

***ZBTB24*, a gene associated with human immunodeficiency-
centromere instability-facial anomalies (ICF) syndrome, regulates
centromeric and pericentromeric heterochromatin formation**

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*"I was here with a throng of companions,
Vivid yet those crowded months and years.
Young we were, schoolmates,
At life's full flowering;
Filled with student enthusiasm
Boldly we cast all restraints aside."*

-----Mao Zedong, 1925

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Summary

Biallelic mutations in ZBTB24, a POZ/BTB domain containing zinc finger protein, are known to cause human immunodeficiency-centromere instability-facial anomalies (ICF) syndrome with defect in centromeric/pericentromeric heterochromatin. However, it remains unexplored how ZBTB24 could regulate centromeric/pericentromeric heterochromatin formation. Here using ChIP-seq, we first observed the enriched DNA binding of ZBTB24 in the vicinity of centromere. Loss-of-function experiments further demonstrated the essential role of ZBTB24 on centromeric/pericentromeric heterochromatic formation. Moreover, via genome-wide analysis of proteins interacted with ZBTB24, in addition to several known heterochromatin regulators, we identified TRIM28, which has been established as a scaffold protein in regulating facultative heterochromatin. Importantly, we could validate functional relevance of the interaction between these two proteins and demonstrate their synergistic effect on regulating centromeric/pericentromeric heterochromatin. Overall, our study represented a direct investigation of centromeric/pericentromeric heterochromatin regulation in human. We, for the first time unambiguously established a zinc-finger protein as an important regulator of human centromeric/pericentromeric heterochromatin. Our results provided the first mechanistic insight into ZBTB24-mediated heterochromatin regulation and extended the function of TRIM28 to the regulation of constitutive heterochromatin.

Zusammenfassung

Biallelische Mutationen im Gen ZBTB24, ein die POZ/BTB Domäne enthaltendes Zinkfinger Protein, sind bekannt dafür, im Mensch das 'immunodeficiency-centromere instability-facial anomalies' (ICF) Syndrom zu verursachen, mit Defekten im zentromeren/ perizentromeren Heterochromatin.

Dennoch ist bis heute unbekannt, wie ZBTB24 die zentromere/ perizentromere Heterochromatinbildung reguliert. Unter Verwendung der ChIP-seq Methode (Chromatin-Immunopräzipitation gefolgt von Sequenzierung) haben wir zuerst die bevorzugte DNA Bindung von ZBTB24 in der Nähe der Zentromere beobachtet. Loss-of-function Experimente zeigten anschließend die essenzielle Rolle von ZBTB24 für die zentromere/ perizentromere Heterochromatinbildung. Durch die genomweite Analyse der mit ZBTB24 interagierenden Proteine identifizierten wir, neben mehreren bekannten Heterochromatinregulatoren, das Gen TRIM28, dessen Protein sich als Gerüstprotein für die Regulation von fakultativem Heterochromatin erwiesen hat. Insbesondere konnten wir die funktionelle Relevanz der Interaktion dieser beiden Proteine zeigen, wie auch deren synergistischen Effekt für die zentromere/ perizentromere Heterochromatinbildung. Zusammengefasst untersucht unsere Studie unmittelbar die zentromere/ perizentromere Heterochromatinregulation im Mensch. Wir haben als erste ein Zinkfingerprotein als wichtigen Regulator der menschlichen zentromeren/ perizentromeren Heterochromatinbildung eindeutig identifiziert. Unsere Ergebnisse bieten die ersten mechanistischen Einblicke in die ZBTB24 bedingte Heterochromatinregulation and erweitert die Funktion von TRIM28 um die Regulation des konstitutiven Heterochromatins.

1. Introduction

1.1 The eukaryotic centromere structure and formation

1.1.1 Function of eukaryotic centromere

Centromere is a specialized region of chromosome, which plays essential roles in eukaryotic cells. It forms the base to recruit diverse proteins responsible for kinetochore assembly to mediate cell mitosis, maintain chromosomal stability and genetic information inheritance (Gieni, Chan, & Hendzel, 2008; Guenatri, Bailly, Maison, & Almouzni, 2004; Pidoux & Allshire, 2000). Eukaryotic cells have developed series of structural and regulatory apparatus to retain genomic integrity and stability during each cell cycle. Before cells begin to divide, chromosomes were firstly duplicated and condensed into sister chromatids, then the sister chromatids aligned to equatorial plate during metaphase and equally segregated into opposite polar. In this procedure, the central phenomenon regulating chromatid segregation is assembly of attachment site for microtubule, called Kinetochore. As the primary interface between chromosome and mitotic spindle, the kinetochore could mediate chromosome movement during mitosis and sense errors of chromosome attachment to mitotic spindle (Chan, Liu, & Yen, 2005; Cleveland, Mao, & Sullivan, 2003; Maiato, DeLuca, Salmon, & Earnshaw, 2004). The centromere is the chromosomal basement for Kinetochore assembly and CENP-A, CENP-B, and CENP-C, the three key proteins which bind to centromere repeat regions directly and formulate the precursor of kinetochore (Schueler & Sullivan, 2006).

Because centromere plays essential role in genetic stability and cell cycle progression, dysfunction of centromere usually causes series of diseases deficient in chromosomal integrity and comprehensive development. For example, almost 30% of breakpoints were in pericentromeric region in osteosarcoma tumors (Bayani et al., 2003). Similarly, jumping translocations were also implicated with a high frequency at centromeric and pericentromeric

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regions in prostate cancer (Squire, 2000; Vukovic et al., 2007). In addition, some congenital disorders were related to centromere instability as well, such as human immunodeficiency-centromere instability-facial anomalies (ICF) syndrome, which will be discussed later.

1.1.2 Genomic structure of eukaryotic centromeres

In genomic sequence level, centromere is extremely variable among different species. Fission yeast (*Schizosaccharomyces pombe*) centromere has a non-repetitive central sequence (cnt) occupying 4-7 kb in genome. Flanking cnt element is centromere specific innermost repeats (imr). Both of cnt and imr elements make up core domain which contributes to kinetochore assembly. Meanwhile, there are long tandem arrays of outer repeats (otr) surrounding core centromere domain in *S. pombe* (Blackwell et al., 2004; Carroll & Straight, 2006) (Figure 1.1). Compared with *S. pombe*, centromeres in metazoans are more complex. Mouse centromere contains two types of satellite repeats which are called minor satellites (~600 kb of 120bp units; Guenatri et al., 2004) and major satellites (6 megabases of 234 bp units; Guenatri et al., 2004). Minor satellites are located in core centromere, adjacent to it are pericentromere enriched with major satellites. (Guenatri et al., 2004; Joseph, Mitchell, & Miller, 1989; Wong & Rattner, 1988).

