# STR Sequence Diversity in Population Samples and Nomenclature Guidance for the "Next Generation"

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### ABSTRACT

As STR loci were being identified in the 1990s, various nomenclature systems were developed for different loci, with the primary variation being whether or not to "count" nonrepeat bases interspersed in the repeat motif. In 1997, the ISFG issued guidelines on STR nomenclature, in an attempt to provide a common currency for information exchange. Historical precedent already existed for some loci, and this was maintained to avoid confusion, resulting in several commonly used forensic loci having complicated and contradictory nomenclature systems. This has not been an issue within the forensic community, as the capillary electrophoresis (CE)-length analyses are kit-based, with corresponding computer programs that automatically count repeats in a standardized manner. Now, as the costs associated with next-generation sequencing (NGS) methods decline, forensic research laboratories are beginning to explore the increase in information sequencing STR loci may provide. As a new generation of scientists begins interrogating these loci on a deeper level, an understanding of historical nomenclature is needed to achieve bioinformatic concordance with existing CE data. In the work presented here, NGS results from population samples exemplify the sequence variation that exists in forensic STR loci (SNPs and InDels within and outside of STR allele regions and repeat motif changes) as well as the complexity and inconsistency of the current nomenclature. This experimental sequence data gives an indication of the level of diversity expected in the larger population and provides examples of how sub-alleles can improve discrimination and mixture deconvolution in forensic casework. The different purposes of nomenclature—manual comparisons, forensic reports, database searching, court explanations—are discussed and examples of possible NGS-compatible nomenclature systems that may meet the needs of the forensic community are shown.

#### MATERIALS and METHODS NIST Amplification Bioinformatics Pop Gen Sequencing & Library Prep • MiSeq Population Prob of Inclusion STRait Razor Samples ExactID (Battelle Heterozygosity • 2 x 0.5 ng input CE concordance • N=183 PowerSeq Auto • Caucasian (70 Hispanic (45) Illumina TruSec African HS "PCR-Free American (68)

### **Figure 1**. Overview of experimental design.

NIST population samples (N=183 consisting of 70 Caucasian, 68 African American, and 45 Hispanic individuals) were amplified twice in 96-well plates, with 0.5 ng input DNA per sample in 25 µL reaction volumes. Duplicate amplicons were combined during the cleanup step, prior to library generation. Sequencing template libraries were prepared in 96-well format with the TruSeq DNA PCR-Free Sample Preparation Kit HS (Illumina, San Diego CA, USA). Sequencing was performed in two runs (96 samples/run) on the MiSeq system (Illumina) using the 600 cycle MiSeq Reagent Kit v3 (Illumina).



Figure 2. Overview of sample preparation workflow. Each clock represents a minimum of one day. All steps other than the actual MiSeq run were performed manually in a 96-well format.

Analysis of .fastq files to produce STR allele calls was performed with two different bioinformatic pipelines: ExactID (Battelle Memorial Institute, Columbus OH, USA, see ISHI 2014 poster #69 for more information), and STRait Razor [1]. Allelic balance based on coverage was evaluated to determine zygosity. Only majority sequences (two for heterozygotes or one for homozygotes) were considered as evidence supporting allele calls, and only the repeat regions of the majority sequences were analyzed further (e.g. sequences that were consistent with stutter, and sequences that did not match the majority sequence within the repeat region were excluded from further analysis). Genotypes from both ExactID and STRaitRazor were independently analyzed for concordance to CE based genotypes (generated previously with PowerPlex Fusion (Promega)). Discordances were evaluated further to determine the true genotype/sequence.





Number of Alleles

**Figure 4.** In blue are the number of different length-based alleles observed in this dataset (N=183), and in red are the number of additional sequenced-based alleles observed. Loci are grouped by repeat motif type (simple vs compound/complex) and sorted within each group by number of length-based alleles, smallest to largest.

### Additional Alleles Obtained by Sequencing



Figure 5. Heatmap showing the variant count for each allele (counts in parentheses, alleles with no parenthetical notation show no sequence variants in this dataset). Alleles are color coded with the darkest green shading representing no sequence variation; shading changes to yellow-orange-red with increasing sequence variation.



HET sequence HET length

**Definition:** Heterozygosity The number of heterozygous loci divided by total number of loci; a measure of allelic variability at a locus.

Figure 6. (left) Percent heterozygosity by length (blue) and by sequence (red), averaged from three populations (N=183) rank ordered by HET length, top eight loci shown. (right) The increase in heterozygosity by sequence, broken out by population.

H C AA



**Definition:** Probability of Identity Chance of randomly choosing two unrelated individuals with the same genotype at a locus.



Global Probability of Identity

Global PI sequence Global PI length ■H ■C ■AA **Figure 7.** (left) Percent probability of identity by length (blue) and by sequence (red), based on average allele frequency from these three populations (N=183) rank ordered by PI length, top eight loci shown. (right) The decrease in probability of identity by sequence, broken out by population.

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EXAMPLE LOCUS
Terrer and the need for the sequence complexity that exists and the need for the set of population samples sequenced in this project (N=183), at the D21S11 locus, equences were found which had not previously been reported (equaling 4.4% of chromosome sequences), see Table 1 rows in red.
rs377498066 C/G rs202066178 -/A rs371415114 C/T rs180693712 G/T rs185123051 G/T rs376648398 C/T
rs373027822 -/CC
deletion -3.2 repeat units
rs11908851 C/1 rs376678344 A/G

Figure 8. GRCh38 sequence (GenBank) at the D21S11 locus (repeat region and 500 bases upstream and downstream), annotated with information relevant to forensic NGS. The subunits of the repeat motif are shown in green, yellow, red, aqua, pink and purple (these regions are "counted", resulting in a 29 allele), while the interspersed non-repeat sequences are shown in gray (these regions are "not counted"). Two different regions where deletions result in .2 alleles, as well as the locations of numerous SNPs (from dbSNP) that have been observed in the flanking regions are shown in orange. Annotation created with Geneious v7.1.7.

