

IMGT, the international ImMunoGeneTics database (<http://imgt.cines.fr:8104>) created in 1989 (Université Montpellier II, CNRS, Montpellier, France) [1] provides, for the first time, a standardized description of the complete human T-cell receptor (TcR) germline repertoire based on the IMGT Scientific chart rules [2–4] and on the IMGT-ONTOLOGY concepts [5].

The human T-cell receptors α - β and γ - δ are the products of four sets of genes:

1. The T-cell receptor α (*TRA*),
2. The T-cell receptor β (*TRB*),
3. The T-cell receptor γ (*TRG*), and
4. The T-cell receptor δ (*TRD*)

localized on chromosome 14, at 14q11.2 for the *TRA* and *TRD* genes, and on chromosome 7, at 7q35 and at 7p15-p14, for the *TRB* and *TRG* genes, re-

Marie-Paule page (<http://imgt.cines.fr:8104>). All the human TcR genes have been officially entered in the GDB (the Genome Database, <http://www.gdb.org>), the repository of the human gene names. In order to facilitate data comparison from various publications, correspondence between the IMGT nomenclature and other previously used nomenclatures is given in Table 2.

TRA Genes

The human *TRA* locus at 14q11.2 spans 1000 kilobases (kb) (see Figure 1). It consists of 54 *TRAV* genes, belonging to 41 subgroups (see Tables 1A and 2A) [6–7], 61 *TRAJ* segments localized on 71 kb, and a unique *TRAC* gene. The most 5' *TRAV* genes occupy the most centromeric position, whereas the *TRAC* gene, 3' of the locus, is the most telomeric gene in the *TRA* locus. The potential repertoire consists of 45–47 functional *TRAV* genes belonging to 35–37 subgroups, 50 functional *TRAJ* segments, and the unique *TRAC* gene. Among the variable genes are included five genes designated as *TRAV/DV* which belong to five different subgroups and which have been found rearranged either to *TRAJ* or to *TRDD* segments and can therefore be used in the synthesis of α or δ chains (see Table 1A) [6–7].

TRB Genes

The human *TRB* locus at 7q35 spans 620 kb (see Figure 2) [8]. It consists of 62–65 *TRBV* genes belonging to 30 subgroups (see Tables 1B and 2B) [6, 9]. Except for *TRBV30*, localized downstream of the *TRBC2* gene, in inverted orientation of transcription, all the other *TRBV* genes are located upstream of a duplicated D-J-C-cluster, which comprises, for the first part, one *TRBD*, six *TRBJ*, and the *TRBC1* gene, and for the second part, one *TRBD*, eight *TRBJ*, and the *TRBC2* gene. The most 5' *TRBV* genes occupy the most centromeric position, whereas the *TRBV30* gene, 3' of the locus, is the most telomeric gene in the *TRB* locus. The potential repertoire consists of 39–46 functional *TRBV* genes belonging to 23 subgroups, two *TRBD*, thirteen *TRBJ*, and two *TRBC* genes [6, 8, 9]. Six *TRBV* orphans have been localized on chromosome 9 at 9p21[6].

TRG Genes

The human *TRG* locus at 7p15-p14 spans 160 kb (see Figure 3) [10]. It consists of 12–15 *TRGV* genes belonging to 6 subgroups (see Table 1C), upstream of a duplicated J-C-cluster, which comprises, for the first part, three *TRGJ* and the *TRGC1* gene, and for the second part, two *TRGJ* and the *TRGC2* gene [6, 10, 11]. The most 5' *TRGV* genes occupy the most

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spectively. The *TRA/TRD*, *TRB*, and *TRG* loci are represented at the same scale in Figures 1, 2, and 3, respectively. An overview of the potential germline variable repertoire, for each locus, is given in Table 1. In that table, the number of functional genes, ORF (open reading frame) or pseudogenes, and the total number of variable genes per subgroup are indicated. The gene functionality is described according to the IMGT Scientific Chart [4]. The IMGT nomenclature for the TcR genes has the objective to provide immunologists and geneticists with a unique nomenclature per locus which will allow extraction and comparison of data for the complex B- and T-cell antigen receptor molecules, whatever the species. IMGT nomenclature for the immunoglobulin- and T-cell receptor genes follows the Human Gene Mapping Nomenclature rules. An exhaustive and standardized list of human TcR gene names [6] is available from the IMGT Repertoire at the IMGT

