those of Dallapiccola et al. (1976) and Snyder et al. (1984 G0404).

A number of new markers have been isolated in the centromeric region of chromosome 10 and used in linkage studies with the locus for the hereditary cancer multiple endocrine neoplasia making it possible to assign the MEN2A locus to p11.2-q11.2, but not possible to determine whether the disease locus is on the p or q arm. Two markers, the β subunit of fibronectin receptor (FNRB) at 10p11.2 (Wu et al., HGM10 A2672; Myers et al., HGM10; Carson and Simpson, HGM10) and the probe 14.34 at D10S34 have been mapped to the p arm by linkage (Mathew et al., HGM10) and flank the disease locus with RBP3 at 10q11.2 (Wu et al., HGM10 A2673; Myers et al., HGM10; Carson and Simpson, HGM10; Mathew et al., HGM10; Lenoir et al., HGM10) and the probe pMCK2 at D10S15 mapped to 10q11.2 (Mathew et al., HGM10; Wu et al., 1989; Myers et al., HGM10; Lenoir et al., HGM10). Although it should be possible to theoretically assign the MEN2A locus to the p or q arm of the chromosome using the polymorphisms of the centromeric α satellite probe (Devilee et al., 1988) at D10SZ no informative crossovers have been found.

Dube et al. (1986) had postulated the existence of T cell neoplasia associated with a putative oncogene leading to T-cell leukemia at 10q24. From a study of somatic cell hybrids derived from a 10;14 (q24;q11) human translocation and mouse leukemic T cells Kagan et al. (1987) showed that the constant region of the α chain of the T-cell antigen receptor gene (TCL3) was translocated to chromosome 10. They suggested that this translocation results in a deregulation of the putative oncogene. Dube et al. (HGM10) report the cloning of the breakpoint in chromosome 10 and that a sequence at the 5' end recognized the presence of RNA in poly (A+) mRNA from human T-cells but not in RNA from B-lineage cells or cells of myeloid origin. We have thus assigned the TCL3 locus more specifically to q24 at HGM10.

Two additional loci have had their regional localizations narrowed since HGM9.5. CDC2, the cell division cycle gene, and EGR2, the locus for early growth, have been localized to q21.1 by combining information from linkage and dosage studies

(Wu et al., 1988 H6739; Wu et al., 1989 A2637; Carson and Simpson, HGM10).

Region of nonrandom deletions

Although not a specific region, the loss of constitutional heterozygosity on chromosome 10 in human glioblastoma tumors has been reported (James et al., 1988; Fujimoto et al., 1989). James et al. (1988) reported that the loss of chromosome 10 heterozygosity was quite specific in 28/29 glioblastomas, the most malignant of gliomas, using three markers D10S1,D10S4, and PLAU from chromosome 10, along with many markers from other chromosomes. Using a different set of markers, Fujimoto et al. (1989) described the loss of heterozygosity in the region 10pter-q23 in tumors from 10/13 patients with glioblastoma multiforme. Bigner et al. (1986) reported earlier cytogenetic loss of chromosome 10 along with other chromosomes in 5/13 of the extremely malignant tumors, glioblastoma multiforme, but also in 1/2 anaplastic astrocytomas. Shen et al. (HGM10) reported that the loss of chromosome 9 and 10 sites are common in gliomas of different histological stages from the study of ten gliomas, four of which were glioblastomas using six chromosome 10 and two chromosome 9 probes. From the above data we propose that there is a site provisionally mapped on chromosome 10 that is commonly lost in gliomas.

Inconsistency

The mapping of the locus for the enzyme neuraminidase remains inconsistent. The locus for neuraminidase has been mapped by using measurements from patients with deficiencies of the enzyme. This has created inconsistencies due to the fact that the diseases are likely the result of genetic heterogeneity. Two Japanese patients have been described that have a deficiency associated with 21-hydroxylase deficiency, the locus for which is on chromosome 6 (Oohira et al., 1985; Harada et al., 1987) and in one of the cases a possible linkage with HLA is described (Oohira et al., 1985). Another neuraminidase deficiency, sialidosis II, is thought to result from a mutation in a gene that is necessary for the expression of both neuraminidase and β-galactosidase and has been mapped to chromosome 20 by complementation studies in appropriate somatic cells (Mueller et al., 1986). On the other hand, the structural locus appears to be on chromosome 10, as shown from similar complementation and somatic cell hybrid studies using a cell line from a patient with sialidosis I, a disorder in which only neuraminidase is thought to be deficient (Mueller et al., 1986). This fact, however, needs to be confirmed and the final proof will likely come from studies when the gene for the enzyme is cloned.

The map

The map is now well flooded with genes and markers on the q arm but rather sparsely populated on the p arm. Bowden (HGM10) has described a linkage map of 29 new anonymous sequences on chromosome 10 at this workshop (Figure 2). All of the probes were mapped to the chromosome by somatic cell hybridization studies. He physically localized two of his probes at D10S11 and D10S63 by in situ hybridization. An attempt was made to integrate Bowden's map with the published map of Nakamura et al. (1988 H6953) and a map from Kidd's and Simpson's laboratories (Farrer et al., 1988; Miki et al., 1988; Carson and Simpson, HGM10; Wu et al., 1988; Wu et al., 1989 A2672 and A2673). However, it can be seen from Figure 2 that only a very few loci were common in the studies. The relation of probes that have been mapped to a reasonably small segment of the chromosome together with their linkage groups are shown in Figure 3. The CEPH consensus map will integrate the maps designated 3 and 4 in Figure 2 in the near future, and by HGM10.5 we expect to have a much more comprehensive map of chromosome 10. Some attempt has been made to integrate the three maps from pairwise scores by Keats (see the Report of the Linkage and Gene Order Committee).