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24	[TCTA] 4-13	[TCTG]3-11	[TCTA]3	TA [	TCTA]2-3	TCA	[TCTA]		[TCTA] 6-15			Platform	Reference
24	[TCTA]4 [TCTA]4	[TCTG]6 [TCTG]3	[TCTA]3 [TCTA]3	TA TA	[TCTA]3 [TCTA]3	TCA   TCA	[TCTA]2 [TCTA]2	TCCATA TCCATA	[TCTA]6 [TCTA]10			Sanger Sanger	Schwartz <i>et al.</i> (1998)
26	[TCTA] 4	[TCTG]6	[TCTA]3	TA	[TCTA]3	TCA	[TCTA]2	ТССАТА	[TCTA]8			Sanger	Möller et al. (1994)
26 27	[TCTA] 6 [TCTA] 4	[TCTG]5 [TCTG]6	[TCTA]3 [TCTA]3	TA TA	[TCTA]3 [TCTA]3	TCA TCA	[TCTA]2 [TCTA]2	TCCATA TCCATA	[TCTA] 7 [TCTA] 9			Sanger Sanger	Wang <i>et al.</i> (2014) Möller <i>et al.</i> (1994)
27	[TCTA] 5	[TCTG]5	[TCTA]3	ТА	[TCTA]3	TCA	[TCTA]2	TCCATA	[TCTA]9			Sanger	Griffiths et al. (1998)
27 28	[TCTA] 6 [TCTA] 4	[TCTG]5 [TCTG]5	[TCTA] 3 [TCTA] 3	TA TA	[TCTA]3 [TCTA]3	TCA TCA	[TCTA]2 [TCTA]2	TCCATA TCCATA	[TCTA] 8 [TCTA] 11			Sanger 454	Schwartz <i>et al.</i> (1996) Gelardi et al. (2014)
28	[TCTA] 4	[TCTG]6	[TCTA]3	TA	[TCTA]3	TCA	[TCTA]2	ТССАТА	[TCTA]10			Sanger	Möller <i>et al.</i> (1994)
<b>28</b>	[TCTA] 5	[TCTG]5	[TCTA]3	TA TA	[TCTA]3	TCA	[TCTA]2	ТССАТА	[TCTA]10			Sanger MiSeq	Wang et al. (2014) NIST 183
28	[TCTA] 5	[TCTG]6	[TCTA] 3	TA	[TCTA]3	TCA	[TCTA]2	ТССАТА	[TCTA] 9			Sanger	Zhou <i>et al.</i> (1997)
28 29	[TCTA] 6 [TCTA] 4	[TCTG]5	[TCTA] 3	TA TA	[TCTA]3 [TCTA]3	TCA   TCA	[TCTA]2	ТССАТА ТССАТА	[TCTA] 9 [TCTA] 11			454 Sanger	Gelardi et al. (2014) Griffiths <i>et al.</i> (1998)
29	[TCTA] 4	[TCTG]7	[TCTA] 3	ТА	[TCTA]3	TCA	[TCTA]2	TCCATA	[TCTA]10			Sanger	Planz <i>et al.</i> (2012)
29 29	[TCTA] 5	[TCTG]6	[TCTA] 3	TA TA	[TCTA]2	TCA	[TCTA]2	ТССАТА	[TCTA]11			MiSeq	NIST 183 Gelardi <i>et al.</i> (2014)
29	[TCTA] 6	[TCTG]5	[TCTA] 3	ТА	[TCTA]3	TCA	[TCTA]2	ТССАТА	[TCTA]10			Sanger	Zhou <i>et al.</i> (1997)
30	[TCTA] 4	[TCTG]6	[TCTA] 3	TA TA	[TCTA]3	TCA	[TCTA]2	ТССАТА	[TCTA]12			Sanger	Schwartz <i>et al.</i> (1996) NIST 183
30	[TCTA] 5	[TCTG]6	[TCTA] 3	TA	[TCTA]3	TCA	[TCTA]2	ТССАТА	[TCTA]11			Sanger	Zhou <i>et al.</i> (1997)
30 30	[TCTA] 6	[TCTG]5	[TCTA]3	TA TA	[TCTA]3	TCA	[TCTA] 2	ТССАТА	[TCTA]11			Sanger	Griffiths (1998) Brinkmann <i>et al.</i> (1996a)
30	[TCTA] 7	[TCTG]5	[TCTA] 3	TA	[TCTA]3	TCA	[TCTA]2	ТССАТА	[TCTA]10			454	Gelardi <i>et al.</i> (2014)
31	[TCTA] 4	[TCTG]6	[TCTA] 3	TA TA	[TCTA]3	TCA	[TCTA] 2	TCCATA	[TCTA]13			454	Gelardi <i>et al.</i> (2014) Griffiths <i>et al.</i> (1998)
31	[TCTA] 6	[TCTG]5	[TCTA] 3	TA	[TCTA]3	TCA	[TCTA]2	ТССАТА	[TCTA]12			Sanger	Möller <i>et al.</i> (1994)
31	[TCTA] 6	[TCTG]6	[TCTA]3	TA TA	[TCTA]3	TCA	[TCTA]2	ТССАТА	[TCTA]11			Sanger	Zhou <i>et al.</i> (1997) Schwartz <i>et al.</i> (1996)
31	[TCTA] 7	[TCTG]6	[TCTA] 3	TA	[TCTA]3	TCA	[TCTA]2	ТССАТА	[TCTA]10			MiSeq	NIST 183
31	[TCTA] 4	[TCTG]6	[TCTA] 3	TA TA	[TCTA]3	TCA	[TCTA] 2	TCCATA	[TCTA]13			Sanger	Wang et al. (2014) Zhou <i>et al.</i> (1997)
32	[TCTA] 6	[TCTG]5	[TCTA] 3	TA	[TCTA] 3	TCA	[TCTA]2	ТССАТА	[TCTA]13			Sanger	Griffiths <i>et al.</i> (1998)
32	[TCTA] 6	[TCTG]6	[TCTA] 3	TA Ta	[TCTA]3	TCA	[TCTA] 2	ТССАТА	[TCTA]12			MiSeq	NIST 183
33	[TCTA] 5	[TCTG]6	[TCTA] 3	TA	[TCTA]3	TCA	[TCTA]2	ТССАТА	[TCTA]14			Sanger	Zhou <i>et al.</i> (1997)
33 33	[TCTA] 6 [TCTA] 9	[TCTG]5 [TCTG]5	[TCTA] 3 [TCTA] 3	TA TA	[TCTA]3 [TCTA]3	TCA   TCA	[TCTA]2 [TCTA]2	ТССАТА ТССАТА	[TCTA]14 [TCTA]11			454 Sanger	Gelardi <i>et al.</i> (2014) Wang <i>et al.</i> (2014)
34	[TCTA] 5	[TCTG]6	[TCTA] 3	TA	[TCTA]3	TCA	[TCTA]2	ТССАТА	[TCTA]15			Sanger	Zhou <i>et al.</i> (1997)
34 34	[TCTA]8 [TCTA]10	[TCTG]5 [TCTG]5	[TCTA]3 [TCTA]3	TA TA	[TCTA]3 [TCTA]3	TCA TCA	[TCTA]2 [TCTA]2	TCCATA TCCATA	[TCTA]13 [TCTA]11			Sanger Sanger	Wang <i>et al.</i> (2014) Brinkmann <i>et al.</i> (1996a)
35	[TCTA] 9	[TCTG]5	[TCTA]3	TA	[TCTA]3	TCA	[TCTA]2	ТССАТА	[TCTA]11			Sanger	Wang <i>et al.</i> (2014)
35	[TCTA]10 [TCTA]10	[TCTG]5	[TCTA] 3 [TCTA] 3	TA TA	[TCTA] 3	TCA	[TCTA]2	ТССАТА	[TCTA]12 [TCTA]10			Sanger MiSeq	NIST 183
35	[TCTA]11	[TCTG]5	[TCTA] 3	TA	[TCTA]3	TCA	[TCTA]2	ТССАТА	[TCTA]11			Sanger	Brinkmann <i>et al.</i> (1996a)
36	[TCTA] 10	[TCTG]5	[TCTA] 3	TA	[TCTA]3	TCA	[TCTA]2	ТССАТА	[TCTA]14 [TCTA]13			Sanger Sanger	Brinkmann <i>et al.</i> (1996a)
36	[TCTA]10	[TCTG]6	[TCTA]3	TA	[TCTA]3	TCA	[TCTA]2	ТССАТА	[TCTA]12			Sanger	Brinkmann <i>et al.</i> (1996a)
36	[TCTA]11	[TCTG]5	[TCTA]3	TA	[TCTA]3	TCA	[TCTA]2	ТССАТА	[TCTA]12			Sanger	Griffiths <i>et al.</i> (1998)
37	[TCTA] 9	[TCTG]5	[TCTA] 3	TA TA	[TCTA]3	TCA	[TCTA] 2	TCCATA	[TCTA]15			Sanger	Wang <i>et al.</i> (2014) Griffiths <i>et al.</i> (1998)
37	[TCTA]11	[TCTG] 8	[TCTA]2	TA	[TCTA]3	TCA	[TCTA]2	ТССАТА	[TCTA]11			MiSeq	NIST 183
38	[TCTA]13	[TCTG]5	[TCTA]3	TA	[TCTA]3	TCA	[TCTA]2	TCCATA	[TCTA]12			Sanger	Griffiths <i>et al.</i> (1998)
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allele         28.2         29.2         30.2         30.2         30.2         31.2         31.2	[TCTA] 4-6 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5	[TCTG]5-6 [TCTG]5 [TCTG]5 [TCTG]5 [TCTG]6 [TCTG]6 [TCTG]5 [TCTG]5	[TCTA] 2-3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3	TA	[TCTA] 2 - [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 2 [TCTA] 3 [TCTA] 3 [TCTA] 3	3TCATCA1TCA1TCA1TCA1TCA1TCA1TCA1TCA1	[TCTA] 2	2 TCCATA	[TCTA]8-16 [TCTA]8 [TCTA]10 [TCTA]11 [TCTA]11 [TCTA]11 [TCTA]10 [TCTA]12 [TCTA]12	TA	[TCTA] TCTA TCTA TCTA TCTA TCTA TCTA TCTA	Platform Sanger Sanger MiSeq Sanger MiSeq Sanger MiSeq MiSeq	Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         NIST 183
allele         28.2         29.2         30.2         30.2         30.2         31.2         31.2         32.2	[TCTA] 4-6 [TCTA] 5 [TCTA] 5	[TCTG]5-6 [TCTG]6 [TCTG]5 [TCTG]5 [TCTG]6 [TCTG]6 [TCTG]5 [TCTG]6 [TCTG]6 [TCTG]6	[TCTA] 2-3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3	TA	[TCTA] 2 - [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3	3TCATCA1TCA1TCA1TCA1TCA1TCA1TCA1TCA1TCA1TCA1	A       [TCTA] 2	2 TCCATA	[TCTA]8-16 [TCTA]8 [TCTA]0 [TCTA]0 [TCTA]11 [TCTA]11 [TCTA]10 [TCTA]12 [TCTA]12 [TCTA]12 [TCTA]11 [TCTA]11	TA          TA	[TCTA] TCTA TCTA TCTA TCTA TCTA TCTA TCTA	Platform Sanger Sanger MiSeq Sanger MiSeq Sanger MiSeq MiSeq Sanger	Reference           Zhou et al. (1997)           Zhou et al. (1997)           NIST 183           Schwartz et al. (1996)           NIST 183           Griffiths et al. (1998)           NIST 183           Griffiths et al. (1998)           NIST 183           Griffiths et al. (1998)           Rist 183           Griffiths et al. (1998)
allele         28.2         29.2         30.2         30.2         30.2         31.2         31.2         32.2         32.2	[TCTA] 4-6 [TCTA] 5 [TCTA] 4 [TCTA] 5	[TCTG]5-6 [TCTG]5 [TCTG]5 [TCTG]5 [TCTG]6 [TCTG]6 [TCTG]6 [TCTG]6 [TCTG]6 [TCTG]6 [TCTG]6	[TCTA] 2-3 [TCTA] 3 [TCTA] 3	TA          TA	[TCTA] 2 - [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3 [TCTA] 3	3TCATCA1TCA1TCA1TCA1TCA1TCA1TCA1TCA1TCA1TCA1TCA1TCA1TCA1	[TCTA] 2	2 TCCATA	[TCTA] 8-16         [TCTA] 8         [TCTA] 10         [TCTA] 11         [TCTA] 11         [TCTA] 11         [TCTA] 10         [TCTA] 11         [TCTA] 10         [TCTA] 11         [TCTA] 10         [TCTA] 11         [TCTA] 12         [TCTA] 13         [TCTA] 12	TA	[TCTA]         TCTA	PlatformSangerSangerMiSeqSangerMiSeqSangerMiSeqSangerSangerSangerSangerSangerSangerSangerSanger	Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1998)         Griffiths et al. (1998)