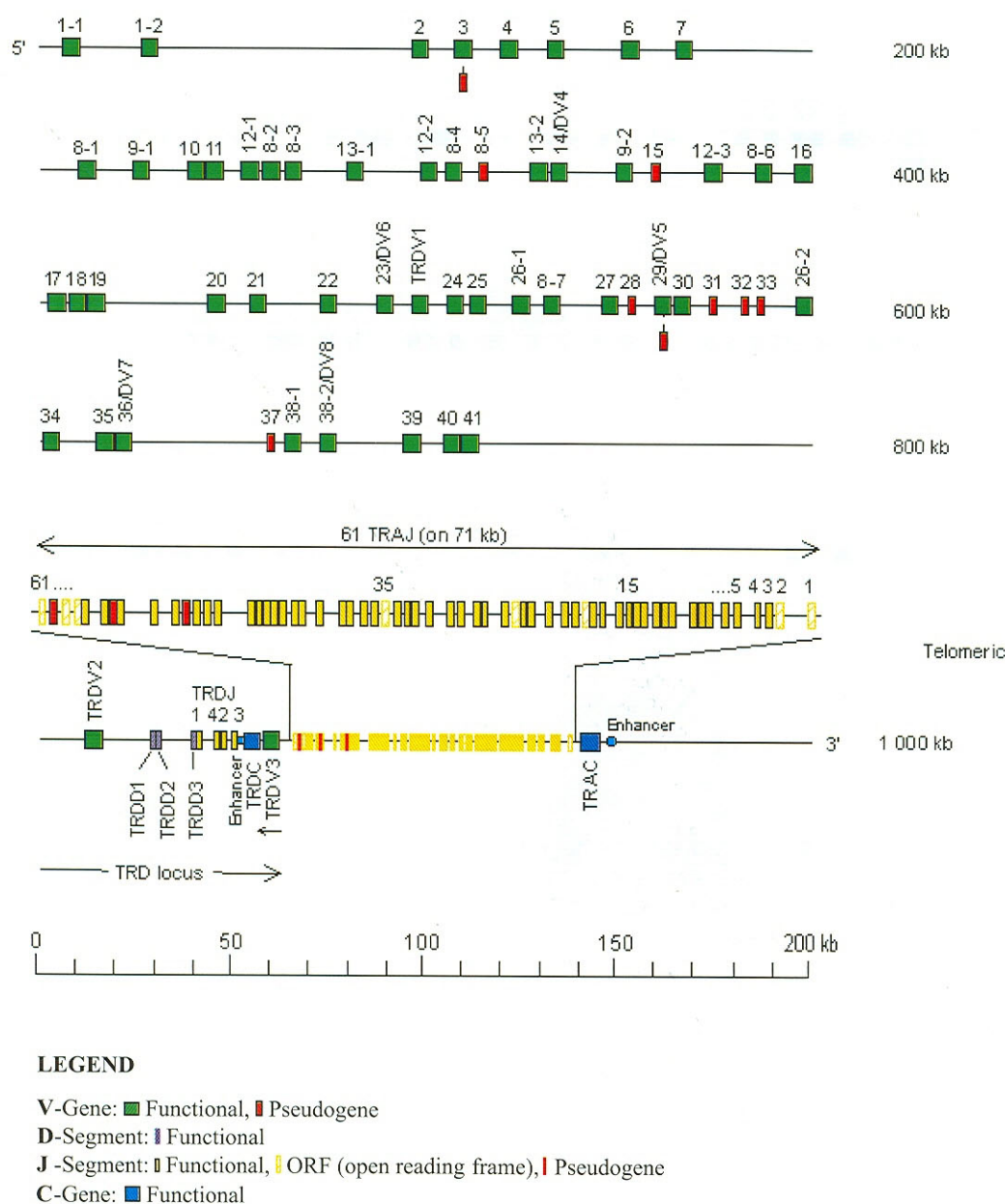


Figure 1. The human *TRA/TRD* locus at 14q11.2. The boxes representing the genes are not to scale. Exons are not shown. For detailed references, see: *TRAV* genes (7); *TRAV* protein display (17); *TRAJ* segments (19); *TRAC* genes (20, 21); *TRA* enhancer (22); *TRDV* genes (14); *TRDD* segments (23, 24); *TRDJ* segments (24–26); *TRDC* genes (23); *TRD* enhancer (27, 28).

centromeric position, whereas the *TRGC2* gene, 3' of the locus, is the most telomeric gene in the *TRG* locus. The potential repertoire consists of 4–6 functional *TRGV* genes belonging to two subgroups, the 5 *TRGJ* and the 2 *TRGC* genes [6, 10, 11].