Human centromere sequences are even more complex, which contains huge arrays of tandem repetitive Alpha satellites (ALR) (Figure 1.1). Alpha satellites can be divided into two groups named chromosome-specific higher-order array of Alpha satellite and monomeric Alpha satellite. Higher-order Alpha satellites can span around 3-5 Mb and are highly homogenous. They are located on the core centromere region where kinetochore assembled (C. Lee, Wevrick, Fisher, Ferguson-Smith, & Lin, 1997; Schueler & Sullivan, 2006; Willard, 1985, 1989). In contrast, monomeric Alpha satellites constitute pericentromeric region where the divergent 170-bp monomers are arranged in a tandem, head-to-tail fashion. (Alexandrov et al., 1993; Maio, 1971; Marquès-Bonet et al., 2004; Rosenberg, Singer, & Rosenberg, 1978;

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Schueler & Sullivan, 2006). In addition, the stretch of monomeric Alpha satellite is frequently interspersed with human satellite 2, 3 repeats (Sat2/3), which are enriched with 5bp (GGAAT) microsatellites and other retro-transposons (Grady et al., 1992; J. H. Kim et al., 2009; Marquès-Bonet et al., 2004; Prosser, Frommer, Paul, & Vincent, 1986; Schueler & Sullivan, 2006; Schueler et al., 2005; Vissel, Nagy, & Choo, 1992) (Figure 1.2).

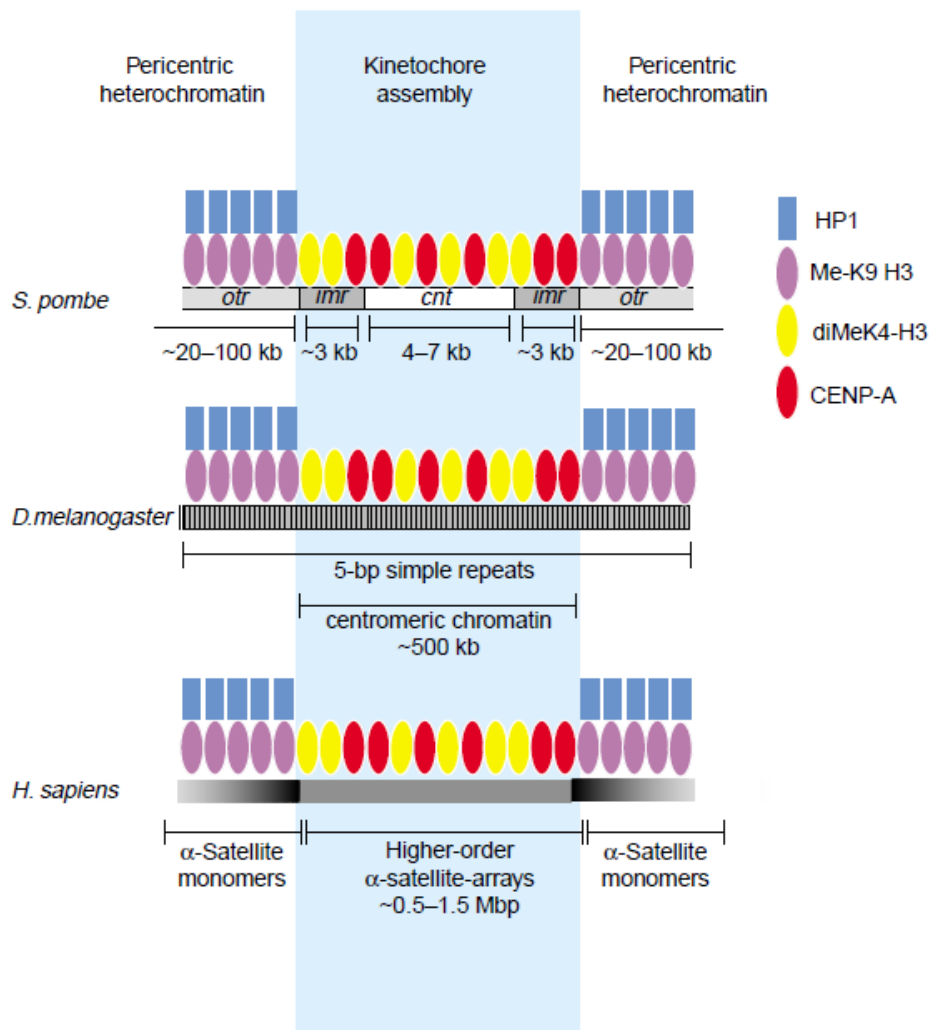


Figure 1.1 - The genomic and epigenetic structure of centromere among *S. pombe*, *D. melanogaster* and *H. sapiens*. The genomic sequence composition are very divergent among species which differs in size and contains distinct repetitive regions. However, the overall epigenetic signatures are conserved across species. (Carroll & Straight, 2006)

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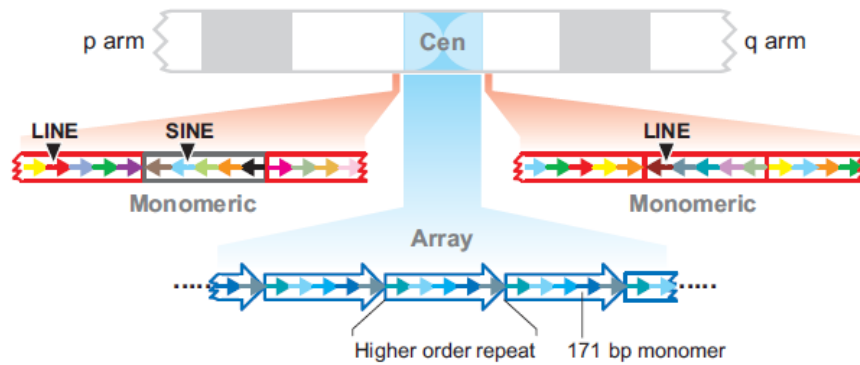


Figure 1.2 - The genomic structure of centromeric and juxtacentromeric region of human. Different satellite repeats are indicated in the chart. (Schueler & Sullivan, 2006)