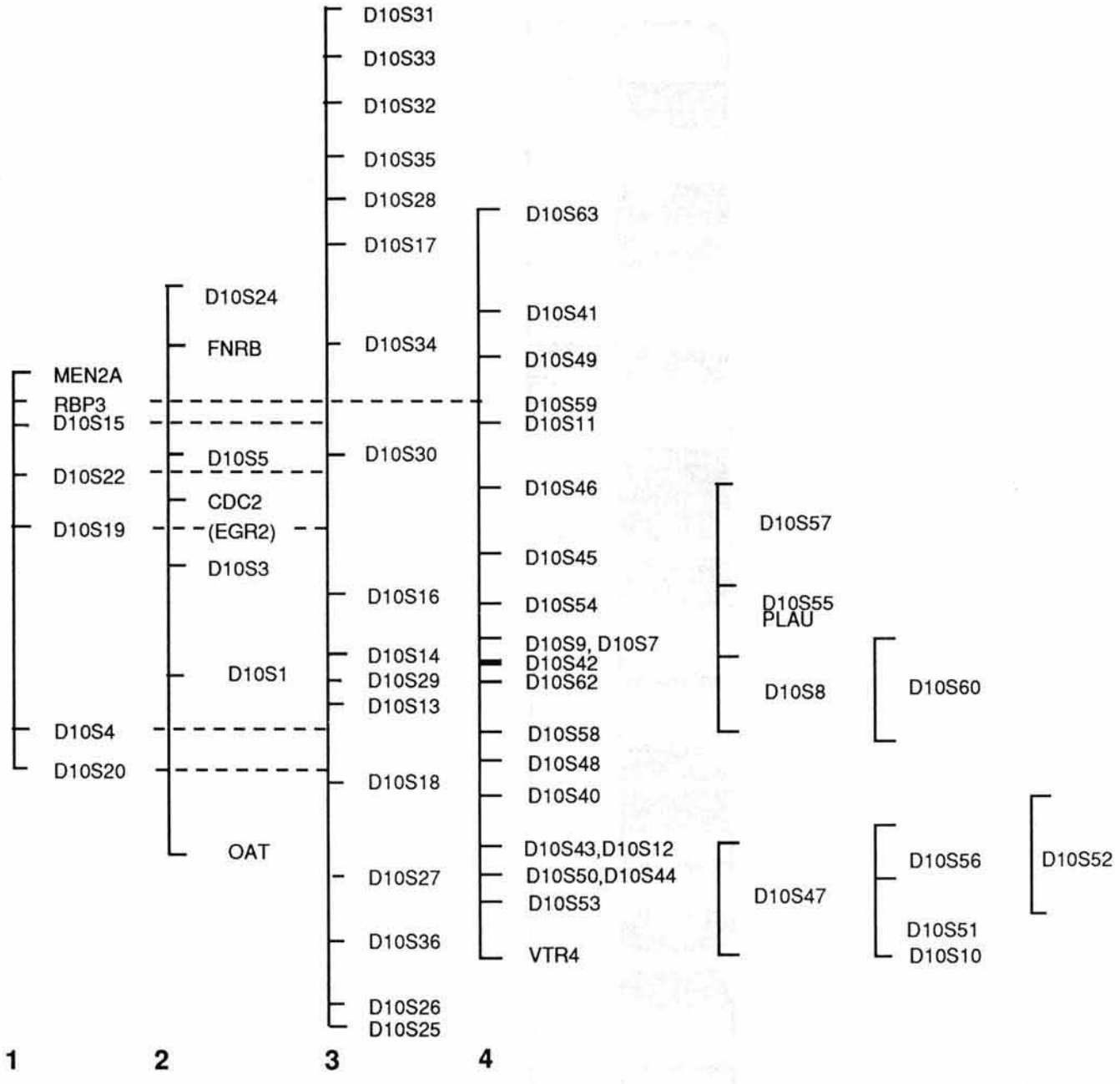

Figure 2. A comparison of three linkage maps on chromosome 10.

Legend: 1 Order of the loci in common drawn approximately proportionately.
2 Loci from the Kidd and Simpson laboratories (see Table for references).
3 Loci from Nakamura et al. (1988).
4 Loci from Bowden et al. (1989).
Short vertical bars on the extreme right represent loci of uncertain order but approximate position in relation to the long bar.

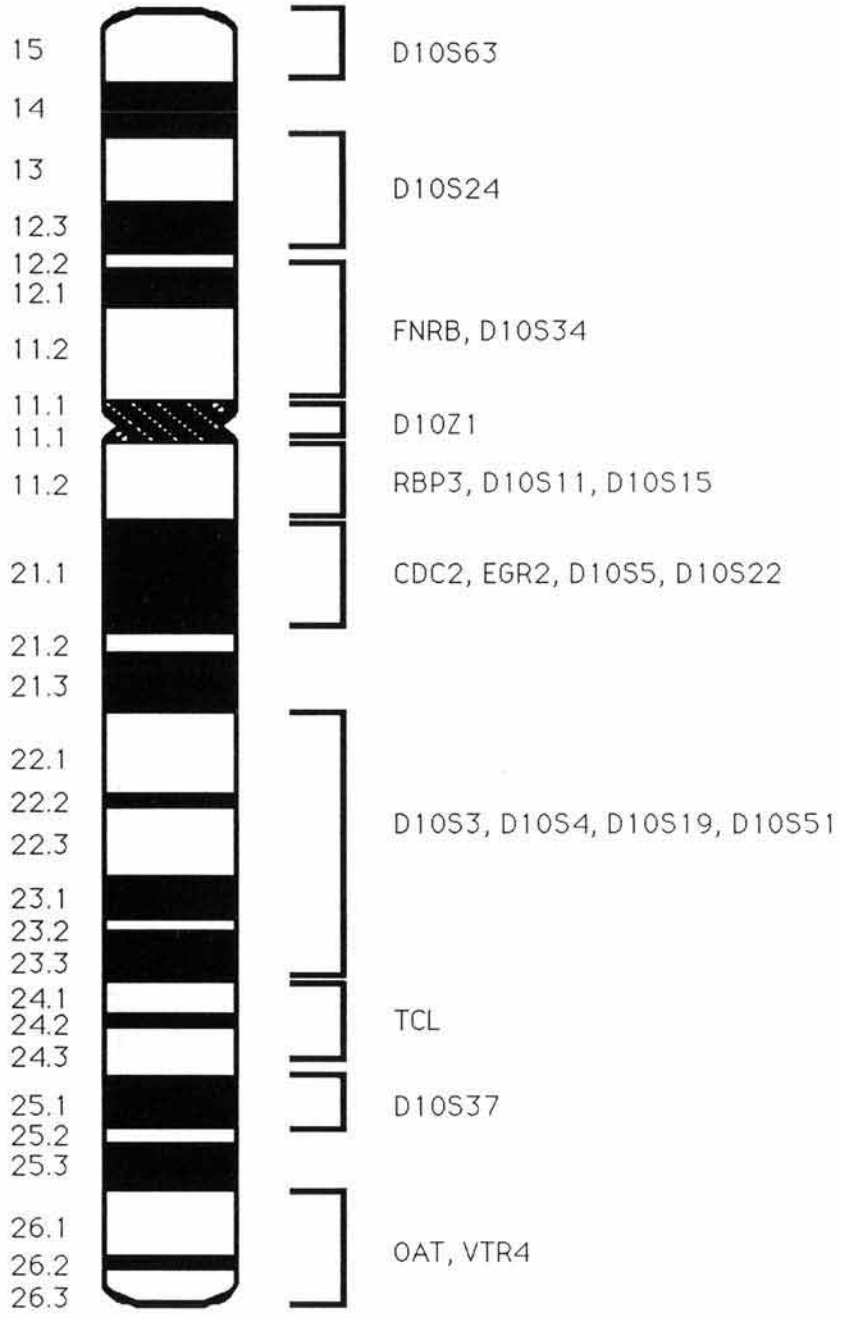

Figure 3. A physical map of those loci on chromosome 10 that have a short SRO and their linkage groups.