allele         28.2         29.2         30.2         30.2         30.2         31.2         31.2         32.2         32.2         32.2         32.2         32.2	[TCTA] 4-6 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 4 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5	[TCTG] 5-6 [TCTG] 6 [TCTG] 5 [TCTG] 6 [TCTG] 6 [TCTG] 6 [TCTG] 6 [TCTG] 6 [TCTG] 6 [TCTG] 6 [TCTG] 6 [TCTG] 6 [TCTG] 6	[TCTA] 2 – 3 [TCTA] 2	TA          TA	[TCTA] 2 - [TCTA] 3 [TCTA] 3	3TCATCATCATCATCATCATCATCATCATCATCATCATCATCATCA	<b>[TCTA]</b> [TCTA]	2       TCCATA         TCCATA       1	[TCTA]8-16 [TCTA]8 [TCTA]10 [TCTA]9 [TCTA]11 [TCTA]11 [TCTA]10 [TCTA]10 [TCTA]12 [TCTA]12 [TCTA]11 [TCTA]13 [TCTA]13 [TCTA]13	TA	[TCTA]         TCTA	PlatformSangerSangerMiSeqSangerMiSeqSangerMiSeqSangerSangerSangerSangerSangerSangerSangerSangerSangerSanger	Reference           Zhou et al. (1997)           Zhou et al. (1997)           NIST 183           Schwartz et al. (1996)           NIST 183           Griffiths et al. (1998)           NIST 183           Griffiths et al. (1998)           NIST 183           Griffiths et al. (1998)           Brinkmann et al. (1998)           Brinkmann et al. (1998)           Brinkmann et al. (1996a)           NIST 183
allele         28.2         29.2         30.2         30.2         30.2         31.2         31.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2	[TCTA] 4-6 [TCTA] 5 [TCTA] 4 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 6	[TCTG]5-6 [TCTG]5 [TCTG]5 [TCTG]5 [TCTG]6 [TCTG]6 [TCTG]6 [TCTG]6 [TCTG]6 [TCTG]6 [TCTG]6 [TCTG]6 [TCTG]6 [TCTG]6	[TCTA] 2 - 3 [TCTA] 2 [TCTA] 3 [TCTA] 3	TA	[TCTA] 2 - [TCTA] 3 [TCTA] 3	3TCATCA1	[TCTA] 2	2       TCCATA         TCCATA       1	[TCTA] 8-16         [TCTA] 8         [TCTA] 10         [TCTA] 11         [TCTA] 11         [TCTA] 11         [TCTA] 11         [TCTA] 12         [TCTA] 12         [TCTA] 13         [TCTA] 13         [TCTA] 12         [TCTA] 13         [TCTA] 13         [TCTA] 13         [TCTA] 13         [TCTA] 13         [TCTA] 13	TA	[TCTA]         TCTA	PlatformSangerSangerMiSeqSangerMiSeqSangerMiSeqSangerSangerSangerSangerSangerSangerSangerSangerMiSeq	Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         NIST 183
allele         28.2         29.2         30.2         30.2         30.2         30.2         31.2         31.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2         33.2	[TCTA] 4-6 [TCTA] 5 [TCTA] 4 [TCTA] 5 [TCTA] 5 [TCTA] 6 [TCTA] 6 [TCTA] 6	[TCTG] 5 - 6 [TCTG] 6 [TCTG] 5 [TCTG] 6 [TCTG] 6 [TCTG] 6 [TCTG] 6 [TCTG] 6 [TCTG] 6 [TCTG] 6 [TCTG] 6 [TCTG] 6 [TCTG] 5 [TCTG] 6 [TCTG] 6	[TCTA] 2 - 3 [TCTA] 3	TA	[TCTA] 2 - [TCTA] 3 [TCTA] 3	3TCATCA1	<b>[TCTA]</b> [TCTA]	2       TCCATA         TCCATA       1	[TCTA] 8-16         [TCTA] 10         [TCTA] 10         [TCTA] 11         [TCTA] 11         [TCTA] 11         [TCTA] 11         [TCTA] 10         [TCTA] 11         [TCTA] 12         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13	TA	[TCTA]         TCTA         TCTA	PlatformSangerSangerMiSeqSangerMiSeqSangerMiSeqSanger	Reference           Zhou et al. (1997)           Zhou et al. (1997)           NIST 183           Schwartz et al. (1996)           NIST 183           Griffiths et al. (1998)           NIST 183           Griffiths et al. (1998)           NIST 183           Griffiths et al. (1998)           Brinkmann et al. (1996a)           Griffiths et al. (1998)           Brinkmann et al. (1996a)           MIST 183           Gelardi et al. (2014)           Griffiths et al. (1998)
allele         28.2         29.2         30.2         30.2         30.2         30.2         31.2         31.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2         32.2         33.2         33.2         33.2         33.2	[TCTA] 4-6 [TCTA] 5 [TCTA] 4 [TCTA] 5 [TCTA] 5 [TCTA] 6 [TCTA] 6 [TCTA] 6 [TCTA] 6 [TCTA] 6	[TCTG] 5 - 6 [TCTG] 6 [TCTG] 5 [TCTG] 5 [TCTG] 6 [TCTG] 5 [TCTG] 5 [TCTG] 5 [TCTG] 5	[TCTA] 2 - 3 [TCTA] 3	TA	[TCTA] 2       [TCTA] 3	3TCATCA1	[TCTA] 2	2       TCCATA         TCCATA       1	[TCTA] 8-16         [TCTA] 8         [TCTA] 10         [TCTA] 11         [TCTA] 11         [TCTA] 11         [TCTA] 11         [TCTA] 12         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13	TA	[TCTA]         TCTA         TCTA	PlatformSangerSangerMiSeqSangerMiSeqSangerMiSeqSanger	Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Brinkmann et al. (1996a)         Brinkmann et al. (1998)         Brinkmann et al. (1998)         Brinkmann et al. (1998)         Brinkmann et al. (1998)
allele         28.2         29.2         30.2         30.2         30.2         31.2         31.2         32.2         33.2         33.2         33.2         33.2         34.2         35.2	[TCTA] 4-6 [TCTA] 5 [TCTA] 4 [TCTA] 5 [TCTA] 5 [TCTA] 6 [TCTA] 6 [TCTA] 6 [TCTA] 6 [TCTA] 6 [TCTA] 5 [TCTA] 5	[TCTG] 5-6         [TCTG] 5         [TCTG] 5         [TCTG] 6	[TCTA] 2 - 3 [TCTA] 3	TA	[TCTA] 2 [TCTA] 3 [TCTA] 3	3TCATCA1	<b>[TCTA]</b> [TCTA]	2       TCCATA         TCCATA       TCOATA         TCCA	[TCTA] 8-16         [TCTA] 8         [TCTA] 10         [TCTA] 11         [TCTA] 11         [TCTA] 11         [TCTA] 10         [TCTA] 11         [TCTA] 10         [TCTA] 11         [TCTA] 12         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13         [TCTA] 14         [TCTA] 14	TA	[TCTA]         TCTA         TCTA	PlatformSangerSangerMiSeqSangerMiSeqSangerMiSeqSanger	Reference           Zhou et al. (1997)           Zhou et al. (1997)           NIST 183           Schwartz et al. (1996)           NIST 183           Griffiths et al. (1998)           NIST 183           Griffiths et al. (1998)           NIST 183           Griffiths et al. (1998)           Brinkmann et al. (1996a)           Griffiths et al. (1998)           Brinkmann et al. (1996a)           Griffiths et al. (2014)           Gelardi et al. (2014)           Griffiths et al. (1998)           Brinkmann et al. (1996a)           Brinkmann et al. (1998)           Brinkmann et al. (1998)           Brinkmann et al. (1997)
allele         28.2         29.2         30.2         30.2         30.2         30.2         30.2         31.2         31.2         32.2         33.2         33.2         33.2         33.2         34.2         35.2         36.2	[TCTA] 4-6 [TCTA] 5 [TCTA] 4 [TCTA] 5 [TCTA] 5 [TCTA] 6 [TCTA] 6 [TCTA] 6 [TCTA] 6 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5	[TCTG] 5 - 6         [TCTG] 5         [TCTG] 6	[TCTA] 2-3 [TCTA] 3 [TCTA] 3	TA	[TCTA] 2 - [TCTA] 3 [TCTA] 3	3TCATCA1	TCTA         [TCTA] 2          [TCTA] 2	2       TCCATA         TCCATA       1	[TCTA]8-16         [TCTA]10         [TCTA]10         [TCTA]11         [TCTA]11         [TCTA]11         [TCTA]12         [TCTA]12         [TCTA]12         [TCTA]13         [TCTA]14         [TCTA]15         [TCTA]16	TA	[TCTA]         TCTA         TCTA	PlatformSangerSangerMiSeqSangerMiSeqSangerMiSeqSanger	Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         NIST 183         Gelardi et al. (2014)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Brinkmann et al. (1998)         Brinkmann et al. (1998)         Brinkmann et al. (1997)         Zhou et al. (1997)
allele         28.2         29.2         30.2         30.2         30.2         30.2         31.2         31.2         32.2         33.2         33.2         33.2         34.2         35.2         36.2	[TCTA] 4-6 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 4 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 6 [TCTA] 6 [TCTA] 6 [TCTA] 6 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5	[TCTG] 5 - 6         [TCTG] 5         [TCTG] 5         [TCTG] 6	[TCTA] 2 - 3 [TCTA] 3	TA	[TCTA] 2   [TCTA] 3	3TCZTCA1 </td <td>ITCTA] 2         [TCTA] 2</td> <td>2       TCCATA         TCCATA       I         TCCATA       I</td> <td>[TCTA] 8-16         [TCTA] 8         [TCTA] 10         [TCTA] 10         [TCTA] 11         [TCTA] 11         [TCTA] 11         [TCTA] 10         [TCTA] 11         [TCTA] 12         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13         [TCTA] 14         [TCTA] 15         [TCTA] 16</td> <td>TA         TA         TA</td> <td>[TCTA]         TCTA         TCTA</td> <td>PlatformSangerSangerMiSeqSangerMiSeqSanger</td> <td>Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         NIST 183         Gelardi et al. (2014)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Brinkmann et al. (1998)         Brinkmann et al. (1998)         Brinkmann et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)</td>	ITCTA] 2         [TCTA] 2	2       TCCATA         TCCATA       I	[TCTA] 8-16         [TCTA] 8         [TCTA] 10         [TCTA] 10         [TCTA] 11         [TCTA] 11         [TCTA] 11         [TCTA] 10         [TCTA] 11         [TCTA] 12         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13         [TCTA] 14         [TCTA] 15         [TCTA] 16	TA	[TCTA]         TCTA         TCTA	PlatformSangerSangerMiSeqSangerMiSeqSanger	Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         NIST 183         Gelardi et al. (2014)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Brinkmann et al. (1998)         Brinkmann et al. (1998)         Brinkmann et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)