TRD Genes

The human *TRD* locus at 14q11.2 comprises a cluster of one *TRDV* gene (*TRDV2*), three *TRDD* segments, and four *TRDJ* segments, upstream of the unique *TRDC* gene; another *TRDV* gene (*TRDV3*) is

localized downstream of the *TRDC* gene, in inverted orientation of transcription (see Table 1D) [6, 12]. This cluster spans 60 kb and is localized inside the *TRA* locus, between the *TRAV* genes and the *TRAJ* segments (see Figure 1). The *TRD* locus also consists of one *TRDV* (*TRDV1*) localized at 360 kb upstream of the *TRDC* gene, among the *TRAV* genes, and the five genes described above as *TRAV/DV* (see Table 1A). The *TRDV* genes are unique members of different subgroups. All the *TRD* genes are functional, with the exception of one *TRAV/DV*, which has been found either functional or as a pseudogene (see Table 1A) [6].

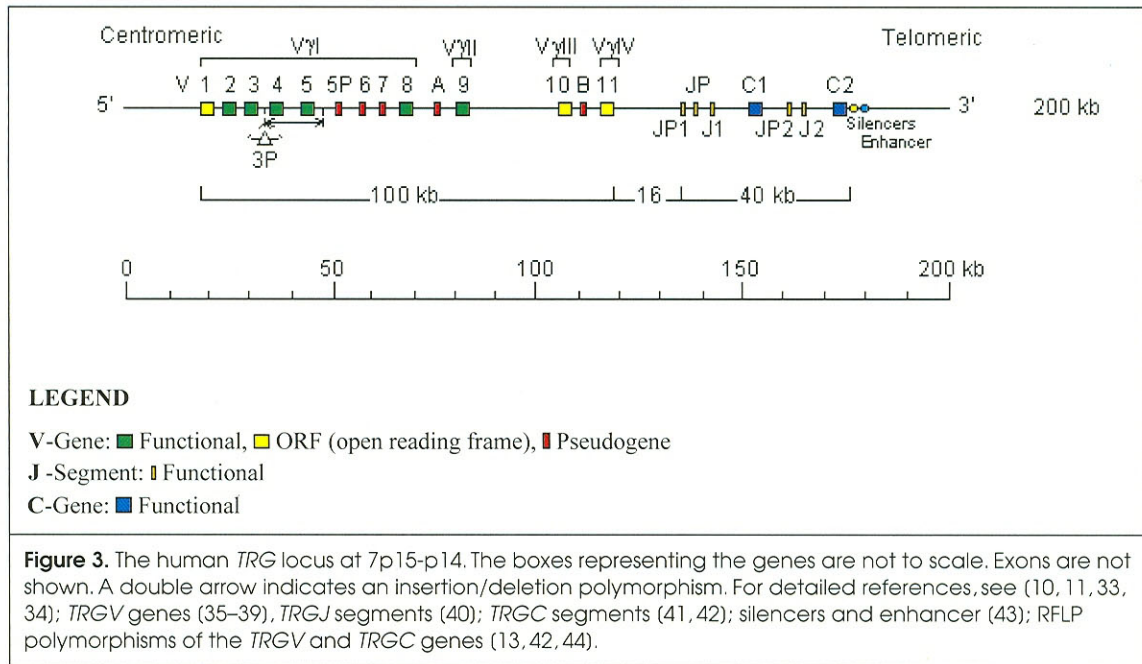
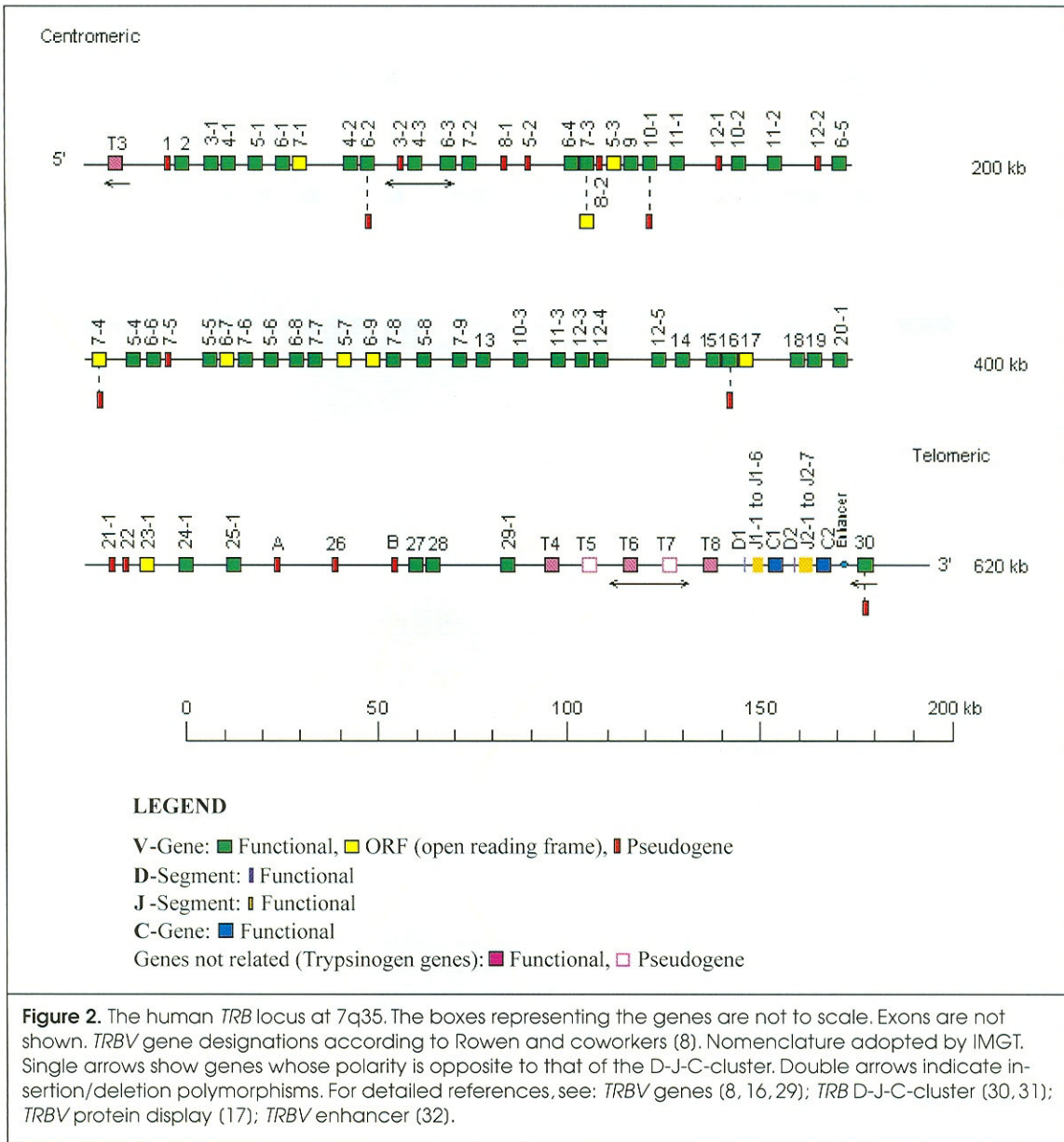


Table 1A. Number of germline variable genes and potential repertoire: Human TRAV at 14q11.2 (7)