Locus table for chromosome 9

Regional assignment	Locus symbol	Polymorph	Locus name	Mode	Status	References
pter-q11	D9S1	+	DNA segment, single copy, probe pHF12-8	S	P	Naylor et al (1984; G0366) Naylor et al (1984; H0414) Naylor et al (1984; G0367)
pter-q12	RLN1		relaxin 1 (H1)	R,S	P	Crawford et al (1984; H0572)
pter-q12	RLN2		relaxin 2 (H2)	R,S	P	Crawford et al (1984; H0572)
pter-q34	LPC2B		lipocortin IIb	R,S	P	Huebner et al (1987; A1194) Huebner et al (1988; H6332)
p24-p13	AK3		adenylate kinase 3	S	C	Povey et al (1976; C0066) Povey et al (1976; C0148) Mohandas et al (1979; A0165)
p23-p22	IFNAP1		interferon, alpha pseudogene 1	A,R	C	Henco et al (1985; H1714) Feinstein et al (1985; H1719)
p22	IFNB1	+	interferon, beta 1, fibroblast	R,S	C	Derynck et al (1980; H4560) Ohlsson et al (1985; H1589) Ohlsson et al (1985; H2326) Diaz et al (1988; H6568)
p22-p13	IFNA	+	interferon, alpha (leukocyte)	D,L,R,S	C	Ohlsson et al (1985; H1589) Ohlsson et al (1985; H2326) Diaz et al (1988; H6568)
p22-q32	ACO1	C	aconitase 1, soluble	S	C	Carritt et al (1979; C1191) Shows & Brown (1977; C1203) Mohandas et al (1979; A0165) Povey et al (1976; C0148)
p21	FRA9A		fragile site, folic acid type, rare, fra(9)(p21)	CH	C	Berger et al (1985; H6050)
p21	FRA9C		fragile site, BrdU type, common, fra(9)(p21)	CH	P	Sutherland et al (1985; H0934)
p21-p13	GGTB2		glycoprotein-4-beta-galactosyltransferase 2	A,R,S	C	Shaper et al (1986; H3371) Duncan et al (1986; H3481)
p21-p12	RMRP		RNA component of mitochondrial RNA processing endoribonuclease	A,S	P	Hsieh et al (HGM10; A2575) Chang & Clayton (1987; H9351)
p13	GALT	C	galactose-1-phosphate uridylyltransferase	D,S	C	Aitken & Ferguson-Smith (1979; A0169) Bruns et al (1978; C1170) Benn et al (1979; C1192) Shih et al (1982; F0091)
p13-q11	ASSP12		argininosuccinate synthetase pseudogene 12	R,S	P	Beaudet et al (1982; F0048)
p13-q13	D9Z2		DNA segment, repetitive, probe pPD9	A	P	Yurov et al (HGM10; A2297) Chang et al (1983; H0053)
p13-cen	D9S38		DNA segment, single copy, probe MC114	L	P	Raimondi et al (HGM10; A2050)
p	NRASL1	+	neuroblastoma RAS viral (v-ras) oncogene homolog-like 1	R,S	P	Middleton-Price et al (1987; A1222)
p	D9S18	+	DNA segment, single copy, probe pHHH20	L	P	Lathrop et al (1987; A1298)
cen-q12	D9Z1		DNA segment, repetitive, probe QP23	A	P	Joste et al (1986; H2598) Yurov et al (HGM10; A2297)
cen-q34	FPGS		folylpolyglutamate synthase	S	C	Jones & Kao (1984; G0299) Jones et al (1980; A0159) Florian et al (HGM10; A2427)
q11-q22	ASSP3	+	argininosuccinate synthetase pseudogene 3	R,S	C	Beaudet et al (1982; F0048)
q11-q22	LPC1		lipocortin I	R,S	P	Huebner et al (1987; A1194) Huebner et al (1988; H6332)
q12	DNCM		DNA associated with cytoplasmic membrane	A	P	Kuo et al (1975; C1193)
q12	FRA9F		fragile site, 5-azacytidine type, common, fra(9)(q12)	CH	P	Yunis et al (1987; H9202) Hecht et al (1988; H6503)
q12	D9Z3		DNA segment, satellite 3, repetitive, probe pHuR98	A	P	Moyzis et al (1987; H4565)
q12-q13	D9S5	+	DNA segment, single copy, probe DR47	A,L	C	Orzechowski et al (1987; A0732) Orzechowski et al (1987; H4339) Fujita et al (HGM10; A2654)

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Regional assignment	Locus symbol	Polymorph	Locus name	Mode	Status	References
q12-qter	HSPBL2		heat shock 27 kD protein-like 2			McGuire et al (1989; H7896)
q13-q21.1	FRDA		Friedreich ataxia	L	C	Chamberlain et al (1988; H6600) Chamberlain et al (1989; H7903) Fujita et al (1989; H7543) Ross et al (HGM10; A2401) Chamberlain et al (HGM10; A2215)
q21.1	ALDH1		aldehyde dehydrogenase 1, soluble	R,S	C	Hsu et al (1985; H2228) Hsu et al (1986; H2721) Raghunathan et al (1988; H6433)
q21-q22	CTSL		cathepsin L	A	P	Fan et al (HGM10; A2237)
q21.3-q22.2	ALDOB	+	aldolase B, fructose bisphosphate	A,CH,R,S	C	Henry et al (1985; H2850) Lebo et al (1985; H1659) Santamaria et al (1987; A1037)
q22.1	FRA9D		fragile site, aphidicolin type, common, fra(9)(q22.1)	CH	C	Green et al (1988; H9197) Yunis & Soreng (1984; H0748) Tedeschi et al (1987; H6039)
q22-q34	C5	C	complement component 5	A,R,S	C	Jeremiah et al (1987; A0891) Lemons et al (1987; A1244) Jeremiah et al (1988; H6391)
q31	D9S29	+	DNA segment, single copy, probe LAMP92	A,L	P	Pandolfo et al (1988; H5656)
q31-qter	APPL1		amyloid beta (A4) precursor protein-like 1	A	P	Jenkins et al (1987; H5219)
q31-qter	ORM1	C	orosomucoid 1	CH,D,R	C	Allderdice et al (1986; H3391) Rocchi et al (1986; H3207) Webb et al (1988; H5820) Board et al (1986; H3125)
q31-qter	ORM2	C	orosomucoid 2	CH,D,R	P	Rocchi et al (1986; H3207) Webb et al (1988; H5820)
q32	FRA9B		fragile site, folic acid type, rare, fra(9)(q32)	CH	C	Sutherland et al (1985; H0934) Petit et al (1986; H9239)
q32	FRA9E		fragile site, aphidicolin type, common, fra(9)(q32)	CH	C	Berger et al (1985; H6050)
q32-q33	ITIL	+	inter-alpha-trypsin inhibitor (protein HC), light polypeptide	A,R,S	C	Traboni et al (1987; A1034) Diarra-Mehrpour et al (1989; H7736)
q32-q34	DYT1		dystonia, torsion 1 (autosomal dominant)	L,R	P	Ozelius et al (HGM10; A2313)
q32-q34	GSN		gelsolin	A,CH,S	C	Kwiatkowski et al (1988; H5513) Matsudaira & Janmey (1988; H6511) Kwiatkowski et al (1986; H5276)
q33-q34	SPTAN1		spectrin, alpha, non-erythrocytic 1 (alpha-fodrin)	R,S	C	Barton et al (1987; A0690) Leto et al (1988; H7383) Birkenmeier et al (1988; H8167)
q34.1-q34.2	ABO	C	ABO blood group	L	C	Cook et al (1978; C1197) Allderdice et al (1986; H3391)
q34.1-q34.2	AK1	+	adenylate kinase 1	D,S	C	Cook et al (1978; C1197) Allderdice et al (1986; H3391)
q34	ABL	+	Abelson murine leukemia viral (v-abl) oncogene homolog	A,R,S	C	Groffen et al (1984; H0922) Jhanwar et al (1984; H0420) Westbrook et al (1985; H2074)
q34	ALAD	C	aminolevulinate, delta-, dehydratase	L,S	C	Potluri et al (1987; H4211) Wang et al (1985; H1507) Wetmur et al (1986; H3215) Wetmur et al (1986; H2846)
q34	DBH		dopamine beta-hydroxylase (dopamine beta-monooxygenase)	L	C	Elston et al (1979; H6212) Asamoah et al (1987; H4165) Keats et al (1987; A1001) Craig et al (1988; H7417)
q34	NPS1		nail patella syndrome 1	L	C	Cook et al (1978; C1197)
q34	WS1		Waardenburg syndrome, type 1	L	T	Cook et al (1978; C1197) Read et al (HGM10; A2549)