allele         28.2         29.2         29.2         30.2         30.2         30.2         31.2         31.2         32.2         33.2         33.2         33.2         34.2         35.2         36.2         allele         24.2         25.2	[TCTA] 4-6 [TCTA] 5 [TCTA] 4 [TCTA] 5 [TCTA] 5 [TCTA] 6 [TCTA] 6 [TCTA] 6 [TCTA] 6 [TCTA] 6 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5 [TCTA] 5	[TCTG] 5 - 6         [TCTG] 5         [TCTG] 5         [TCTG] 6	[TCTA] 2-3 [TCTA] 3 [TCTA] 3	TA	[TCTA] 2       [TCTA] 3	3     TCA       TCA     1       TCA	ITCTA         [TCTA] 2	2       TCCATA         TCCATA       I	[TCTA]8-16         [TCTA]8         [TCTA]10         [TCTA]11         [TCTA]11         [TCTA]12         [TCTA]12         [TCTA]12         [TCTA]13         [TCTA]14         [TCTA]15         [TCTA]16	TA	[TCTA]         TCTA         TCTA	PlatformSangerSangerMiSeqSangerMiSeqSangerMiSeqSanger	Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (2014)         Gelardi et al. (2014)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Brinkmann et al. (1998)         Brinkmann et al. (1998)         Brinkmann et al. (1998)         Brinkmann et al. (1998)         Zhou et al. (1997)         Zhou et al. (1997)         Reference         Griffiths et al. (1998)
allele         28.2         29.2         30.2         30.2         30.2         30.2         30.2         31.2         31.2         32.2         33.2         33.2         33.2         34.2         35.2         36.2         allele         24.2         25.2         25.2         25.2	[TCTA] 4-6         [TCTA] 5         [TCTA] 6         [TCTA] 6         [TCTA] 5	[TCTG] 5-6         [TCTG] 5         [TCTG] 6	[TCTA] 2-3 [TCTA] 3 [TCTA] 3	TA	[TCTA] 2       [TCTA] 3	3     TCA       TCA     1       TCA	[TCTA] 2	2       TCCATA         TCCATA       I	[TCTA]8-16         [TCTA]8         [TCTA]10         [TCTA]11         [TCTA]11         [TCTA]11         [TCTA]10         [TCTA]11         [TCTA]12         [TCTA]12         [TCTA]13         [TCTA]14         [TCTA]15         [TCTA]16	TA	[TCTA]         TCTA         TCTA	PlatformSangerSangerMiSeqSangerMiSeqSangerMiSeqSangerMiSeq	Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1998)         Brinkmann et al. (1998)         Brinkmann et al. (1998)         Griffiths et al. (1998)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1998)         Reference         Griffiths et al. (1998)         MIST 183
allele         28.2         29.2         30.2         30.2         30.2         30.2         30.2         31.2         31.2         32.2         33.2         33.2         33.2         33.2         34.2         35.2         36.2         allele         24.2         25.2         37.2         37.2         37.2	[TCTA] 4-6         [TCTA] 5         [TCTA] 6         [TCTA] 6         [TCTA] 5         [TCTA] 6         [TCTA] 5         [TCTA] 7         [TCTA] 9	[TCTG] 5-6         [TCTG] 5         [TCTG] 5         [TCTG] 6	[TCTA] 2-3 [TCTA] 3 [TCTA] 3	TA	[TCTA] 2       [TCTA] 3	3TCATCA1 </td <td>ITCTA         [TCTA] 2          [TCTA] 2    </td> <td>2       TCCATA         TCCATA       I         TCCATA       I</td> <td>[TCTA]8-16         [TCTA]8         [TCTA]10         [TCTA]11         [TCTA]11         [TCTA]12         [TCTA]12         [TCTA]13         [TCTA]12         [TCTA]13         [TCTA]14         [TCTA]15         [TCTA]16         TCTA]10         [TCTA]10         [TCTA]12         [TCTA]12</td> <td>TA         TA         TA</td> <td>[TCTA]         TCTA         TCTA</td> <td>PlatformSangerSangerMiSeqSangerMiSeqSanger</td> <td>Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         NIST 183         Gelardi et al. (2014)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Brinkmann et al. (1998)         Schou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Walsh et al. (2003)         Walsh et al. (2003)</td>	ITCTA         [TCTA] 2          [TCTA] 2	2       TCCATA         TCCATA       I	[TCTA]8-16         [TCTA]8         [TCTA]10         [TCTA]11         [TCTA]11         [TCTA]12         [TCTA]12         [TCTA]13         [TCTA]12         [TCTA]13         [TCTA]14         [TCTA]15         [TCTA]16         TCTA]10         [TCTA]10         [TCTA]12         [TCTA]12	TA	[TCTA]         TCTA         TCTA	PlatformSangerSangerMiSeqSangerMiSeqSanger	Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         NIST 183         Gelardi et al. (2014)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Brinkmann et al. (1998)         Schou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Walsh et al. (2003)         Walsh et al. (2003)
allele         28.2         29.2         29.2         30.2         30.2         30.2         30.2         31.2         31.2         32.2         33.2         33.2         33.2         33.2         33.2         34.2         35.2         36.2         25.2         25.2         37.2         37.2         38.2	[TCTA] 4-6         [TCTA] 5         [TCTA] 6         [TCTA] 6         [TCTA] 5         [TCTA] 6         [TCTA] 5         [TCTA] 7         [TCTA] 9         [TCTA] 9	[TCTG] 5 - 6         [TCTG] 5         [TCTG] 5         [TCTG] 6         [TCTG] 14	[TCTA] 2-3 [TCTA] 3 [TCTA] 3	TA	ITCTA] 2       [TCTA] 3	3     TCA       TCA     1       TCA	[TCTA] 2	2       TCCATA         TCCATA       I	[TCTA]8-16         [TCTA]8         [TCTA]10         [TCTA]11         [TCTA]11         [TCTA]10         [TCTA]11         [TCTA]12         [TCTA]12         [TCTA]13         [TCTA]14         [TCTA]15         [TCTA]16         [TCTA]16         [TCTA]10         [TCTA]12         [TCTA]12         [TCTA]12         [TCTA]12         [TCTA]12         [TCTA]12	TA	[TCTA]         TCTA         TCTA	PlatformSangerSangerMiSeqSangerMiSeqSangerMiSeqSanger	Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Walsh et al. (2003)         Walsh et al. (2003)         Walsh et al. (2003)
allele         28.2         29.2         30.2         30.2         30.2         30.2         30.2         31.2         31.2         32.2         33.2         33.2         33.2         33.2         33.2         34.2         35.2         36.2         25.2         37.2         38.2         37.2         38.2         37.2         38.2	[TCTA] 4-6         [TCTA] 5         [TCTA] 6         [TCTA] 6         [TCTA] 5         [TCTA] 6         [TCTA] 5         [TCTA] 7         [TCTA] 9         [TCTA] 9         [TCTA] 9         [TCTA] 9         [TCTA] 9	[TCTG] 5-6         [TCTG] 6         [TCTG] 5         [TCTG] 6         [TCTG] 12         [TCTG] 12         [TCTG] 13	[TCTA] 2-3         [TCTA] 3         [TCTA] 3	TA      TA <tbbr></tbbr> <tbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbb< td=""><td>ITCTA] 2       [TCTA] 3       [TCTA] 3</td><td>3TCZTCA1<!