Subgroup	Functional	ORF	Pseudogene	Total
TRAV1	2	—	—	2
TRAV2	1	—	—	1
TRAV3	(1*)	—	(1*)	1
TRAV4	1	—	—	1
TRAV5	1	—	—	1
TRAV6	1	—	—	1
TRAV7	1	—	—	1
TRAV8	6	—	1	7
TRAV9	2	—	—	2
TRAV10	1	—	—	1
TRAV11	1	—	—	1
TRAV12	3	—	—	3
TRAV13	2	—	—	2
TRAV14/DV4	1	—	—	1
TRAV15	—	—	1	1
TRAV16	1	—	—	1
TRAV17	1	—	—	1
TRAV18	1	—	—	1
TRAV19	1	—	—	1
TRAV20	1	—	—	1
TRAV21	1	—	—	1
TRAV22	1	—	—	1
TRAV23/DV6	1	—	—	1
TRAV24	1	—	—	1
TRAV25	1	—	—	1
TRAV26	2	—	—	2
TRAV27	1	—	—	1
TRAV28	—	—	1	1
TRAV29/DV5	(1)*	—	(1)*	1
TRAV30	1	—	—	1
TRAV31	—	—	1	1
TRAV32	—	—	1	1
TRAV33	—	—	1	1
TRAV34	1	—	—	1
TRAV35	1	—	—	1
TRAV36/DV7	1	—	—	1
TRAV37	—	—	1	1
TRAV38/DV8	2	—	—	2
TRAV39	1	—	—	1
TRAV40	1	—	—	1
TRAV41	1	—	—	1
Total	45(+2)*	0	7(+2)*	54

Notes

* Functional or pseudogene (TRAV3, TRAV29).

IMGT TRAV subgroups are according to reference (14). 54 TRAV genes belonging to 41 subgroups, on 700 kilobases: 45 functional, 7 pseudogene, 2 functional or pseudogene. Criteria of functionality are described in the IMGT Scientific chart (4). The potential repertoire is 45–47 functional TRAV genes, belonging to 35–37 subgroups.

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Table 1B. Number of germline variable genes and potential repertoire: Human TRBV at 7q35 (9)

Subgroup	Functional	ORF	Pseudogene	Total
TRBV1	—	—	1	1
TRBV2	1	—	—	1
TRBV3	1	—	0–1**	1–2**
TRBV4	2–3**	—	—	2–3**
TRBV5	5	2	1	8
TRBV6	5 (+1)*–6** (+1)*	2	(1)*	8–9**
TRBV7	5 (+1)*	1 (+2)*	1 (+1)*	9
TRBV8	—	—	2	2
TRBV9	1	—	—	1
TRBV10	2 (+1)*	—	(1)*	3
TRBV11	3	—	—	3
TRBV12	3	—	2	5
TRBV13	1	—	—	1
TRBV14	1	—	—	1
TRBV15	1	—	—	1
TRBV16	(1)*	—	(1)*	1
TRBV17	—	1	—	1
TRBV18	1	—	—	1
TRBV19	1	—	—	1
TRBV20	1	—	—	1
TRBV21	—	—	1	1
TRBV22	—	—	1	1
TRBV23	—	1	—	1
TRBV24	1	—	—	1
TRBV25	1	—	—	1
TRBV26	—	—	1	1
TRBV27	1	—	—	1
TRBV28	1	—	—	1
TRBV29	1	—	—	1
TRBV30	(1)*	—	(1)*	1
Total	39–41 (+5)*	7 (+2)*	10–11 (+5)*	62–65

Notes

* Functional or pseudogene (TRBV6–2, TRBV10–1, TRBV16, TRBV30); functional or ORF (TRBV7–3); ORF or pseudogene (TRBV7–4).

** Allelic polymorphism by insertion/deletion (TRBV3–2, TRBV4–3, TRBV6–3).

IMGT TRBV subgroups are according to reference (8).

There are 62–65 TRBV genes belonging to 30 subgroups on 620 kilobases: 39–41 functional, 7 ORF (open reading frame), 10–11 pseudogene, 4 functional or pseudogene, 1 functional or ORF, 1 ORF or pseudogene.

The potential repertoire is 39–46 functional TRBV genes, belonging to 23 subgroups.