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Regional assignment	Locus symbol	Polymorph	Locus name	Mode	Status	References
q34	D9S7	+	DNA segment, single copy, probe pEFD126.3	L	P	Nakamura et al (1987; H4814)
q34	D9S17	+	DNA segment, single copy, probe pEKZ19.3	L	P	Kumlin-Wolff et al (1987; H4821)
q34	D9S31	+	DNA segment, single copy, probe pKKA40	L	P	Nakamura et al (1988; H7468)
q34-qter	ASS	+	argininosuccinate synthetase	R,S	C	Carritt et al (1977; C1171) Beaudet et al (1982; F0048) Haines et al (HGM10; A2173)
q	GRP78		glucose regulated protein (78kD)	R,S	P	Law et al (1984; G0320)
q	TSC1		tuberous sclerosis 1	L	P	Connor et al (1987; H5599) Fryer et al (1987; H5087) Smith et al (1987; A0912) Povey et al (1988; H7032) Haines et al (HGM10; A2173)
q	D9S6	+	DNA segment, single copy, probe pYNM17	L	P	Nakamura et al (1987; H4815)
q	D9S10	+	DNA segment, single copy, probe pMCT136	L,S	P	Carlson et al (1987; H4810)
q	D9S11	+	DNA segment, single copy, probe pMHZ10	L	P	Nakamura et al (1987; H4816)
q	D9S13	+	DNA segment, single copy, probe pMHZ13	L	P	Nakamura et al (1988; H5183)
q	D9S14	+	DNA segment, single copy, probe pMCT96.1	L	P	Nakamura et al (1988; H6686)
q	D9S15	+	DNA segment, single copy, probe pMCT112	L	P	Carlson et al (1987; H4811)
q	D9S16	+	DNA segment, single copy, probe pMCOA12	L,S	P	Lathrop et al (1988; H7451) Nakamura et al (1988; H7468)
q	D9S28		DNA segment, single copy, probe pMCOA12	L	P	Carlson et al (1988; H5168)
q	D9S30	+	DNA segment, single copy, probe pMHZ21	L	P	Nakamura et al (1988; H6685)
q	D9S39	+	DNA segment, single copy, probe pFF9.59.1	S	P	Florian et al (HGM10; A2427)
	CPO		coproporphyrinogen oxidase	S	C	Grandchamp et al (1983; H0010) McColl & Goldberg (1983; G0608)
	FTHL12		ferritin, heavy polypeptide-like 12	A,R	P	Gatti et al (1987; A0685) Gatti et al (1987; H4545)
	IGHEP2		immunoglobulin epsilon pseudogene 2	R,S	P	Battey et al (1982; F0088)
	KRT18L3		keratin 18-like 3	A,S	T	Romano et al (1988; H7942)
	LDHAL4		lactate dehydrogenase A-like 4			Li et al (1988; H7414)
	MSK34		antigen identified by monoclonal antibody CNT/6	S	P	Rettig et al (1987; A1016)
	MTAP		methylthioadenosine phosphorylase	S	P	Carrera et al (1984; H0434)
	PRPS1L2		phosphoribosyl pyrophosphate synthetase 1-like 2			Taira et al (1989; H7723)
	PYHG14		protein spot in 2-D gels (MW 37kD)	S	P	Taggart & Francke (1982; B0463)
	PYHG15		protein spot in 2-D gels (MW 35kD)	S	P	Taggart & Francke (1982; B0463)
	PYHG16		protein spot in 2-D gels (MW 38kD)	S	P	Taggart & Francke (1982; B0463)
	VARS		valyl-tRNA sythetase	S	P	Walter et al (1987; A0913)
	D9F1S4		DNA segment, numerous copies, probe pAX-6	S	T	Balazs et al (1984; H0514)
	D9S2		DNA segment, single copy, probe 9ER1	S	P	Kao et al (1984; G0311)
	D9S3	+	DNA segment, single copy, probe DR6	L,S	C	Icking et al (1985; H2234) Chamberlain et al (HGM10; A2215)
	D9S4	+	DNA segment, single copy, probe phage 42	S	P	Spurr et al (1985; H2397) Spurr et al (1986; H2707)
	D9S8	+	DNA segment, single copy, probe pEFD40.3	L	P	Fujimoto et al (1987; H4809)
	D9S9	+	DNA segment, single copy, probe pEKZ130	L,S	P	Kumlin-Wolff et al (1987; H4808)
	D9S12	+	DNA segment, single copy, probe pTHH22	L	P	Holm et al (1988; H5179)
	D9S19	+	DNA segment, single copy, probes CRI-L1263, LAM 1263	L,S	P	Donis-Keller et al (1987; H4642)
	D9S20	+	DNA segment, single copy, probe CRI-R3	L,S	P	Donis-Keller et al (1987; H4642)
	D9S21	+	DNA segment, single copy, probe CRI-P111	L	P	Donis-Keller et al (1987; H4642)