1.1.3 Chromatin structure and epigenetic modifications of eukaryotic centromeres

Although the genomic sequences of centromere are highly divergent among species, to some extent, the epigenetic modifications are conserved. The centromere and juxtacentric regions are transcriptionally silent and embedded with constitutive heterochromatin regardless of species variety (Bulut-Karslioglu et al., 2012; Carroll & Straight, 2006; Grewal & Elgin, 2007). All the studied core centromere among species until now are defined by a H3 histone variant, centromere protein A (CENP-A), which can recruit series of proteins to formulate kinetochore (Amor, Kalitsis, Sumer, & Choo, 2004). However, it seems that core centromere also contains normal histone 3 (H3) which inserts into the chromatin gap between CENP-A blocks (Sullivan & Karpen, 2004). In human, CENP-A, CENP-B and CENP-C are three core components of centromere and play key role on prekinetochore assembly. Theoretically, CENP-B, a DNA binding protein, could bind to 17-bp sequence motif (CENP-B box) at every other 170-bp monomer of a higher-order array. Binding of CENP-B could phase nucleosome so that the centromere DNA is wound around nucleosomes containing CENP-A and other histones (Figure 1.3) (Schueler & Sullivan, 2006). Meanwhile, two dimensional interspersed CENP-A and H3 nucleosomes could generate a unique three dimensional structure that stacks

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of CENP-A nucleosomes face outside of chromosome to further recruit additional kinetochore proteins and direct sister kinetochores toward opposite spindle poles. On the contrary, H3 subdomains are positioned toward interior face of chromosome to establish heterochromatin and recruit centromeric cohesion protein (Figure 1.4) (Schueler & Sullivan, 2006).

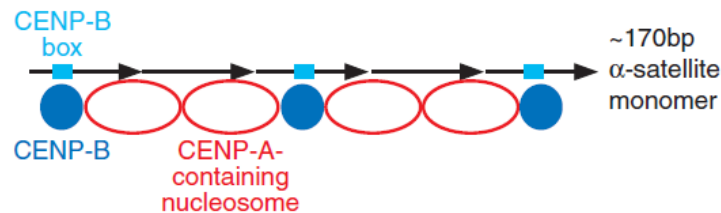


Figure 1.3 - Arrangement of CENP proteins on Alpha satellite repeats. CENP-B binds specifically to 17-bp sequence motif which is present within every two monomeric Alpha satellite. Binding of CENP-B make DNA be wound around nucleosomes containing CENP-A and core histones. (Schueler & Sullivan, 2006)

It has been reported that both of minor- and major- satellites in mouse are labeled with methylated histone H3 (H3K9me) (Guenatri et al., 2004). Immuno-fluorescence on human centromere revealed that human core centromere where kinetochore assembled lacked heterochromatin repression signatures such as H3 Lys9-triMe (H3K9me3), H3 Lys9-diMe (H3K9me2), and de-acetylation of H3. In contrast, H3 Lys4-diMe (H3K4me2), which is considered as "open" chromatin and "poised" transcription marker was significantly enriched (Figure 1.1) (Sullivan & Karpen, 2004). This indicates that centromeric and pericentromeric chromatin are functionally distinct. But where is and how to define the boundary between core centromere and pericentromere on epigenetics level is still in debate. Compared with core centromere, the chromatin structure of pericentromeric region has been more investigated and it is routinely termed "pericentromeric heterochromatin" because of typical heterochromatin features, highly condensed structure and constitutive transcription repression.

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In *S. pombe*, the pericentromeric heterochromatin is enriched in Swi6 (The fission yeast analog of Heterochromatin protein 1-Hp1), methylation on Lys9 of H3 and depleted of acetylated histone H3. This model is carried forward upon most of metazoans such as mouse and human. As we mentioned before, the major satellite repeats in mouse are enriched with H3K9me3 and H4K20me3 (Bulut-Karslioglu et al., 2012; Lachner, Sengupta, Schotta, & Jenuwein, 2004; Wongtawan, Taylor, Lawson, Wilmut, & Pennings, 2011). Human pericentric heterochromatin is predominantly marked with H3K9me2 and H3K9me3 (Sullivan & Karpen, 2004). Therefore, in general, methylation on Lys9 of H3, especially H3K9me3, is the common signature of pericentric heterochromatin. It plays a key role on heterochromatin protein1 (HP1) recruitment to facilitate heterochromatin formation (Bulut-Karslioglu et al., 2012; Nozawa et al., 2010; Rosnoblet, Vandamme, Völkel, & Angrand, 2011).

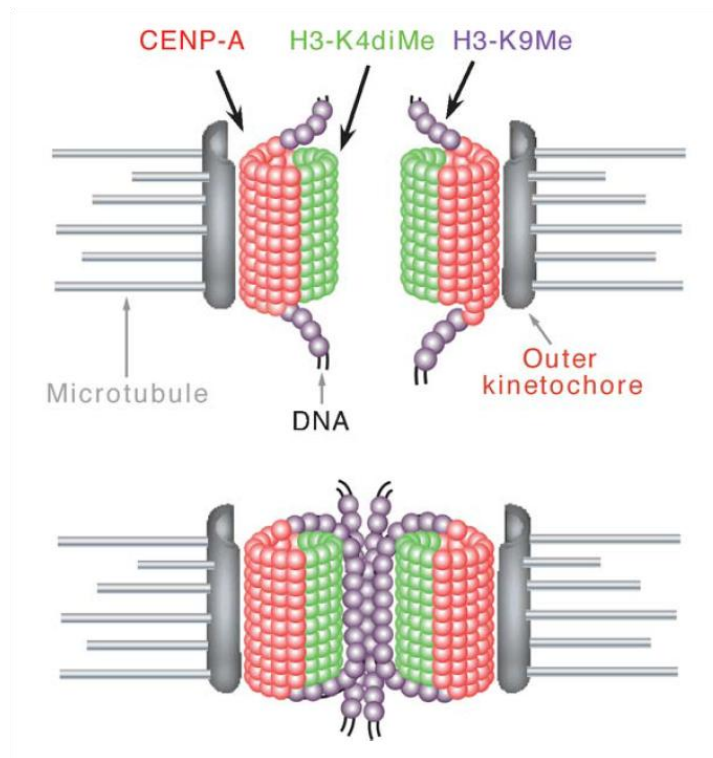


Figure 1.4 - Three dimensional organization of human centromere regions. At metaphase (upper panel), when chromosomes condense, the coiled centromeric DNA make stacks of

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CENP-A present to the poleward face of chromosome where they can interact with kinetochore complex. Meanwhile, the H3K9 methylation defined heterochromatin are targeted between sister kinetochores which is distinct from core centromere chromatin (lower panel). (Schueler & Sullivan, 2006)

DNA methylation is another epigenetic marker of centromeric and pericentromeric heterochromatin. It is conserved in metazoans and synthesized by three kinds of DNA methyl-transferases (DNMTs) in mouse and human: the maintenance methyl-transferase DNMT1 (Rountree, Bachman, & Baylin, 2000), the de novo methyl-transferase DNMT3A and DNMT3B (Bachman, Rountree, & Baylin, 2001; Loria, Duke, Rand, & Hobert, 2003). It has been reported that DNA methylation could prevent formation of facultative heterochromatin marker H3K27me₃ and in this process (Saksouk et al., 2014), whereas H3K9me₃ is essential for targeting DNMT1 (Loria et al., 2003; Saksouk et al., 2014), which indicates an intimate relationship between Histones and DNA modification and their redundant functions on pericentric heterochromatin formation (Saksouk et al., 2014).