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Table 1C. Number of germline variable genes and potential repertoire: Human *TRGV* at 7p15-p14 (10)

<i>TRGV</i> subgroup	<i>TRGV</i> gene name	Functional	ORF	Pseudogene	Total
1	<i>TRGV1</i>	–	1	–	1
	<i>TRGV2</i>	1	–	–	1
	<i>TRGV3</i>	1	–	–	1
	<i>TRGV3P</i>	–	–	–	0–1*
	<i>TRGV4</i>	0–1*	–	–	0–1*
	<i>TRGV5</i>	0–1*	–	–	0–1*
	<i>TRGV5P</i>	–	–	1	1
	<i>TRGV6</i>	–	–	1	1
	<i>TRGV7</i>	–	–	1	1
	<i>TRGV8</i>	1	–	–	1
2	<i>TRGV9</i>	1	–	–	1
3	<i>TRGV10</i>	–	1	–	1
4	<i>TRGV11</i>	–	1	–	1
A	<i>TRGVA</i>	–	–	1	1
B	<i>TRGVB</i>	–	–	1	1
Total		4–6	3	5	12–15

Notes

* Allelic polymorphism by insertion/deletion.

There are 12–15 *TRGV* genes belonging to 6 subgroups, on 120 kilobases: 4–6 functional, 3 ORF (open reading frame), 5 pseudogene. The potential repertoire is 4–6 functional *TRGV* genes belonging to 2 subgroups.

The most frequent haplotype comprises 14 *TRGV* genes (6 functional + 3 ORF + 5 pseudogene) with V4 and V5 present, and V3P absent. The *TRGV3P* gene has been identified by Southern hybridization but has not been sequenced [13].

Table 1D. Number of germline variable genes and potential repertoire: Human *TRDV* at 14q11.2

<i>TRDV</i> subgroup	<i>TRDV</i> gene name	Functional	ORF	Pseudogene	Total
1	<i>TRDV1</i>	1	–	–	1
2	<i>TRDV2</i>	1	–	–	1
3	<i>TRDV3</i>	1	–	–	1
Total		3	0	0	3

Notes

There are 3 *TRDV* genes belonging to 3 subgroups, and 5 *TRAV/DV* genes belonging to 5 subgroups (these genes are reported in Table 1A).

The potential repertoire is 3 functional *TRDV* genes belonging to 3 subgroups and 4–5 functional *TRAV/DV* genes belonging to 4–5 subgroups (see Table 1A).

Internet Resources

- IMGT, the international ImMunoGeneTics database [1], <http://imgt.cines.fr:8104>
- IMGT/LIGM-DB: Contains the germline and rearranged sequences of the immunoglobulin and T-cell receptor genes of human and other vertebrates (35,000 sequences of 81 species in December 1999).
- “IMGT Scientific Chart”: Describes the standardized rules for the description and classification of the immunoglobulin- and T-cell receptor genes and alleles [2–4] based on the IMGT-ONTOLOGY concepts [5].
- “IMGT Repertoire”: Provides the locus representations, germline gene tables, potential germline repertoires, correspondence between gene nomenclatures, protein displays, alignments of alleles, and tables of alleles for all the human *TRA*, *TRB*, *TRG*, and *TRD* genes. 2D graphical representations designated as Colliers de Perles are provided for the variable genes.

Table 2A. Correspondence between the different gene nomenclatures: Human TRAV

IMGT TRAV gene name	Boysen et al. (14)	Arden et al. (15)
TRAV41	41S1	19S1
TRAV40	40S1	31S1
TRAV39	39S1	27S1
TRAV38-2/DV8	hADV38S2	14S1-ADV14S1
TRAV38-1	38S1	14S2
TRAV37	37S1	
TRAV36/DV7	hADV36S1	28S1-DV28S1
TRAV35	35S1	25S1
TRAV34	34S1	26S1
TRAV26-2	26S2	4S1
TRAV33	33S1	
TRAV32	32S1	
TRAV31	31S1	
TRAV30	30S1	29S1
TRAV29/DV5	hADV29S1	21S1-ADV21S1
TRAV28	28S1	
TRAV27	27S1	10S1
TRAV8-7	8S7	
TRAV26-1	26S1	4S2
TRAV25	25S1	32S1
TRAV24	24S1	18S1
TRAV23/DV6	hADV23S1	17S1-ADV17S1
TRAV22	22S1	13S1
TRAV21	21S1	23S1
TRAV20	20S1	30S1
TRAV19	19S1	12S1
TRAV18	18S1	
TRAV17	17S1	3S1
TRAV16	16S1	9S1
TRAV8-6	8S6	1S3
TRAV12-3	12S3	2S2
TRAV15	15S1	
TRAV9-2	9S2	22S1
TRAV14/DV4	hADV14S1	6S1-ADV6S1
TRAV13-2	13S2	8S2
TRAV8-5	8S5	
TRAV8-4	8S4	1S2
TRAV12-2	12S2	2S1
TRAV13-1	13S1	8S1
TRAV8-3	8S3	1S4
TRAV8-2	8S2	1S5
TRAV12-1	12S1	2S3
TRAV11	11S1	
TRAV10	10S1	24S1
TRAV9-1	9S1	
TRAV8-1	8S1	1S1
TRAV7	7S1	
TRAV6	6S1	5S1
TRAV5	5S1	15S1
TRAV4	4S1	20S1
TRAV3	3S1	16S1
TRAV2	2S1	11S1
TRAV1-2	1S2	7S2
TRAV1-1	1S1	7S1