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Regional assignment	Locus symbol	Poly-morph	Locus name	Mode	Status	References
	D9S22	+	DNA segment, single copy, probe CRI-P110	L	P	Donis-Keller et al (1987; H4642)
	D9S23	+	DNA segment, single copy, probe CRI-L1424	L	P	Donis-Keller et al (1987; H4642)
	D9S25	+	DNA segment, single copy, probe CRI-L1022	L	P	Donis-Keller et al (1987; H4642)
	D9S26	+	DNA segment, single copy, probe CRI-L659	L	P	Donis-Keller et al (1987; H4642)
	D9S27	+	DNA segment, single copy, probe pHHH202	L	P	Hoff et al (1987; H4813)
	D9S33	+	DNA segment, single copy, probe CRI-L944	L	C	Donis-Keller et al (1987; H4642) Smith et al (1987; A0854)
	D9S34	+	DNA segment, single copy, probe MCOA9	L	P	Nakamura et al (1988; H7468)
	D9S35	+	DNA segment, single copy, probe KKA40	L	P	Nakamura et al (1988; H7468)
	D9S41	+	DNA segment, single copy, probe H35	S	P	Retief et al (HGM10; A2311)
	D9S42		DNA segment, single copy, probe lambda8A	S	P	Hogg et al (1986; H3486) Kouri et al (HGM10; A2352)

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Locus symbol	Regional assignment	Locus symbol	Regional assignment	Locus symbol	Regional assignment	Locus symbol	Regional assignment
Genes		FRA9F	q12	PYHG16		D9S15	q
		FRDA	q13-q21.1	RLN1	pter-q12	D9S16	q
ABL	q34	FTHL12		RLN2	pter-q12	D9S17	q34
ABO	q34.1-q34.2	GALT	p13	RMRP	p21-p12	D9S18	p
ACO1	p22-q32	GGTB2	p21-p13	SPTAN1	q33-q34	D9S19	
AK1	q34.1-q34.2	GRP78	q	TSC1	q	D9S20	
AK3	p24-p13	GSN	q32-q34	VARS		D9S21	
ALAD	q34	HSPBL2	q12-qter	WS1	q34	D9S22	
ALDH1	q21.1	IFNA	p22-p13			D9S23	
ALDOB	q21.3-q22.2	IFNAP1	p23-p22	**D segments**		D9S25	
APPL1	q31-qter	IFNB1	p22			D9S26	
ASS	q34-qter	IGHEP2		D9F1S4		D9S27	
ASSP3	q11-q22	ITIL	q32-q33	D9S1	pter-q11	D9S28	q
ASSP12	p13-q11	KRT18L3		D9S2		D9S29	q31
C5	q22-q34	LDHAL4		D9S3		D9S30	q
CPO		LPC1	q11-q22	D9S4		D9S31	q34
CTSL	q21-q22	LPC2B	pter-q34	D9S5	q12-q13	D9S33	
DBH	q34	MSK34		D9S6	q	D9S34	
DNCM	q12	MTAP		D9S7	q34	D9S35	
DYT1	q32-q34	NPS1	q34	D9S8		D9S38	p13-cen
FPGS	cen-q34	NRASL1	p	D9S9		D9S39	q
FRA9A	p21	ORM1	q31-qter	D9S10	q	D9S41	
FRA9B	q32	ORM2	q31-qter	D9S11	q	D9S42	
FRA9C	p21	PRPS1L2		D9S12		D9Z1	cen-q12
FRA9D	q22.1	PYHG14		D9S13	q	D9Z2	p13-q13
FRA9E	q32	PYHG15		D9S14	q	D9Z3	q12

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Regional assignment	Locus symbol	Polymorph	Locus name	Mode	Status	References
pter-p13	D10S17	+	DNA segment, single copy, probe pMHZ15	L,S	C	Hoff et al (1988; H4796) Lathrop et al (1988; H6361) Mathew et al (HGM10; A2250)
pter-p13	D10S28	+	DNA segment, single copy, probe cTBQ7	L,S	C	Nakamura et al (1988; H6953) Bragg et al (1988; H7279) Mathew et al (HGM10; A2250)
pter-p11.1	PFKP		phosphofructokinase, platelet type	S	C	Weil et al (1980; A0186) Vora et al (1983; G0157) Schwartz et al (1984; H0532)
pter-q11.2	MEN2B		multiple endocrine neoplasia IIB	L	P	Jackson et al (1988; H7308)
pter-q11	D10S86		DNA segment, single copy, probe p19dIII2.0	S	P	Goodfellow et al (HGM10; A2597)
pter-q11	D10S87		DNA segment, single copy, probe p31RI1.0	S	P	Goodfellow et al (HGM10; A2597)
pter-q23 or 6	NEU		neuraminidase	D,L,S	I	Oohira et al (1985; H1685) Mueller et al (1986; H2549) Oohira et al (1986; H6141) Harada et al (1987; H3535)
p15	ITIH2		inter-alpha-trypsin inhibitor (protein HC), H2 polypeptide	A	P	Diarra-Mehrpour et al (1989; H7736)
p15	D10S63	+	DNA segment, single copy, probe CRI-JD12	A,L,S,W	P	Bowden et al (HGM10; A2016)
p15-p14	IL2R	+	interleukin 2 receptor	A,R,W	P	Leonard et al (1985; H1537) Ardinger & Murray (1988; H5985)
p14-p11.2	D10S49	+	DNA segment, single copy, probe CRI-J170	L,S	P	Bowden et al (HGM10; A2016)
p14-q11.2	D10S41	+	DNA segment, single copy, probe CRI-J93	L,S	P	Bowden et al (HGM10; A2016)
p13	VIM		vimentin	A,R,S	C	Quax et al (1985; H1999) Ferrari et al (1987; H4543) Marcus et al (1988; H6493) Carson & Simpson (HGM10; A2210) Mathew et al (HGM10; A2250)
p13-p12.2	D10S24	+	DNA segment, single copy, probe p7A9.	D,L	P	Wu et al (1988; H6809) Myers et al (HGM10; A2671) Wu et al (HGM10; A2673) Carson & Simpson (HGM10; A2210)
p11.2	FNRB	+	fibronectin receptor, beta polypeptide	A,L,R,S	C	Zhang et al (1988; H5077) Goodfellow et al (1989; H7768) Wu et al (HGM10; A2672) Myers et al (HGM10; A2671) Carson & Simpson (HGM10; A2210)
p11.2-q11.2	MEN2A		multiple endocrine neoplasia IIA	L	C	Mathew et al (1987; H4145) Simpson et al (1987; H4144) Sobol et al (1988; H8342) Mathew et al (HGM10; A2250) Myers et al (HGM10; A2671)
p11-q23	D10S13	+	DNA segment, single copy, probe pTHH105.1	L	P	Lathrop et al (1988; H6361)
p11-q23	D10S14	+	DNA segment, single copy, probe pTHH54	L	P	Lathrop et al (1988; H6361) Holm et al (1988; H4812)
p11-q23	D10S16	+	DNA segment, single copy, probe pCMM17.1	L	P	Martin et al (1988; H5141) Lathrop et al (1988; H6361)
p	D10S31	+	DNA segment, single copy, probe cTBQ20	L,S	P	Nakamura et al (1988; H6953) Bragg et al (1988; H7285)
p	D10S33	+	DNA segment, single copy, probe cTBQ14.16	L	P	Nakamura et al (1988; H6953) Bragg et al (1988; H7283)
p	D10S34	+	DNA segment, single copy, probe cTBQ14.34	D,L,S	C	Nakamura et al (1988; H6953) Mathew et al (HGM10; A2250)
p	D10S35	+	DNA segment, single copy, probe cTBQ14.36	L	P	Nakamura et al (1988; H6953) Bragg et al (1988; H7282)
p	D10S39	+	DNA segment, single copy, probe pCMH10.2	S	P	Mathew et al (HGM10; A2250)