1.1.4 The mechanisms of eukaryotic centromeric and pericentromeric heterochromatin formation

In addition to chromatin structure of eukaryotic centromeres, the mechanisms underlying pericentromeric heterochromatin formation have been studied. Many transcription regulators and chromatin state mediators are involved, some of which are conserved across different species (Carroll & Straight, 2006). In general, the assembly and inheritance of pericentromeric heterochromatin partially relies on the formation of methylation of H3 on Lysine 9 (H3K9me) mediated by histone methyltransferase Suv39h, binding of Heterochromatin protein1 (HP1) to H3K9me₃ signature and RNA interference (RNAi) machinery (Grewal & Moazed, 2003).

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The best characterized model is in fission yeast. There, the pericentromeric heterochromatin is assembled on repetitive region of Otr centromeric DNA and is crucial for sister chromatids cohesion (Bernard et al., 2001; Nonaka et al., 2002). A RNAi mediated heterochromatin formation mechanism has been well elucidated in *S. pombe*. Small double strand siRNAs processed from centromeric transcripts could mediate the targeting of Histone-modifying factors (Grewal & Elgin, 2007; Hall et al., 2002; Volpe et al., 2002), including Clr4 containing complex, to methylate H3K9 (E.-J. E. Hong, Villén, Gerace, Gygi, & Moazed, 2005; Horn, Bastie, & Peterson, 2005; Jia, Kobayashi, & Grewal, 2005; Nakayama, Rice, Strahl, Allis, & Grewal, 2001; Rea et al., 2000; Thon et al., 2005). This methylation could recruit heterochromatin protein Swi6 (Bannister et al., 2001; Nakayama et al., 2001; Partridge, Scott, Bannister, Kouzarides, & Allshire, 2002; Sadaie, Iida, Urano, & Nakayama, 2004), which, together with other proteins, mediate the spreading of various factors (Grewal & Elgin, 2002, 2007; Hall et al., 2002), such as SNF2- and histone deacetylase (HDAC)-containing repressor complex (SHREC). SHREC further facilitates the organization of higher-order chromatin structure that is essential for heterochromatin functions, including transcriptional silencing (Grewal & Elgin, 2002, 2007; Sugiyama et al., 2007; Yamada, Fischle, Sugiyama, Allis, & Grewal, 2005) (Figure 1.5).

To what extent could RNAi mechanism described in *S. pombe* regulate heterochromatin formation in metazoans is still elusive. Since many of them, including *Drosophila* and mammals, seem to lack canonical RNA-dependent RNA polymerase (Grewal & Elgin, 2007). This implies compared with fission yeast, metazoans may carry different heterochromatin formation pathway although it seems that siRNA still have some functions in metazoans heterochromatin formation as well. For example, the *Drosophila* genome encodes five PAZ and PIWI domain containing proteins, PIWI, aubergine (AUB), AGO1, AGO2 and AGO3, which can bind small RNAs (Kalmykova, Klenov, & Gvozdev, 2005). Mutations of AGO2 in early *Drosophila* embryos showed deficiencies on chromosomal condensation, nuclear kinesis

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and spindle assembly (Deshpande, Calhoun, & Schedl, 2005), all of which potentially is correlated with centromeric heterochromatin dysfunction. Besides, Dicer deficient mouse embryonic stem cells manifested reduced small RNAs from minor/major satellite repeats and epigenetic silencing of centromere (Kanellopoulou et al., 2005). However, until nowadays, heterochromatin formation in metazoon is only partially understood, the detailed mechanism still needs to be further investigated.

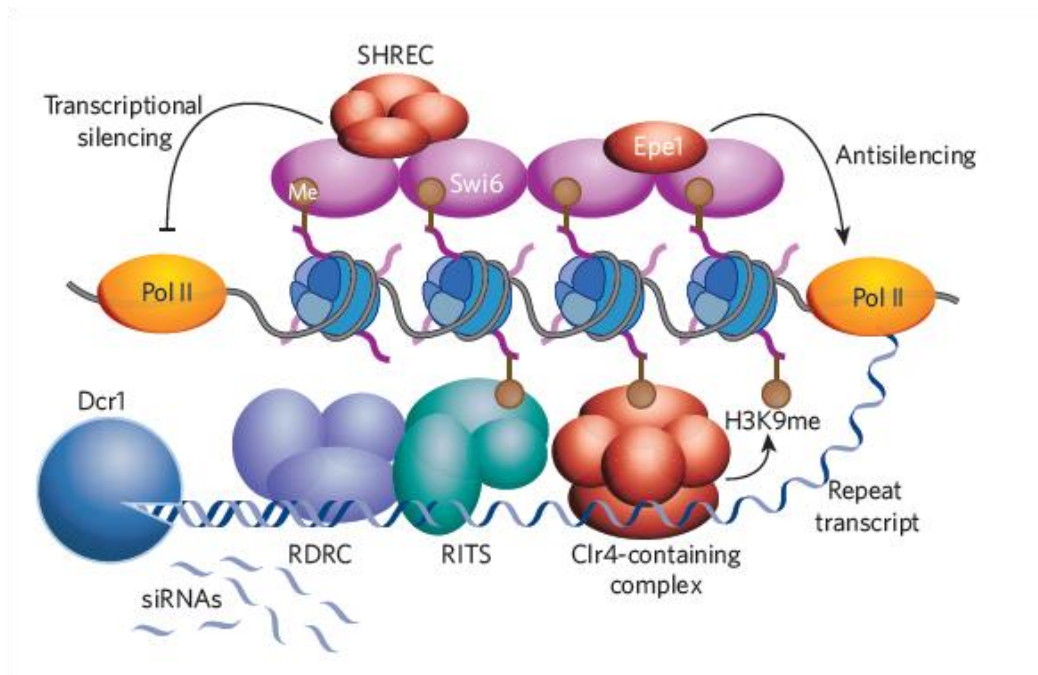


Figure 1.5 - The model of RNAi mediated heterochromatin assembly and silencing in *S. pombe*. The centromeric transcripts produced by Pol II are processed into siRNAs by RITS and RDRC complexes at first and then targets Clr4-containing complex to centromeric heterochromatin region to modify Histones. The methylation of H3K9 by Clr4 can recruit Swi6 together with other factors such as SHREC, which is essential for high order organization of heterochromatin. (Grewal & Elgin, 2007)