Notes

TRAV genes are listed from 3' (top of the table) to 5' (bottom of the table). TRAV genes are designated by a number for the subgroup (14) followed, whenever there are several genes belonging to the same subgroup, by a dash and a number for their relative localization in the locus.

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Table 2B. Correspondence between the different gene nomenclatures:
Human *TRBV*

IMGT <i>TRBV</i> gene name (9)	Wei et al. (16)	Arden et al. (15)	Rowen et al. (18)
30	20S1	20S1	30
29-1	4S1	4S1	29-1
28	3S1	3S1	28
27	14S1	14S1	27
B		34S1	
26		28S1	26
A		33S1	
25-1	11S1	11S1	25-1
24-1	15S1	15S1	24-1
23-1	19S1	19S1	23-1
22		29S1	22-1
21-1	10S1	10S1	21-1
20-1	2S1	2S1	20-1
19	17S1	17S1	19
18	18S1	18S1	18
17		26S1	17
16	25S1	25S1	16
15	24S1	24S1	15
14	16S1	16S1	14
12-5	8S3	8S3	12-5
12-4	8S2	8S2	12-4
12-3	8S1	8S1	12-3
11-3	21S4	21S2	11-3
10-3	12S2	12S1	10-3
13	23S1	23s1	13
7-9	6S5	6S4	7-9
5-8	5S8	5S4	5-8
7-8	6S3	6S2	7-8
6-9	13S4	13S4	6-9
5-7	5S7	5S7	5-7
7-7	6S14	6S6	7-7
6-8	13S7	13S7	6-8
5-6	5S2	5S2	5-6
7-6	6S4	6S3	7-6
6-7	13S8	13S8	6-7
5-5	5S3	5S3	5-5
7-5	6S12	6S9	7-5
6-6	13S6	13S6	6-6
5-4	5S6	5S6	5-4
7-4	6S11	6S8	7-4
6-5	13S1	13S1	6-5
12-2	8S5	8S5	12-2
11-2	21S3	21S3	11-2
10-2	12S3	12S3	10-2
12-1	8S4	8S4	12-1
11-1	21S1	21S1	11-1
10-1	12S4	12S2	10-1
9	1S1	1S1	9
5-3	5S5	5S5	5-3
8-2		32S1	8-2
7-3	6S1	6S1	7-3
6-4	13S5	13S5	6-4
5-2		31S1	5-2
8-1		30S1	8-1
7-2	6S7	6S5	7-2
6-3	13S2b	13S2b	6-3
4-3	7S2	7S2	4-3
3-2	9S2	9S2	3-2
6-2	13S2a	13S2a	6-2
4-2	7S3	7S3	4-2
7-1	6S10	6S7	7-1
6-1	13S3	13S3	6-1
5-1	5S1	5S1	5-1
4-1	7S1	7S1	4-1
3-1	9S1	9S1	3-1
2	22S1	22S1	2
1		27S1	1

Notes

TRBV genes are listed from 3' (top of the table) to 5' (bottom of the table). *TRBV* genes are designated by a number for the subgroup (8) followed, whenever there are several genes belonging to the same subgroup, by a dash and a number for their relative localization in the locus. Orphons having been described for each of the following subgroups: *TRBV* 20, 21, 23, 24, 25, and 29, the single member gene in the main locus is designated by the subgroup number followed by a dash and the number 1. To date, no orphon has been reported which belongs to subgroup 22, therefore the IMGT designation of the single member gene is *TRBV*22.26S1 was defined in (18).