--</td--><td>ITCTA         ITCTA         ITCTA</td><td>2       TCCATA         TCCATA       I         TCCATA       I</td><td>[TCTA]8-16         [TCTA]8         [TCTA]10         [TCTA]11         [TCTA]11         [TCTA]12         [TCTA]12         [TCTA]12         [TCTA]13         [TCTA]14         [TCTA]15         [TCTA]16         [TCTA]16         [TCTA]16         [TCTA]10         [TCTA]12         [TCTA]12         [TCTA]13         [TCTA]13</td><td>TA         TA         TA</td><td>[TCTA]         TCTA         TCTA</td><td>PlatformSangerSangerMiSeqSangerMiSeqSanger</td><td>Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (2014)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Zhou et al. (1997)         Walsh et al. (2003)         Walsh et al. (2003)         Walsh et al. (2003)         Walsh et al. (2003)         Walsh et al. (2003)</td></td></tbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbb<>	ITCTA] 2       [TCTA] 3	3TCZTCA1 </td <td>ITCTA         ITCTA         ITCTA</td> <td>2       TCCATA         TCCATA       I         TCCATA       I</td> <td>[TCTA]8-16         [TCTA]8         [TCTA]10         [TCTA]11         [TCTA]11         [TCTA]12         [TCTA]12         [TCTA]12         [TCTA]13         [TCTA]14         [TCTA]15         [TCTA]16         [TCTA]16         [TCTA]16         [TCTA]10         [TCTA]12         [TCTA]12         [TCTA]13         [TCTA]13</td> <td>TA         TA         TA</td> <td>[TCTA]         TCTA         TCTA</td> <td>PlatformSangerSangerMiSeqSangerMiSeqSanger</td> <td>Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (2014)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Zhou et al. (1997)         Walsh et al. (2003)         Walsh et al. (2003)         Walsh et al. (2003)         Walsh et al. (2003)         Walsh et al. (2003)</td>	ITCTA	2       TCCATA         TCCATA       I	[TCTA]8-16         [TCTA]8         [TCTA]10         [TCTA]11         [TCTA]11         [TCTA]12         [TCTA]12         [TCTA]12         [TCTA]13         [TCTA]14         [TCTA]15         [TCTA]16         [TCTA]16         [TCTA]16         [TCTA]10         [TCTA]12         [TCTA]12         [TCTA]13         [TCTA]13	TA	[TCTA]         TCTA         TCTA	PlatformSangerSangerMiSeqSangerMiSeqSanger	Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (2014)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Zhou et al. (1997)         Walsh et al. (2003)
allele         28.2         29.2         29.2         30.2         30.2         30.2         30.2         31.2         31.2         32.2         33.2         33.2         33.2         33.2         33.2         33.2         34.2         35.2         36.2         25.2         37.2         38.2         37.2         38.2         37.2         38.2         37.2         38.2	[TCTA] 4-6         [TCTA] 5         [TCTA] 6         [TCTA] 6         [TCTA] 6         [TCTA] 5         [TCTA] 7         [TCTA] 9         [TCTA] 9         [TCTA] 10	[TCTG] 5 - 6         [TCTG] 5         [TCTG] 5         [TCTG] 6         [TCTG] 14         [TCTG] 12         [TCTG] 13         [TCTG] 13	[TCTA] 2-3         [TCTA] 3         [TCTA] 3	TA      TA <t< td=""><td>[TCTA] 2 [TCTA] 3 [TCTA] 3</td><td>3     TCA       TCA     1       TCA</td><td>ITCTA         ITCTA         ITCTA</td><td>2       TCCATA         TCCATA       I         TCCATA       I</td><td>[TCTA]8-16         [TCTA]8         [TCTA]10         [TCTA]11         [TCTA]11         [TCTA]12         [TCTA]12         [TCTA]12         [TCTA]13         [TCTA]14         [TCTA]15         [TCTA]16         TCTA]13         [TCTA]16         [TCTA]10         [TCTA]12         [TCTA]13         [TCTA]13         [TCTA]13         [TCTA]12         [TCTA]13         [TCTA]13         [TCTA]13         [TCTA]13         [TCTA]13</td><td>TA         TA         TA</td><td>[TCTA]TCTA</td><td>PlatformSangerSangerMiSeqSangerMiSeqSanger</td></t<> <td>Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Zhou et al. (1997)         Zhou et al. (1998)         Griffiths et al. (1998)         Walsh et al. (2003)         Walsh et al. (2003)</td>	[TCTA] 2 [TCTA] 3	3     TCA       TCA     1       TCA	ITCTA	2       TCCATA         TCCATA       I	[TCTA]8-16         [TCTA]8         [TCTA]10         [TCTA]11         [TCTA]11         [TCTA]12         [TCTA]12         [TCTA]12         [TCTA]13         [TCTA]14         [TCTA]15         [TCTA]16         TCTA]13         [TCTA]16         [TCTA]10         [TCTA]12         [TCTA]13         [TCTA]13         [TCTA]13         [TCTA]12         [TCTA]13         [TCTA]13         [TCTA]13         [TCTA]13         [TCTA]13	TA	[TCTA]TCTA	PlatformSangerSangerMiSeqSangerMiSeqSanger	Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Zhou et al. (1997)         Zhou et al. (1998)         Griffiths et al. (1998)         Walsh et al. (2003)
allele         28.2         29.2         30.2         30.2         30.2         30.2         30.2         31.2         31.2         32.2         33.2         33.2         33.2         33.2         33.2         34.2         35.2         36.2         25.2         37.2         38.2         37.2         38.2         37.2         38.2         37.2         38.2         39.2	[TCTA] 4-6         [TCTA] 5         [TCTA] 6         [TCTA] 6         [TCTA] 5         [TCTA] 7         [TCTA] 9         [TCTA] 9         [TCTA] 10         [TCTA] 10	[TCTG] 5-6         [TCTG] 5         [TCTG] 5         [TCTG] 6         [TCTG] 12         [TCTG] 12         [TCTG] 13         [TCTG] 13         [TCTG] 13	[TCTA] 2-3         [TCTA] 3         [TCTA] 3	TA      TA <t< td=""><td>ITCTA] 2       [TCTA] 3       [TCTA] 3</td><td>3TCZTCA1</td><td>ITCTA         ITCTA         ITCTA</td><td>2     TCCATA       TCCATA</td><td>[TCTA] 8-16         [TCTA] 8         [TCTA] 10         [TCTA] 11         [TCTA] 11         [TCTA] 12         [TCTA] 12         [TCTA] 12         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13         [TCTA] 14         [TCTA] 15         [TCTA] 16         [TCTA] 16         [TCTA] 16         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 12         [TCTA] 12         [TCTA] 12         [TCTA] 12         [TCTA] 12         [TCTA] 12    </td><td>TA         TA         TA</td><td>[TCTA]TCTA</td><td>PlatformSangerSangerMiSeqSangerMiSeqSanger</td></t<> <td>Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Zhou et al. (1997)         Zhou et al. (1998)         Griffiths et al. (1998)         Griffiths et al. (2003)         Walsh et al. (2003)</td>	ITCTA] 2       [TCTA] 3       [TCTA] 3	3TCZTCA1	ITCTA	2     TCCATA	[TCTA] 8-16         [TCTA] 8         [TCTA] 10         [TCTA] 11         [TCTA] 11         [TCTA] 12         [TCTA] 12         [TCTA] 12         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13         [TCTA] 14         [TCTA] 15         [TCTA] 16         [TCTA] 16         [TCTA] 16         [TCTA] 12         [TCTA] 13         [TCTA] 12	TA	[TCTA]TCTA	PlatformSangerSangerMiSeqSangerMiSeqSanger	Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Zhou et al. (1997)         Zhou et al. (1998)         Griffiths et al. (1998)         Griffiths et al. (2003)         Walsh et al. (2003)
allele         28.2         29.2         30.2         30.2         30.2         30.2         30.2         31.2         31.2         32.2         33.2         33.2         33.2         33.2         33.2         33.2         33.2         33.2         33.2         33.2         33.2         33.2         33.2         33.2         33.2         33.2         33.2         33.2         33.2	[TCTA] 4-6         [TCTA] 5         [TCTA] 6         [TCTA] 5         [TCTA] 6         [TCTA] 5         [TCTA] 7         [TCTA] 9         [TCTA] 10         [TCTA] 10         [TCTA] 10         [TCTA] 10	[TCTG] 5 - 6         [TCTG] 5         [TCTG] 5         [TCTG] 6         [TCTG] 12         [TCTG] 12         [TCTG] 13         [TCTG] 13         [TCTG] 13         [TCTG] 13         [TCTG] 14	[TCTA] 2-3         [TCTA] 3         [TCTA] 3	TA       TA <td>ITCTA] 2       [TCTA] 3       [TCTA] 3</td> <td>3TCATCA1<!