Recently, a transcription factor mediated mouse pericentromeric heterochromatin formation model had been proposed. that compared with euchromatin, heterochromatic regions lack coordinated binding and interaction of transcription factors (Figure 1.6) (Bulut-Karslioglu et

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al., 2012)., which would defy the controlled and processed RNA transcription. In this study, Pax3 and Pax9, two known transcription factors, were shown to be redundant regulators for mouse pericentric heterochromatin. They repressed transcription from major satellite repeats, maintained heterochromatic signature and integrity. Besides these two factors, multiple transcription factors binding sites on major satellite repeats such as Sall1, Gfi1b and Zeb1 have also been identified. This indicated in cells other than ESC and fibroblasts, other Pax proteins or other cell specific transcription factors could mediate heterochromatin silencing as well. In addition to mouse, it seemed that the same mechanisms also existed in other organisms. For example, the *S. pombe* mat locus contained binding sites of CREB family transcription factors (Jia, Noma, & Grewal, 2004). In *Drosophila*, zinc-finger containing proteins such as SUV3-7 (Cléard & Spierer, 2001), GAGA (Tsukiyama, Becker, & Wu, 1994), Prod (Platero, Csink, Quintanilla, & Henikoff, 1998) were associated with heterochromatic chromocentre. Moreover, sequence analysis of human Alpha satellites (ALR) revealed ZEB1, an important zinc finger and homeodomain developmental regulator, was putative factor for safeguarding human heterochromatin (Bulut-Karslioglu et al., 2012). This new perspective needs to be further explore in the formation of human centromeric and pericentromeric heterochromatin, the mechanism of which is still underexplored till now.

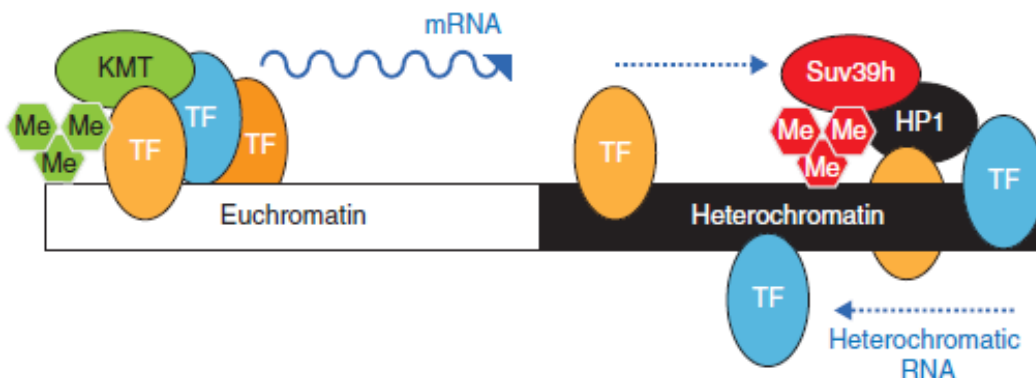


Figure 1.6 - Transcription factor based model for mouse heterochromatin formation.

The organization of transcription factors binding sites in euchromatin are highly synergistic.

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However, it is more random in heterochromatin region. TF, transcription factor; KMT, histone methyltransferase; Me, methyl group (Bulut-Karslioglu et al., 2012).

Human diseases resulted from centromere dysfunction could provided nature resources to study human centromere. By identifying the putative pathogenic mutations from patients, we can associate genes harboring the mutation with corresponding phenotypes and further elucidate underlying biological mechanisms by functional studies. In this regard, the immunodeficiency-centromere instability-facial anomalies (ICF) syndrome is one of the best disease models.

1.2 ICF syndrome, an important human disease relative to centromere dysfunction

1.2.1 The phenotypes and subtypes of ICF syndrome

Patients with ICF syndromes manifest phenotypes including facial dysmorphism, variable immunodeficiency, immuno-globulin defects and developmental retardation (De Greef et al., 2011; von Bernuth et al., 2014). Some of them also manifest mental disability, motor developmental delay and gastrointestinal problems as well. The heterogeneous clinical phenotypes of ICF patient reflect that although it may be classified as one disease clinically, the underlying pathogenic mechanisms and genetic background are diverse.

The genetic defects causing ICF syndrome have been revealed. According to the genetic mutations identified, ICF could be classified into three subtypes, which are named as ICF1, ICF2 and ICFX. Around 60% of ICF syndrome is due to the mutations in DNMT3B, which encode a de-novo DNA methyltransferase, and referred as ICF1 (Hansen et al., 1999; Xu et al., 1999). The other cases are either ICF2 (~30%) caused by mutations in a zinc-finger and BTB-domain containing protein, ZBTB24 or ICFX without any identified pathogenic mutations (Cerbone et al., 2012; Chouery et al., 2012; De Greef et al., 2011; Nitta et al., 2013; Weemaes et al., 2013). Very recently, Peter E. Thijssen et al. reported that cell division cycle associated 7 (CDCA7) and helicase, lymphoid-specific genes (HELLS) were mutated in 10

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ICFX patients (Thijssen et al., 2015). These data further highlight the genetic heterogeneity of ICF syndrome.

In cytology level, most of ICF patients harbor more or less dysmorphisms of chromosomes which is even more frequent in Chr1, 9, 16 and more significant in centromere region. Chromosomal stretching, mispairing, multipolar, decondensation and multibrach chromosomes are often observed in ICF patients, The translocation and deletion also exist occasionally (Fryns et al., 1981; Maraschio, Zuffardi, Dalla Fior, & Tiepolo, 1988). Moreover, besides deformation of entire chromosome, centromeric and pericentromeric decondensation was identified.

Compared with ICF1 patients who manifest hypo-methylation of HSATII and SATIII in pericentromere, ICF2 and ICFX patients have additional DNA hypo-methylation of Alpha satellites (ALR) and de-condensed centromere had been observed in ICF2 lymphocytes (De Greef et al., 2011). This indicates ICF2 and some of ICFX may share similar pathological pathway.