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Regional assignment	Locus symbol	Polymorph	Locus name	Mode	Status	References
cen	D10Z1	+	DNA segment, alpha satellite, repetitive, probes pYAM11-19 and pPD10-1	A,S	C	Devilee et al (1988; H6921) Yurov et al (1987; A0665) Kouri et al (HGM10; A2352)
cen-q24	ADK		adenosine kinase	D,S	C	Chan et al (1978; C1212) Francke & Thompson (1979; C1225) Snyder et al (1984; H0581)
q11	ERCC6		excision repair cross complementing rodent repair deficiency, comp lementation group 6	A	P	Hoeijmakers et al (HGM10; A2358)
q11.1-q24	PP		pyrophosphatase (inorganic)	D,S	C	Fisher et al (1976; C1214) McAlpine et al (1976; C1218) Van Cong et al (1975; C1220) Chern (1976; C1226) Snyder et al (1984; H0581)
q11.2	RBP3	+	retinol-binding protein 3, interstitial	A,D,L,R,S	C	Liou et al (1987; H3698) Farrer et al (1988; H6897) Nakamura et al (1988; H6953) Mathew et al (HGM10; A2250) Carson & Simpson (HGM10; A2210)
q11.2	TST1	+	transforming sequence, thyroid 1	A,R,S	P	Fusco et al (1987; H8861) Radice et al (1988; H6492) Donghi et al (1989; H9148) Radice et al (HGM10; A2599)
q11.2	D10S11	+	DNA segment, single copy, probe CRI-L647	A,L,S	P	Donis-Keller et al (1987; H4642) Bowden et al (HGM10; A2016)
q11.2	D10S15	+	DNA segment, single copy, probe pMCK2	D,L	C	Nakamura et al (1988; H4797) Lathrop et al (1988; H6361) Carson & Simpson (HGM10; A2210) Mathew et al (HGM10; A2250)
q11.2	D10S59	+	DNA segment, single copy, probe CRI-JC145	L,S	P	Bowden et al (HGM10; A2016)
q11.2-q22	D10S30	+	DNA segment, single copy, probe cTBQ16	L	C	Nakamura et al (1988; H6953) Bragg et al (1988; H6689) Mathew et al (HGM10; A2250)
q11.2-qter	D10S78		DNA segment, single copy, probe phage 8	S	P	Goodfellow et al (HGM10; A2597)
q11.2-qter	D10S79		DNA segment, single copy, probe pladIII/R10.5	S	P	Goodfellow et al (HGM10; A2597)
q11.2-qter	D10S80		DNA segment, single copy, probe p15RI3.5	S	P	Goodfellow et al (HGM10; A2597)
q11.2-qter	D10S81		DNA segment, single copy, probe p23RI/dIII1.3	S	P	Goodfellow et al (HGM10; A2597)
q11.2-qter	D10S82		DNA segment, single copy, probe p25dIII2.5	S	P	Goodfellow et al (HGM10; A2597)
q11.2-qter	D10S83		DNA segment, single copy, probe p35RI/dIII0.8	S	P	Goodfellow et al (HGM10; A2597)
q11.2-qter	D10S84		DNA segment, single copy, probe p2RI/dIII0.5	S	P	Goodfellow et al (HGM10; A2597)
q11.2-qter	D10S85		DNA segment, single copy, probe p4dIII/RI0.55	S	P	Goodfellow et al (HGM10; A2597)
q21.1	CDC2	+	cell division cycle 2, G1 to S and G2 to M	D,L,R,S	C	Spurr et al (1988; H5863) Myers et al (1988; H6952) Wu et al (HGM10; A2673) Carson & Simpson (HGM10; A2210)
q21.1	EGR2	+	early growth response 2	A,D,L,R,S	C	Joseph et al (1988; H7121) Wu et al (1988; H6739) Wu et al (HGM10; A2673) Carson & Simpson (HGM10; A2210)
q21.1	D10S5	+	DNA segment, single copy, probe p9-12A (aka p19-12A/2dIII2.5)	A,D,L	C	McDermid et al (1987; H3949) Farrer et al (1988; H6897) Carson & Simpson (HGM10; A2210) Shen et al (HGM10; A2036) Wu et al (HGM10; A2673)
q21.1	D10S22	+	DNA segment, single copy, probe pTB10.163	D,L,S	C	Bragg et al (1988; H5151) Lathrop et al (1988; H6361) Carson & Simpson (HGM10; A2210) Wu et al (HGM10; A2673) Mathew et al (HGM10; A2250)

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Regional assignment	Locus symbol	Polymorph	Locus name	Mode	Status	References
q21	FRA10C		fragile site, BrdU type, common, fra(10)(q21)	CH	P	Sutherland et al (1985; H0934)
q21-q22	LPC2C		lipocortin IIc	R,S	P	Huebner et al (1987; A1194)
q21-q22	SAP1	C	sphingolipid activator protein 1	A,R,S	P	Inui et al (1985; H0931) Dewji et al (1987; H4751)
q21.1-q22	D10S19	+	DNA segment, single copy, probe pTB10.171	D,L,S	C	Nakamura et al (1988; H5149) Lathrop et al (1988; H6361) Shen et al (HGM10; A2036) Carson & Simpson (HGM10; A2210) Wu et al (HGM10; A2673)
q21-q24	SFTP1	+	surfactant-associated protein 1	A,R,S	C	Bruns et al (1987; H3886) Fisher et al (1987; H4016) Floros et al (1987; H4263)
q21-q26	D10S20	+	DNA segment, single copy, probes OS-2, OS-3	L	C	Miki et al (1988; H6623) Lathrop et al (1988; H6361) Wu et al (1988; H6959)
q22.1	FRA10D		fragile site, aphidicolin type, common, fra(10)(q22.1)	CH	C	Tedeschi et al (1987; H6039) Yunis & Soreng (1984; H0748) Rao et al (1988; H6954)
q22	HK1	C	hexokinase 1	A,D,R,S	C	Shows (1974; C1222) Dallapiccola et al (1979; C1224) Gitelman & Simpson (1982; B0152) Shows et al (HGM10; A2233)
q22-q23	D10S1	+	DNA segment, single copy, probe 5-1	D,L,S	C	Dryja et al (1984; G0268) Farrer et al (1988; H6897) Shen et al (HGM10; A2036) Carson & Simpson (HGM10; A2210)
q22-q23	D10S3	+	DNA segment, single copy, probe phage10	D,L,S	C	Spurr et al (1986; H2707) Farrer et al (1988; H6897) Shen et al (HGM10; A2036) Carson & Simpson (HGM10; A2210)
q22-q23	D10S4	+	DNA segment, single copy, probe p1-101	D,L,S	C	Litt et al (1987; H3704) Farrer et al (1988; H6897) Miki et al (1988; H6623) Shen et al (HGM10; A2036) Carson & Simpson (HGM10; A2210)
q23-q24	DNTT		deoxynucleotidyltransferase, terminal	A,R,S	C	Isobe et al (1985; H1669) Kagan et al (1987; H4158) Yang-Feng et al (1986; H3568)
q23-q24	GLUD	+	glutamate dehydrogenase	R,S	P	Hanauer et al (1985; H2212) Hanauer et al (1987; H4337)
q23-q24	RBP4		retinol-binding protein 4, interstitial	A,R,S	P	Rocchi et al (1987; A1033) Rocchi et al (1989; H7898)
q23.3 or q24.2	FRA10A		fragile site, folic acid type, rare, fra(10)(q23.3) or fra(10)(q24.2)	CH	C	Berger et al (1985; H6050) Dutrillaux et al (1985; H6066) Sutherland (1979; A0462)
q24.1-q24.3	CYP2C		cytochrome P450, subfamily IIC (mephenytoin 4-hydroxylase)	A,R,S	C	Spurr et al (1987; A1329) Riddell et al (1987; A1170) Meehan et al (1988; H4956) Okino et al (1987; H4729)
q24	TCL3		T cell lymphoma 3 associated breakpoint	CH,R,S	P	Dube et al (1986; H8680) Kagan et al (1987; H4158) Dube et al (HGM10; A2307)
q24-q26	ADRA2R	+	adrenergic, alpha-2-, receptor	A,R,S	P	Yang-Feng et al (1987; A0695) Kobilka et al (1987; H4594) Hoehe et al (1988; H6489)
q24-qter	PLAU	+	plasminogen activator, urokinase	R,S	C	Tripputi et al (1985; H1588) Sebastio et al (1985; H1619) Rajput et al (1985; H1792)