--</td--><td>TCTA         [TCTA] 2         <t< td=""><td>2       TCCATA         TCCATA       I         TCCATA       I</td><td>[TCTA] 8-16         [TCTA] 8         [TCTA] 10         [TCTA] 11         [TCTA] 11         [TCTA] 12         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13         [TCTA] 14         [TCTA] 15         [TCTA] 16         [TCTA] 16         [TCTA] 16         [TCTA] 13         [TCTA] 14         [TCTA] 15         [TCTA] 16         [TCTA] 16         [TCTA] 12         [TCTA] 12         [TCTA] 12         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13</td><td>TA         TA         TA</td><td>[TCTA]TCTA</td><td>PlatformSangerSangerMiSeqSangerMiSeqSangerMiSeqSanger<td>Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1998)         Griffiths et al. (1998)         Griffiths et al. (1998)         NIST 183         Walsh et al. (2003)         Walsh et al. (2003)</td></td></t<></td></td>	ITCTA] 2       [TCTA] 3       [TCTA] 3	3TCATCA1 </td <td>TCTA         [TCTA] 2         <t< td=""><td>2       TCCATA         TCCATA       I         TCCATA       I</td><td>[TCTA] 8-16         [TCTA] 8         [TCTA] 10         [TCTA] 11         [TCTA] 11         [TCTA] 12         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13         [TCTA] 14         [TCTA] 15         [TCTA] 16         [TCTA] 16         [TCTA] 16         [TCTA] 13         [TCTA] 14         [TCTA] 15         [TCTA] 16         [TCTA] 16         [TCTA] 12         [TCTA] 12         [TCTA] 12         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13</td><td>TA         TA         TA</td><td>[TCTA]TCTA</td><td>PlatformSangerSangerMiSeqSangerMiSeqSangerMiSeqSanger<td>Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1998)         Griffiths et al. (1998)         Griffiths et al. (1998)         NIST 183         Walsh et al. (2003)         Walsh et al. (2003)</td></td></t<></td>	TCTA         [TCTA] 2         [TCTA] 2 <t< td=""><td>2       TCCATA         TCCATA       I         TCCATA       I</td><td>[TCTA] 8-16         [TCTA] 8         [TCTA] 10         [TCTA] 11         [TCTA] 11         [TCTA] 12         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13         [TCTA] 14         [TCTA] 15         [TCTA] 16         [TCTA] 16         [TCTA] 16         [TCTA] 13         [TCTA] 14         [TCTA] 15         [TCTA] 16         [TCTA] 16         [TCTA] 12         [TCTA] 12         [TCTA] 12         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13</td><td>TA         TA         TA</td><td>[TCTA]TCTA</td><td>PlatformSangerSangerMiSeqSangerMiSeqSangerMiSeqSanger<td>Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1998)         Griffiths et al. (1998)         Griffiths et al. (1998)         NIST 183         Walsh et al. (2003)         Walsh et al. (2003)</td></td></t<>	2       TCCATA         TCCATA       I	[TCTA] 8-16         [TCTA] 8         [TCTA] 10         [TCTA] 11         [TCTA] 11         [TCTA] 12         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13         [TCTA] 14         [TCTA] 15         [TCTA] 16         [TCTA] 16         [TCTA] 16         [TCTA] 13         [TCTA] 14         [TCTA] 15         [TCTA] 16         [TCTA] 16         [TCTA] 12         [TCTA] 12         [TCTA] 12         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13	TA	[TCTA]TCTA	PlatformSangerSangerMiSeqSangerMiSeqSangerMiSeqSanger <td>Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1998)         Griffiths et al. (1998)         Griffiths et al. (1998)         NIST 183         Walsh et al. (2003)         Walsh et al. (2003)</td>	Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1998)         Griffiths et al. (1998)         Griffiths et al. (1998)         NIST 183         Walsh et al. (2003)
allele         28.2         29.2         30.2         30.2         30.2         30.2         30.2         30.2         31.2         31.2         32.2         33.2         33.2         33.2         33.2         33.2         34.2         35.2         36.2         25.2         25.2         37.2         38.2         37.2         38.2         37.2         38.2         37.2         38.2         37.2	[TCTA] 4-6[TCTA] 5[TCTA] 6[TCTA] 6[TCTA] 5[TCTA] 5[TCTA] 5[TCTA] 5[TCTA] 5[TCTA] 6[TCTA] 5[TCTA] 5[TCTA] 5[TCTA] 5[TCTA] 5[TCTA] 5[TCTA] 5[TCTA] 5[TCTA] 7[TCTA] 7[TCTA] 9[TCTA] 10[TCTA] 10[TCTA] 10[TCTA] 10[TCTA] 11[TCTA] 11	[TCTG] 5-6         [TCTG] 5         [TCTG] 5         [TCTG] 6         [TCTG] 12         [TCTG] 12         [TCTG] 13         [TCTG] 13         [TCTG] 13         [TCTG] 14         [TCTG] 13         [TCTG] 14         [TCTG] 13         [TCTG] 14	[TCTA] 2-3         [TCTA] 3         [TCTA] 3	TA       TA <td>ITCTA] 2       [TCTA] 3       [TCTA] 3       ITCTA] 3       ITCTA] 3       [TCTA] 3</td> <td>3TCATCA1<!--</td--><td>[TCTA] 2         [TCTA] 2</td><td>2TCCATATCCA</td><td>[TCTA]8-16[TCTA]8[TCTA]10[TCTA]11[TCTA]11[TCTA]12[TCTA]12[TCTA]12[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]14[TCTA]15[TCTA]16[TCTA]16[TCTA]12</td><td>TA         TA         TA</td><td>[TCTA]TCTA</td><td>PlatformSangerSangerMiSeqSangerMiSeqSangerMiSeqSanger<td>Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1998)         Griffiths et al. (1998)         Griffiths et al. (1998)         Walsh et al. (2003)         Walsh et a</td></td></td>	ITCTA] 2       [TCTA] 3       [TCTA] 3       ITCTA] 3       ITCTA] 3       [TCTA] 3	3TCATCA1 </td <td>[TCTA] 2         [TCTA] 2</td> <td>2TCCATATCCA</td> <td>[TCTA]8-16[TCTA]8[TCTA]10[TCTA]11[TCTA]11[TCTA]12[TCTA]12[TCTA]12[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]14[TCTA]15[TCTA]16[TCTA]16[TCTA]12</td> <td>TA         TA         TA</td> <td>[TCTA]TCTA</td> <td>PlatformSangerSangerMiSeqSangerMiSeqSangerMiSeqSanger<td>Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1998)         Griffiths et al. (1998)         Griffiths et al. (1998)         Walsh et al. (2003)         Walsh et a</td></td>	[TCTA] 2	2TCCATATCCA	[TCTA]8-16[TCTA]8[TCTA]10[TCTA]11[TCTA]11[TCTA]12[TCTA]12[TCTA]12[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]13[TCTA]14[TCTA]15[TCTA]16[TCTA]16[TCTA]12	TA	[TCTA]TCTA	PlatformSangerSangerMiSeqSangerMiSeqSangerMiSeqSanger <td>Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1998)         Griffiths et al. (1998)         Griffiths et al. (1998)         Walsh et al. (2003)         Walsh et a</td>	Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1998)         Griffiths et al. (1998)         Griffiths et al. (1998)         Walsh et al. (2003)         Walsh et a
allele         28.2         29.2         30.2         30.2         30.2         30.2         30.2         30.2         31.2         31.2         32.2         33.2         33.2         33.2         33.2         33.2         33.2         33.2         33.2         34.2         35.2         37.2         38.2         37.2         38.2         37.2         38.2         37.2         38.2         37.2	[TCTA] 4-6         [TCTA] 5         [TCTA] 6         [TCTA] 6         [TCTA] 5         [TCTA] 7         [TCTA] 9         [TCTA] 9         [TCTA] 10         [TCTA] 10         [TCTA] 10         [TCTA] 11	[TCTG] 5 - 6         [TCTG] 5         [TCTG] 5         [TCTG] 6         [TCTG] 12         [TCTG] 12         [TCTG] 13         [TCTG] 13         [TCTG] 13         [TCTG] 14         [TCTG] 13         [TCTG] 14         [TCTG] 13         [TCTG] 14         [TCTG] 13	[TCTA] 2-3         [TCTA] 3         [TCTA] 3	TA       TA <td>ITCTA] 2       [TCTA] 3       [TCTA] 3</td> <td>3TCATCA1<!--</td--><td>ITCTA         ITCTA         ITCTA</td><td>2     TCCATA       TCCATA</td><td>[TCTA] 8-16         [TCTA] 10         [TCTA] 10         [TCTA] 11         [TCTA] 11         [TCTA] 12         [TCTA] 12         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13         [TCTA] 14         [TCTA] 15         [TCTA] 16         [TCTA] 16         [TCTA] 16         [TCTA] 12         [TCTA] 14         [TCTA] 15         [TCTA] 16         [TCTA] 12         [TCTA] 12</td><td>TA         TA         TA</td><td>[TCTA]         TCTA         TCTA</td><td>Platform         Sanger         Sanger         MiSeq         Sanger         MiSeq         Sanger         MiSeq         Sanger         MiSeq         Sanger         Sanger<!