1.2.2 The underlying pathogenic mechanisms for ICF syndromes

The detailed molecular mechanisms regarding ICF syndrome are still underexplored. In addition to hypomethylation in juxtacentromere region such as Satellite 2/3, genome-wide bisulfite sequencing showed decrease of DNA methylation of 42% across the genome in DNMT3B mutated ICF1 lymphocytes, with most profound reduction in inactive heterochromatic regions, satellite repeats and transposons (Heyn et al., 2012). It is easy to link global hypomethylation to malfunction of DNMT3B in ICF1 because the proteins encoded by DNMT3B is a classical de-novo methyltransferase. DNA methylation is a very important epigenetic modification which takes part in various biology phenomenon such as heterochromatin maintenance, global transcription regulation, chromosome stability, embryonic stem cells and adult lineages (Smith & Meissner, 2013). In this case, DNA

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hypomethylation resulted from DNMT3B could result in series of developmental and cellular defects. To further explore this, Bilian Jin et al. investigated altered epigenetic modifications and gene expression, compared lymphoblastoid cell lines (LCLs) derived from ICF1 patient with those from healthy donors. Their study showed significant expression changes of the genes in ICF1 which were critical for development, immune function and neurogenesis. Approximately half of up-regulated genes in ICF1 cells carried loss of DNA methylation, transcriptional repression Histone markers (H3K27me3) and gained active Histone modifications such as H3K9 acetylation. In addition, they observed binding defects of SUZ12, component of PRC2 polycomb repression complex and DNMT3B in derepressed genes, including many homeobox genes critical for immune system, brain and craniofacial development (Jin et al., 2008). Meanwhile, Yoshihide et al. reported a mouse model harboring mutations in DNMT3B as identified in ICF1 patient. This mouse manifested hypomethylation of satellite repeats, low body weight, distinct cranial facial anomalies and T cell apoptosis which were identical to ICF1 phenotypes. This further demonstrated direct pathogenic links between DNMT3B and ICF1 syndrome (Ueda et al., 2006). But how DNMT3B could regulate ICF related biological phenomenon in detail need to be further investigated. Interestingly, it has been reported that in ICF1 cells, *ZBTB24*, the gene mutated in Type 2 ICF patients, harbored hypermethylated DMR in its promoter region (Heyn et al., 2012). This finding revealed inactivating hypermethylation of *ZBTB24* might also contribute to ICF1 phenotypes.

Pathogenic mechanism of ICF2 and ICFX syndromes is still elusive. Although presenting the similar clinical phenotypes, in molecular level, besides hypomethylation in pericentromeric region in ICF1, ICF2 and ICFX carry additional hypomethylation on centromeric Alpha satellite (ALR) repeats (De Greef et al., 2011). Decondensation of centromere/pericentromere has been observed in ICF2/X patient cells as well (Thijssen et al., 2015; von Bernuth et al., 2014). Depletion of *ZBTB24*, *CDCA7* and *HELLS*, but not *DNMT3B*, resulted in

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hypomethylation of mouse centromeric satellite repeats (Thijssen et al., 2015). Here our study focused on the pathogenic gene of ICF2 syndrome, *ZBTB24*.

1.3 *ZBTB24*, an unidentified gene associated with human ICF2 syndrome

ZBTB24 encodes a zinc finger protein which comprises a Broad-complex, Tramtrack and Bric-à-brac domain (BTB), an AT hook domain and 8 consecutive C2H2 zinc finger domains. According to the protein structure, *ZBTB24* was classified into a gene family called POZ (Poxvirus and Zinc finger)/BTB domain containing zinc finger proteins (ZBTB) family, (Table I) (S. U. Lee & Maeda, 2012). In human, there are 46 members in ZBTB family which profoundly function on transcription regulation, hematopoietic lineage commitment and immune-system development (Table II) (S. U. Lee & Maeda, 2012; Siggs & Beutler, 2012). For example, the *ZBTB7A*, *PATZ1/ZBTB19*, *BCL6/ZBTB27*, *BCL6B /ZBTB28* and *ZBTB32* are critical to T cell development while *ZBTB1*, *LRF /ZBTB7A*, *ZBTB10*, *MIZ1/ZBTB17*, *BCL6/ZBTB27* and *ZBTB32* are known regulator of B cell maturation (Bilic & Ellmeier, 2007; Chevrier & Corcoran, 2014). Besides, recent reports revealed that some members in this family such as *ZBTB1* and *ZBTB7A* acted as integrator protein or transcription regulator and further regulated chromosomal remodeling and tumor suppression (H. Kim et al., 2014; Liu et al., 2014). In general, BTB domain mediates protein-protein interaction and the proteins containing this domain could form homo-/hetero- dimer and oligomer with other proteins (Perez-Torrado, Yamada, & Defossez, 2006; Stogios, Downs, Jauhal, Nandra, & Privé, 2005). Several BTB domain-containing zinc finger proteins are known to regulate transcription via interacting with transcriptional co-factors. Known co-factors include SIN3 transcription regulator family member A (SIN3A), Nuclear receptor corepressor 1 and 2 (NCOR1 and NCOR2/SMRT) (David et al., 1998; Dhordain et al., 1997; S. H. Hong, David, Wong, Dejean, & Privalsky, 1997; Lin et al., 1998). The AT hook motif which only exist in *ZBTB24* and *PATZ1* of ZBTB family, has preference to bind to AT rich

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sequences that are frequently found in repeat region, including centromeric and pericentromeric satellite DNA. Cys₂His₂-like (C₂H₂) zinc finger domain is the best characterized zinc finger class by far which could be found in many transcription factors. The C₂H₂ zinc fingers have a variety of functions such as DNA/RNA binding and protein-protein interaction, but it is the best known for its role on the binding between proteins and sequence specific DNA. It contains a simple ββα fold and amino acid motif : X₂-Cys-X_{2,4}-Cys-X₁₂-His-X_{3,4,5}-His. In this motif, paired Cys and His residues could catch Zinc ions and then mediate binding to genomic DNA. Such a domain structure suggests ZBTB24 might be able to bind to human centromeric/pericentromeric region and thereafter recruits other cofactors to take its function.