Locus table for chromosome 10

Regional assignment	Locus symbol	Polymorph	Locus name	Mode	Status	References
q24-qter	D10S18	+	DNA segment, single copy, probe pYNZ156	L	P	Nakamura et al (1988; H4798) Lathrop et al (1988; H6361)
q24.3-qter	D10S21	+	DNA segment, single copy, probe CARLPII	S	C	Raeymaekers et al (1988; H5604) Mathew et al (HGM10; A2250)
q25.1	D10S37	+	DNA segment, single copy, probe H38	A,L	C	Warnich et al (1989; H7216) Nakamura et al (1988; H6953)
q25-q26	G10P1	+	interferon, alpha-inducible protein (MW 56kD)	A,R,S	P	Kusari et al (1987; H3917) Wathelet et al (1988; H7115)
q25.2	FRA10B		fragile site, BrdU type, rare, fra(10)(q25.2)	CH	C	Berger et al (1985; H6050)
q25.2	FRA10E		fragile site, aphidicolin type, common, fra(10)(q25.2)	CH	P	Yunis & Soreng (1984; H0748) Tedeschi et al (1987; H6039)
q25.3	GOT1	C	glutamic-oxaloacetic transaminase 1, soluble	D,S	C	Creagan et al (1973; C1213) Chern et al (1976; C1229) Hellkuhl & Grzeschik (1976; C1231) Junien et al (1982; H0107)
q25.3	PGAM1		phosphoglycerate mutase 1 (brain)	D,S	C	Evans-Jones et al (1983; H0106) Junien et al (1982; H0107)
q26.1	FRA10F		fragile site, aphidicolin type, common, fra(10)(q26.1)	CH	C	Yunis & Soreng (1984; H0748) Tedeschi et al (1987; H6039) Green et al (1988; H9197)
q26	OAT	+	ornithine aminotransferase	A,L,R,S	C	Ramesh et al (1986; H4155) Mitchell et al (1986; H3185) Wu et al (1988; H6959) Barrett et al (1987; H6955) Mitchell et al (1988; H5942)
q26	D10S6		DNA segment, single copy, probe A	A	T	Colb et al (1986; H3272)
q	G10P2		interferon, alpha-inducible protein (MW 54kD)	R,S	P	Wathelet et al (1988; H7115)
q	D10S7	+	DNA segment, single copy, probe CRI-L1083	L	P	Donis-Keller et al (1987; H4642) Bowden et al (HGM10; A2016)
q	D10S8	+	DNA segment, single copy, probe CRI-L1005	L	P	Donis-Keller et al (1987; H4642)
q	D10S9	+	DNA segment, single copy, probe CRI-L941	L	P	Donis-Keller et al (1987; H4642) Bowden et al (HGM10; A2016)
q	D10S10	+	DNA segment, single copy, probe CRI-L893	L	P	Donis-Keller et al (1987; H4642)
q	D10S12	+	DNA segment, single copy, probes CRI-L368, CARY 368	L	P	Donis-Keller et al (1987; H4642)
q	D10S23	+	DNA segment, single copy, probe pCMM17.4	L	T	Martin et al (1988; H5159)
q	D10S25	+	DNA segment, single copy, probe pEFD75	D,L	C	Nakamura et al (1987; H3688) Nakamura et al (1988; H6953) Shen et al (HGM10; A2036)
q	D10S26	+	DNA segment, single copy, probe pEFD70.2	L	P	Nakamura et al (1988; H6953) Nakamura et al (1988; H6688)
q	D10S27	+	DNA segment, single copy, cTBQ4	L	P	Nakamura et al (1988; H6953)
q	D10S29	+	DNA segment, single copy, probe cTBQ12	L	P	Nakamura et al (1988; H6953) Bragg et al (1988; H7286)
q	D10S32	+	DNA segment, single copy, probe cTBQ14.15	L	P	Nakamura et al (1988; H6953) Bragg et al (1988; H7284)
q	D10S36	+	DNA segment, single copy, probe pMCT122.2	L	P	Nakamura et al (1988; H6690) Nakamura et al (1988; H6953)
q	D10S40	+	DNA segment, single copy, probe CRI-J90	L,S	P	Bowden et al (HGM10; A2016)
q	D10S42		DNA segment, single copy, probe CRI-J97	L,S	P	Bowden et al (HGM10; A2016)
q	D10S43	+	DNA segment, single copy, probe CRI-J101	L,S	P	Bowden et al (HGM10; A2016)
q	D10S44	+	DNA segment, single copy, probe CRI-J125	L,S	P	Bowden et al (HGM10; A2016)
q	D10S45	+	DNA segment, single copy, probe CRI-J127	L,S	P	Bowden et al (HGM10; A2016)
q	D10S46	+	DNA segment, single copy, probe CRI-J128	L,S	P	Bowden et al (HGM10; A2016)