--</td--><td>Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1998)         Griffiths et al. (1998)         Griffiths et al. (1998)         Walsh et al. (2003)         Wa</td></td></td>	ITCTA] 2       [TCTA] 3       [TCTA] 3	3TCATCA1 </td <td>ITCTA         ITCTA         ITCTA</td> <td>2     TCCATA       TCCATA</td> <td>[TCTA] 8-16         [TCTA] 10         [TCTA] 10         [TCTA] 11         [TCTA] 11         [TCTA] 12         [TCTA] 12         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13         [TCTA] 14         [TCTA] 15         [TCTA] 16         [TCTA] 16         [TCTA] 16         [TCTA] 12         [TCTA] 14         [TCTA] 15         [TCTA] 16         [TCTA] 12         [TCTA] 12</td> <td>TA         TA         TA</td> <td>[TCTA]         TCTA         TCTA</td> <td>Platform         Sanger         Sanger         MiSeq         Sanger         MiSeq         Sanger         MiSeq         Sanger         MiSeq         Sanger         Sanger<!--</td--><td>Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1998)         Griffiths et al. (1998)         Griffiths et al. (1998)         Walsh et al. (2003)         Wa</td></td>	ITCTA	2     TCCATA	[TCTA] 8-16         [TCTA] 10         [TCTA] 10         [TCTA] 11         [TCTA] 11         [TCTA] 12         [TCTA] 12         [TCTA] 12         [TCTA] 13         [TCTA] 12         [TCTA] 13         [TCTA] 14         [TCTA] 15         [TCTA] 16         [TCTA] 16         [TCTA] 16         [TCTA] 12         [TCTA] 14         [TCTA] 15         [TCTA] 16         [TCTA] 12	TA	[TCTA]         TCTA         TCTA	Platform         Sanger         Sanger         MiSeq         Sanger         MiSeq         Sanger         MiSeq         Sanger         MiSeq         Sanger         Sanger </td <td>Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1998)         Griffiths et al. (1998)         Griffiths et al. (1998)         Walsh et al. (2003)         Wa</td>	Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1997)         Zhou et al. (1998)         Griffiths et al. (1998)         Griffiths et al. (1998)         Walsh et al. (2003)         Wa
allele         28.2         29.2         30.2         30.2         30.2         30.2         30.2         31.2         31.2         32.2         33.2         33.2         33.2         33.2         33.2         34.2         35.2         37.2         38.2         37.2         38.2         37.2         38.2         37.2         38.2         37.2         38.2         37.2         38.2	[TCTA] 4-6         [TCTA] 5         [TCTA] 6         [TCTA] 6         [TCTA] 5         [TCTA] 7         [TCTA] 9         [TCTA] 10         [TCTA] 10         [TCTA] 10         [TCTA] 11         [TCTA] 5-6         [TCTA] 6	[TCTG]5-6         [TCTG]5         [TCTG]5         [TCTG]6         [TCTG]12         [TCTG]13         [TCTG]13         [TCTG]13         [TCTG]14         [TCTG]13         [TCTG]14         [TCTG]13         [TCTG]14         [TCTG]14         [TCTG]14	[TCTA] 2-3         [TCTA] 3         [TCTA] 3	TA                  TA        TA        TA        TA <td>ITCTA] 2       [TCTA] 3       [TCTA] 3</td> <td>3TCATCA1<!--</td--><td>ITCTA         ITCTA         ITCTA</td><td>2TCCATATCCA</td><td>[TCTA] 8-16[TCTA] 10[TCTA] 10[TCTA] 11[TCTA] 11[TCTA] 12[TCTA] 12[TCTA] 12[TCTA] 12[TCTA] 12[TCTA] 12[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 12[TCTA] 14[TCTA] 15[TCTA] 16[TCTA] 16[TCTA] 16[TCTA] 16[TCTA] 12[TCTA] 13[TCTA] 12[TCTA] 13[TCTA] 12[TCTA] 13[TCTA] 12[TCTA] 13[TCTA] 12[TCTA] 12[TCTA] 13[TCTA] 12</td><td>TA<td>[TCTA]TCTA</td><td>PlatformSangerSangerMiSeqSangerMiSeqSanger<td>Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (2014)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Zhou et al. (1997)         Zhou et al. (1998)         Griffiths et al. (1998)         Griffiths et al. (2003)         Walsh et al. (2003)         Bagd</td></td></td></td>	ITCTA] 2       [TCTA] 3       [TCTA] 3	3TCATCA1 </td <td>ITCTA         ITCTA         ITCTA</td> <td>2TCCATATCCA</td> <td>[TCTA] 8-16[TCTA] 10[TCTA] 10[TCTA] 11[TCTA] 11[TCTA] 12[TCTA] 12[TCTA] 12[TCTA] 12[TCTA] 12[TCTA] 12[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 12[TCTA] 14[TCTA] 15[TCTA] 16[TCTA] 16[TCTA] 16[TCTA] 16[TCTA] 12[TCTA] 13[TCTA] 12[TCTA] 13[TCTA] 12[TCTA] 13[TCTA] 12[TCTA] 13[TCTA] 12[TCTA] 12[TCTA] 13[TCTA] 12</td> <td>TA<td>[TCTA]TCTA</td><td>PlatformSangerSangerMiSeqSangerMiSeqSanger<td>Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (2014)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Zhou et al. (1997)         Zhou et al. (1998)         Griffiths et al. (1998)         Griffiths et al. (2003)         Walsh et al. (2003)         Bagd</td></td></td>	ITCTA	2TCCATATCCA	[TCTA] 8-16[TCTA] 10[TCTA] 10[TCTA] 11[TCTA] 11[TCTA] 12[TCTA] 12[TCTA] 12[TCTA] 12[TCTA] 12[TCTA] 12[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 13[TCTA] 12[TCTA] 14[TCTA] 15[TCTA] 16[TCTA] 16[TCTA] 16[TCTA] 16[TCTA] 12[TCTA] 13[TCTA] 12[TCTA] 13[TCTA] 12[TCTA] 13[TCTA] 12[TCTA] 13[TCTA] 12[TCTA] 12[TCTA] 13[TCTA] 12	TA <td>[TCTA]TCTA</td> <td>PlatformSangerSangerMiSeqSangerMiSeqSanger<td>Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (2014)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Zhou et al. (1997)         Zhou et al. (1998)         Griffiths et al. (1998)         Griffiths et al. (2003)         Walsh et al. (2003)         Bagd</td></td>	[TCTA]TCTA	PlatformSangerSangerMiSeqSangerMiSeqSanger <td>Reference         Zhou et al. (1997)         Zhou et al. (1997)         NIST 183         Schwartz et al. (1996)         NIST 183         Griffiths et al. (1998)         NIST 183         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Griffiths et al. (2014)         Griffiths et al. (1998)         Brinkmann et al. (1996a)         Brinkmann et al. (1996a)         Griffiths et al. 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allele         28.2         29.2         30.2         30.2         30.2         30.2         31.2         31.2         31.2         32.2         33.2         33.2         33.2         34.2         35.2         37.2         38.2         37.2         38.2         37.2         38.2         37.2         38.2         37.2         38.2         37.2         38.2         37.2         38.2         37.2	[TCTA] 4-6[TCTA] 5[TCTA] 6[TCTA] 6[TCTA] 5[TCTA] 5[TCTA] 6[TCTA] 5[TCTA] 5[TCTA] 6[TCTA] 5[TCTA] 6[TCTA] 7[TCTA] 9[TCTA] 10[TCTA] 10[TCTA] 10[TCTA] 10[TCTA] 10[TCTA] 11[TCTA] 5[TCTA] 5[TCTA] 10[TCTA] 10[TCTA] 10[TCTA] 10[TCTA] 10[TCTA] 10[TCTA] 5[TCTA] 5	[TCTG] 5-6         [TCTG] 5         [TCTG] 6         [TCTG] 12         [TCTG] 12         [TCTG] 13         [TCTG] 13         [TCTG] 13         [TCTG] 13         [TCTG] 14         [TCTG] 13         [TCTG] 13         [TCTG] 14         [TCTG] 15         [TCTG] 5         [TCTG] 5         [TCTG] 5         [TCTG] 5         [TCTG] 5	[TCTA] 2-3         [TCTA] 3         [TCTA] 3	TA      TA <tbbr></tbbr> <tbr></tbr> <tbr <="" td=""><td>[TCTA] 2[TCTA] 3[TCTA] 3</td><td>3TCATCA1<!--</td--><td>ITCTA         ITCTA         ITCTA</td><td>2TCCATATCCA</td><td>[TCTA] 8-16[TCTA] 8[TCTA] 10[TCTA] 11[TCTA] 11[TCTA] 12[TCTA] 12[TCTA] 12[TCTA] 12[TCTA] 12[TCTA] 13[TCTA] 12[TCTA] 14[TCTA] 15[TCTA] 16[TCTA] 16[TCTA] 12[TCTA] 13[TCTA] 14</td><td>TA<td>[TCTA]TCTA</td><td>Platform         Sanger         Sanger         MiSeq         Sanger         MiSeq         Sanger         MiSeq         Sanger         MiSeq         Sanger         Sanger&lt;</td><td>Reference         Zhou et al. 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Forensic DNA Typing: Wethodology [2] (rows in white, see book for complete references), from more recent literature [3-5](rows in blue), or from this project (rows in red), grouped by repeat motif (motifs and subunit size ranges shown in dark gray). This table contains 91 unique sequences for 33 length-based genotypes. Then number of unique sequences will continue to grow as more samples are sequenced. Top row: consensus motif at D21S11, color coded to match Figure 8.