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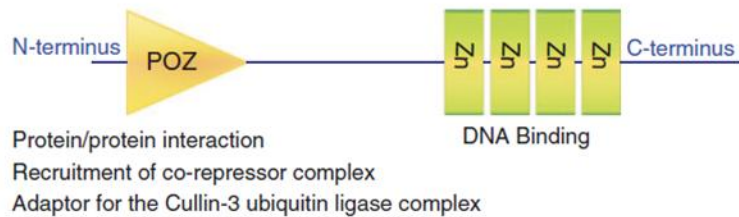
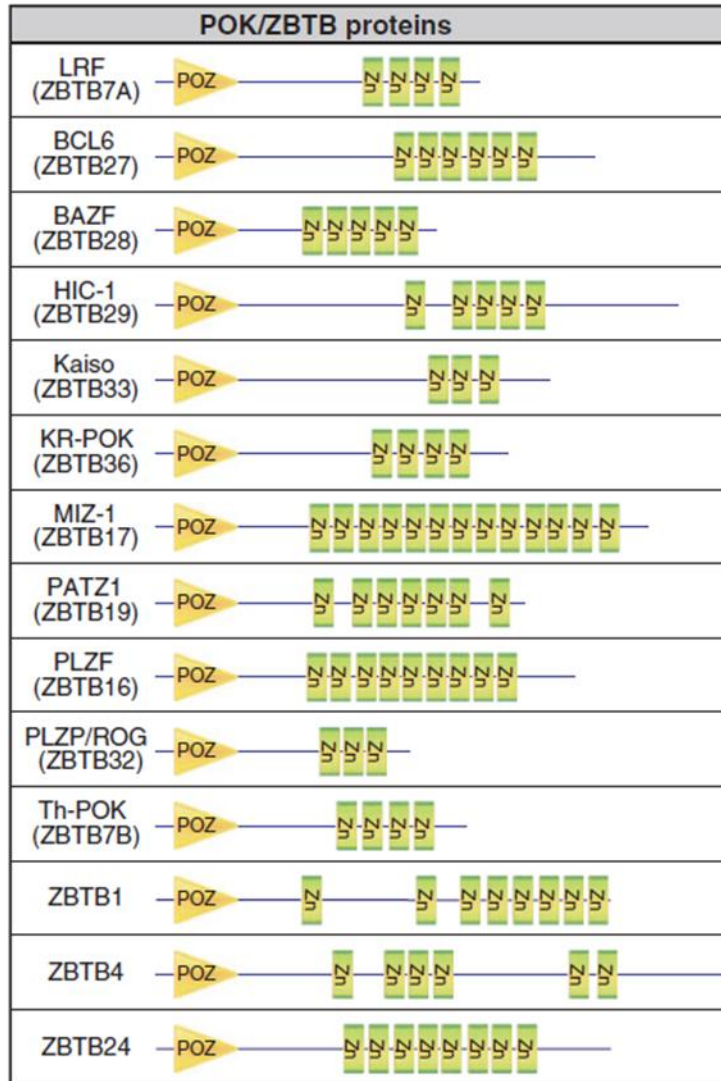


Table I - The domain structure of some members of ZBTB family proteins. POZ/ BTB domain and Zinc finger domains are indicated in the chart (S. U. Lee & Maeda, 2012).

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Zbtb no.	Synonyms	Expression	Function
Zbtb1	ZNF909	Pre-B cells	Lymphoid development
Zbtb2	ZNF437	Gastric cancer	Cell proliferation
Zbtb3			
Zbtb4	KAISO-L1, ZNF903	Breast/prostate cancer	Cell cycle regulation, repression of p21
Zbtb5			Cell cycle regulation, repression of p21
Zbtb6	ZID, ZFN 482		
Zbtb7	FBI-1, LRF, pokemon, ZNF857A, Zbtb7a	B cells, erythrocytes, osteoclasts	Cell cycle, survival, osteoclast, erythroid and lymphoid lineage
Zbtb15	c-Krox, Th-POK, Zbtb7b , ZFP67, ZNF857B	Thymocytes, chondrocytes	CD4 T- and NKT-cell development, ECM formation
Zbtb36	APM-1, Kr-pok, ZNF857C, Zbtb7c	Kidney, brain, BM cancer	Cell cycle regulation
Zbtb8A	BOZF1, Zbtb8, ZNF916A	Prostate, breast, cervix cancer	Cell cycle regulation, repression of p21
Zbtb8B	ZNF916B		
Zbtb9	ZNF919		
Zbtb10	RINZF	Colon, breast, ovarian cancer	Sp1 protein inhibitor
Zbtb11	ZNF913	Repressed in HCC	
Zbtb12	G10, NG35, D6S59E	ER-positive breast cancer	
Zbtb14	ZNF478, Zfp161 , ZF5	Lung, ovary and brain	Cell cycle regulation, dopamin transporter regulator
Zbtb16	PLZF, ZNF145		NKT biology, cell cycle and apoptosis, skeleton, reproduction
Zbtb17	MIZ1, pHZ-67, ZNF151, ZNF60	Ubiquitous	Gastrulation, cell cycle progression, B-cell development, GC
Zbtb18	C2H2-171, TAZ-1, RP58, Zfp238	Brain	CNS development
Zbtb19	MAZR, RIAZ, Patz1 , ZNF278, ZSG	Thymocytes, stem cells, testis	CDB T-cell development, ES cell identity, spermatogenesis, survival
Zbtb20	ODA-8S, DKFZp566F123, DPZF	Nervous, liver, B1, GC, ASC	CNS development, liver metabolism, ASC survival
Zbtb21	ZNF295		Associated with down syndrome
Zbtb22	BING1, ZNF297A, fruitless, fru, Zbtb22A		
Zbtb23	dJ322G13.2, Zbtb23, Gzf1	Kidney	Tubular function
Zbtb24	BIF1, Patz2, ZNF450		Immunodeficiency, centromeric instability and facial anomalies
Zbtb25	KUP, ZNF46	T cells	NFAT repressor
Zbtb26	ZNF481		
Zbtb27	LAZ3, BCL5, BCL6A, ZNF51, Bcl6	GC, T _{FH} , osteoclast, macrophage	B, NKT, memT, cDC development, GC B and T _{FH} , proliferation and survival inhibit inflammation
Zbtb28	Bcl6b , BAZF	Epithelial cells, T cells	Activation of naive T cells, angiogenesis
Zbtb29	Hic1 , ZNF901		Tumor suppressor
Zbtb30	Hic2 , HRG22, ZNF907		
Zbtb31	SBBIZ1, ZNF902, Mynn	Muscle, neuromuscular junction	Potential synaptic gene regulator
Zbtb32	PLZP, FAXF, FAZF, Rog, TZFP, ZNF53B	T cells, B1, ASCs	HSC and T-cell proliferation, cytokine secretion, MHCII repression
Zbtb33	KAISO, ZNF-kaiso, ZNF348		Gastrulation, synapse formation, Wnt signaling, inflammation
Zbtb34	ZNF918	Ubiquitous	Transcriptional repressor
Zbtb35	Zfp131	CNS, testis and thymus	Transcriptional activator
Zbtb37	ZNF908		
Zbtb38	CIBZ, ZNF921	Post-mitotic neurons	Inhibit apoptosis, promote cell cycle
Zbtb39	ZNF922		
Zbtb40	ZNF923		Bone mineral density
Zbtb41	FRBZ1, ZNF924		
Zbtb42	ZNF925	Muscle, ovary	Potential function in metabolic syndrome
Zbtb43	ZNF-X, ZNF197b, Zbtb22B		
Zbtb44	BTBD15, ZNF851		
Zbtb45	ZNF499		Glial differentiation of neural and oligodendrocyte progenitor cells
Zbtb46	BTBD4, RINZF, ZNF340, zDC	cDC, erythroid precursor, EC	Full cDC differentiation
Zbtb47	Zfp651 , ZNF651		
Zbtb48	HKR3, ZNF855	Ubiquitous	Cancer
Zbtb49	ZNF509		

Table II: List of ZBTB family proteins in human with tissue expression pattern and functions. ASC, antibody secreting cells; BM, bone marrow; CNS, central nervous system; EC, endothelial cell; ECM, extracellular matrix; ER, estrogen receptor; ES, embryonic stem

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cell; GC, germinal center; HCC, hepatocellular carcinoma; NFAT, nuclear factor of activated T cells; NK, natural killer (Chevrier & Corcoran, 2014).