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Regional assignment	Locus symbol	Polymorph	Locus name	Mode	Status	References
q	D10S47	+	DNA segment, single copy, probe CRI-J137	L,S	P	Bowden et al (HGM10; A2016)
q	D10S48	+	DNA segment, single copy, probe CRI-J167	L,S	P	Bowden et al (HGM10; A2016)
q	D10S50	+	DNA segment, single copy, probe CRI-J179	L,S	P	Bowden et al (HGM10; A2016)
q	D10S51	+	DNA segment, single copy, probe CRI-J182	L,S	P	Bowden et al (HGM10; A2016)
q	D10S52	+	DNA segment, single copy, probe CRI-J193	L,S	P	Bowden et al (HGM10; A2016)
q	D10S53	+	DNA segment, single copy, probe CRI-J198	L,S	P	Bowden et al (HGM10; A2016)
q	D10S54	+	DNA segment, single copy, probe CRI-JC109	L,S	P	Bowden et al (HGM10; A2016)
q	D10S55	+	DNA segment, single copy, probe CRI-JC114	L,S	P	Bowden et al (HGM10; A2016)
q	D10S56	+	DNA segment, single copy, probe CRI-JC140	L,S	P	Bowden et al (HGM10; A2016)
q	D10S57	+	DNA segment, single copy, probe CRI-JC143	L,S	P	Bowden et al (HGM10; A2016)
q	D10S58	+	DNA segment, single copy, probe CRI-JC144	L,S	P	Bowden et al (HGM10; A2016)
q	D10S62	+	DNA segment, single copy, probe CRI-JM14	L,S,W	P	Bowden et al (HGM10; A2016)
	ALDOAP2		aldolase A, fructose-bisphosphate, pseudogene 2	R,S	P	Serero et al (1987; A1120) Serero et al (1988; H5320)
	ATPM		ATPase, mitochondrial	S	P	Webster et al (1982; B0149)
	CTSLL		cathepsin L-like	R,S	P	Fan et al (HGM10; A2237)
	CYP2E	+	cytochrome P450, subfamily IIE (ethanol-inducible)	R,S	P	McBride et al (1987; H4785) Umeno et al (1988; H7526)
	CYP17		cytochrome P450, subfamily XVII (steroid 17-alpha-hydroxylase)	R,S	P	Matteson et al (1986; H4031) Chung et al (1987; H5118) Picado-Leonard & Miller (1987; H5247)
	FUSE		polykaryocytosis promoter	S	P	Wright & Shows (1979; C1223)
	GSAS		glutamate gamma-semialdehyde synthetase	S	P	Jones (1975; C1215) Jones et al (1976; C1216)
	HEP10		hepatic protein 10	R,S	T	McGill et al (1986; H3184)
	LDHAL5		lactate dehydrogenase A-like 5	R,W	P	Li et al (1988; H7414)
	LIPA		lipase A, lysosomal acid (Wolman disease)	S	C	Koch et al (1981; A0183) Van Cong et al (1980; A0184) Hoeg et al (1984; H1435)
	M130		external membrane protein (MW 130kD)	S	P	Owerbach et al (1979; C1221)
	NCF1		neutrophil cytosolic factor 1 (47 kD, chronic granulomatous diseas e, autosomal 1)	R,S	P	Hsieh et al (HGM10; A2573)
	PRG		proteoglycan, secretory granule	R,S	P	Rettig et al (1986; H2498) Stevens et al (1988; H5967)
	PYGBL		phosphorylase, glycogen; brain-like	R,S	P	Newgard et al (1988; H5508)
	PYHG1		protein spot in 2-D gels (MW 218kD)	S	P	Taggart & Francke (1982; B0463)
	PYHG18		protein spot in 2-D gels (MW 31kD)	S	P	Taggart & Francke (1982; B0463)
	SAP2	C	sphingolipid activator protein 2	R,S	P	Fujibayashi et al (1985; H1653)
	TSHRL3		thyroid stimulating hormone receptor-like 3	R,S	T	McBride et al (1987; H4600)
	D10S2		DNA segment, single copy, probe p3-10	S	P	Kao et al (1982; B0148)
	D10S60	+	DNA segment, single copy, probe CRI-JC147	L,S	P	Bowden et al (HGM10; A2016)

Locus table index for chromosome 10

Locus symbol	Map location	Locus symbol	Map location	Locus symbol	Map location	Locus symbol	Map location
Genes		LPC2C	q21-q22	D10S7	q	D10S41	p14-q11.2
		M130		D10S8	q	D10S42	q
ADK	cen-q24	MEN2A	p11.2-q11.2	D10S9	q	D10S43	q
ADRA2R	q24-q26	MEN2B	pter-q11.2	D10S10	q	D10S44	q
ALDOAP2		NCF1		D10S11	q11.2	D10S45	q
ATPM		NEU	pter-q23 or 6	D10S12	q	D10S46	q
CDC2	q21.1	OAT	q26	D10S13	p11-q23	D10S47	q
CTSLL		PFKP	pter-p11.1	D10S14	p11-q23	D10S48	q
CYP17		PGAM1	q25.3	D10S15	q11.2	D10S49	p14-p11.2
CYP2C	q24.1-q24.3	PLAU	q24-qter	D10S16	p11-q23	D10S50	q
CYP2E		PP	q11.1-q24	D10S17	pter-p13	D10S51	q
DNTT	q23-q24	PRG		D10S18	q24-qter	D10S52	q
EGR2	q21.1	PYGBL		D10S19	q21.1-q22	D10S53	q
ERCC6	q11	PYHG1		D10S20	q21-q26	D10S54	q
FNRB	p11.2	PYHG18		D10S21	q24.3-qter	D10S55	q
FRA10A	q23.3 or q24.2	RBP3	q11.2	D10S22	q21.1	D10S56	q
FRA10B	q25.2	RBP4	q23-q24	D10S23	q	D10S57	q
FRA10C	q21	SAP1	q21-q22	D10S24	p13-p12.2	D10S58	q
FRA10D	q22.1	SAP2		D10S25	q	D10S59	q11.2
FRA10E	q25.2	SFTP1	q21-q24	D10S26	q	D10S60	
FRA10F	q26.1	TCL3	q24	D10S27	q	D10S62	q
FUSE		TSHRL3		D10S28	pter-p13	D10S63	p15
G10P1	q25-q26	TST1	q11.2	D10S29	q	D10S78	q11.2-qter
G10P2	q	VIM	p13	D10S30	q11.2-q22	D10S79	q11.2-qter
GLUD	q23-q24			D10S31	p	D10S80	q11.2-qter
GOT1	q25.3	**D segments**		D10S32	q	D10S81	q11.2-qter
GSAS				D10S33	p	D10S82	q11.2-qter
HEP10		D10S1	q22-q23	D10S34	p	D10S83	q11.2-qter
HK1	q22	D10S2		D10S35	p	D10S84	q11.2-qter
IL2R	p15-p14	D10S3	q22-q23	D10S36	q	D10S85	q11.2-qter
ITIH2	p15	D10S4	q22-q23	D10S37	q25.1	D10S86	pter-q11
LDHAL5		D10S5	q21.1	D10S39	p	D10S87	pter-q11
LIPA		D10S6	q26	D10S40	q	D10Z1	cen

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