## NOMENCLATURE

STR genotypes based on sequence data should maintain back-compatibility with length-based genotyping. The original guidance document for length-based genotypes [6] is paraphrased here:

### **Guidelines for STR sequence and repeat designations**

- In protein coding genes, pseudogenes, and introns, the coding strand should be reported
- For loci that are not known to be coding, the sequence originally described in the literature is the standard reference and strand for nomenclature
- If forensic nomenclature is already established but is not in accordance with the aforementioned guidelines, the existing nomenclature should be maintained
- The first 5' nucleotides that form a motif are used to define the repeat sequence motif
- Allele designations should observe these structural principles:

Simple repeats are straightforward, the number of repeat units are counted	CSF1PO	$[AGAT]_{10} = 10$ allele
In compound repeats, alleles are designated by counting the total number of full repeats	vWA	[TCTA][TCTG] <sub>4</sub> [TCTA] <sub>13</sub> = 18 allele
Microvariant alleles are designated by counting the number of full repeats, adding a decimal point, and then counting the number of basepairs in the incomplete repeat	TH01	[AATG] <sub>6</sub> A-TG[AATG] <sub>3</sub> = 9.3 allele
Complex repeat systems should have a mathematical relationship to the bp length of a consensus allele	D21S11 consensus	$[TCTA]_{4}[TCTG]_{6}[TCTA]_{3}TA[TCTA]_{3}TCA[TCTA]_{2}TCCATA[TCTA]_{9}$ $\frac{119 \text{ bp} - 11 \text{ bp}}{4} = 27 \text{ allele}^{*}$
For more highly variable systems, alleles should be identified according to their size in bp, compared to a sequenced ladder	D21S11 deletion in "constant" region	$[TCTA]_{4}[TCTG]_{6}[]_{3}[TCTA]_{3}TCA[TCTA]_{2}TCCATA[TCTA]_{9}$ <u>105 bp - 11 bp</u> = 23.2 allele* 4

\*Note: Designation of D21S11 alleles has changed since the guidelines [6] were published, the above example reflects current nomenclature, where bases shown in gray are "not counted" toward the allele designation.

### NGS Nomenclature Considerations and Possibilities

Obtaining full sequence data at forensic STR loci will be within reach of forensic casework and databasing laboratories in the near future. How this information will be used for comparisons and database searching, reported to investigators, and stored, are questions that will need to be addressed prior to implementation. Three options for representing the sequence data, and their possible applications, are outlined below.

### (1) Complete Sequence String The entire string of generated sequence, including all flanking regions:

ATCATACCCTTTATATATATATAACCTTAAAATAACTCCATAGTCA

(2) Bracketed sequence This format is described in detail in the recent article by Gelardi, et al. [4]. It primarily consists of the repeat region, with repetitive elements enclosed in brackets and a numeric representation of the repeat length (as seen in Table 1 and in [2-6]). Additionally, polymorphisms (SNPs or InDels) in the flanking regions should be identified by their "rs" number (the dbSNP ID number, e.g. rs206437, see Figure 8). These rs numbers correspond to specific locations in the GenBank human genome assembly (current version GRCh38), and therefore eliminate the ambiguity that could result from lab-originated designations such as "upstream 13 bp C $\rightarrow$ T". If an rs number is not present in dbSNP for a particular flank polymorphism, the data can be submitted to NCBI for rs number assignment; however, some lab-specific designation may be needed in the interim.

(3) Unique Identifier A designation for each allele, either numeric (representing the repeat length) with an additional sequence-specific designator and flank polymorphism designator (e.g. "13d rs206437C" where 13 is the repeat length, d is the sequence version, and the rs number is a flank polymorphism), or a computer-generated code that is applied to each unique sequence string within a defined region (e.g. "@j\*5").

**Reporting/Manual Comparisons** Any or all of the above options could be used to report STR region sequences. If the unique identifier can be readily "decoded" by a human, this may be helpful for quick comparisons. The bracketed sequence is intuitive and may help in explaining results to the investigator. The complete sequence could be appended to the report.

**Database Searching** The ideal nomenclature for database searching is unambigous and computationally inexpensive (i.e. fast). The two most likely possibilities are the computer-generated unique identifier and the complete sequence string.

**Data Storage** The string of nucleotides from the complete region sequenced, as well as the corresponding quality scores (as reported in the .fastq files that are automatically generated in an NGS run) will need to be maintained for re-analysis/possible future analyses. In this project, sequencing 24 loci at approximately 1000x coverage per locus on the MiSeq generates .fastq files of approximately 50 MB per sample. Based on these metrics, .fastq files from 20,000 samples could be stored on a 1 TB drive (current cost < \$100). The .fastq files are generated by the instrument itself, using signal detection algorithms that have been optimized by the manufacturer. If it is possible for the NGS user to make changes to these algorithms for a particular NGS platform, then all files generated from the sequencer should be maintained. Within this project, maintaining all files would equal approximately 200 MB per sample, meaning approximately 5,000 samples could be stored on a 1 TB drive. It should be noted that larger storage systems are less expensive per unit of data.

Summary/Conclusions Sequencing more population samples at forensic STR loci will help guide nomenclature decisions. As was the case with mtDNA, phylogenetic approaches may be useful. In addition, the informatic approaches available/created for genotyping and databasing of sequences is an important factor. These issues should be addressed by the global forensic community, and we encourage an open dialogue among forensic experts in forums such as an ISFG subcommittee, the SWGDAM NGS Working Group, and a NIST-OSAC subcommittee.

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