1.4 Research objective and overview

Until now, the mechanism underlying human centromeric and pericentromeric heterochromatin formation is still underexplored. Biallelic mutations in ZBTB24, a POZ/BTB domain containing zinc finger protein, are known to cause ICF syndrome with defect in centromeric/pericentromeric heterochromatin. However, it remains unexplored how ZBTB24 could regulate centromeric/pericentromeric heterochromatin formation.

In this project, to investigate whether ZBTB24 could indeed regulate human centromeric and pericentromeric heterochromatin formation and if so, what is the underlying molecular mechanisms, we started with unbiased identification of ZBTB24 DNA binding sites, which turned out to be enriched in human centromeric and pericentromeric repetitive regions. Then, based on ChIP-qPCR and RNA expression analysis, we could demonstrate that two defining features of heterochromatin, i.e. transcriptional silencing and methylation of histone H3 at Lys9 (H3K9me3), were disrupted at centromeric and pericentromeric regions following ZBTB24 depletion. Consistent with previous studies (von Bernuth et al., 2014), such heterochromatin defects led to cell growth retardation and additional cell cycle arrest.

Furthermore, to establish the molecular link between ZBTB24 DNA binding and heterochromatin regulation, we sought to globally characterize its protein interaction partners. Besides many proteins composing well-known transcriptional repressor or histone modification complexes, we identified TRIM28 as a ZBTB24 interaction partner, a protein previously known as a scaffold protein with important function in regulating facultative heterochromatin formation at promoter, imprinted region as well as around transposon elements (Doerks, Copley, Schultz, Ponting, & Bork, 2002; Quenneville et al., 2011; Schultz,

Ayyanathan, Negorev, Maul, & Rauscher, 2002; Turelli et al., 2014). Finally, we could validate the functional relevance of the interaction between the two proteins by demonstrating their synergistic effect in regulating heterochromatin formation at centromeric and pericentromeric regions, particularly at those containing Sat2/3 repeats.

2. Materials and Methods

2.1 Materials

2.1.1 Cell lines

HEK 293 Flp-In T-REx Cell Line: The human embryonic kidney cell line which contains a FRT integrated site and stably expresses Tet repressor protein is kindly supported by Landthaler Lab in Max Delbrück Center for Molecular Medicine (MDC) and it is commercially available in Invitrogen (Flp-In™ 293 T-REx cell line; R780-07).

FLAG/HA tagged ZBTB24 stably overexpressed HEK Cell Lines: *ZBTB24* wild type (Wt) and mutant (Mt) CDS region were constructed into corresponded overexpressing vector and integrated into HEK 293 Flp-In T-REx Cell Line genome respectively as following described.

Lymphoblastoid cell lines: The Lymphoblastoid cell lines derived from normal controls and ICF patient were kindly provided by Prof. Dr. Hans Hilger Ropers Lab in Max Planck Institute for Molecular Genetics and Dr. Angela Kaindl in Charité - Universitätsmedizin Berlin respectively.

2.1.2 Vectors

pGEM-T Easy Vector (Promega)

pENTR/D-TOPO (Invitrogen)

pOG44 (courtesy of Landthaler Lab)

pFRT /DEST FLAG-HA (courtesy of Landthaler Lab)

pFRT /TO/DEST FLAG-HA (courtesy of Landthaler Lab)

pFRT/DEST FLAG-HA-GFP (courtesy of Landthaler Lab)

2.1.3 Cell culture mediums

Maintenance medium for HEK 293 Flp-In T-REx cell line:

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High glucose DMEM (Gibco) supplemented with 10% final concentration of FBS (heat inactivated fetal bovine serum, Gibco), 100 U/ml of penicillin, 100 µg/ml streptomycin (Gibco), 15 µg/ml Blasticidin (InvivoGen) and 100 µg/ml Zeocin (InvivoGen).

Antibiotic free medium for transfection:

DMEM with 10% final concentration of FBS.

Stably overexpressed cell line selection medium:

DMEM with 10% final concentration of FBS, 100 U/ml of penicillin, 100 µg/ml streptomycin, 15 µg/ml Blasticidin and 100 µg/ml Hygromycin.

Freezing medium:

90% FBS and 10% DMSO. Cool to 4°C before using.

2.1.4 Enzymes

Benzonase (Merck Millipore)

BsmI Restriction enzymes (New England Biolabs)

Gateway LR Clonase II enzyme mix (Invitrogen)

GoTaq DNA Polymerase (Promega)

OptiKinase (Affymetrix)

Phusion High-Fidelity DNA polymerase (Finnzymes)

RNase A (Fermentas)

SuperScript III reverse transcriptase (Invitrogen)

T7 RNA polymerase (Roche)

2.1.5 Kits and Reagents

Agencourt AMPure XP Kit (Beckman Coulter)

Agilent RNA 6000 Nano and Pico Kit (Agilent Technologies)

Agilent DNA 1000, 7500 Kit (Agilent Technologies)

ATP Gamma 32P (Perkin Elmer)

Decade Marker System (Ambion)

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Dynabeads Oligo (dT) (Invitrogen)

Dynabeads protein G (Invitrogen)

ERCC RNA Spike-In Control Mixes (Ambion)

GeneJET Plasmid Miniprep Kit (Fermentas)

Histone ChIP Kit (Diagenode)

iDeal ChIP Kit for Histones (Diagenode)

iDeal ChIP Kit for transcription factors (Diagenode)

Illumina Sequencing Kit (Illumina)

Lipofectamine 2000 reagent (Invitrogen)

Lipofectamine RNAiMAX reagent (Invitrogen)

Transcription Factor ChIP Kit (Diagenode)

TruSeq Stranded Total RNA Sample Preparation Kit (Illumina)

TruSeq ChIP Sample Preparation Kit (Illumina)

TUOBO DNA free Kit (Ambion)

pENTR/D-TOPO Cloning Kit (Invitrogen)

Premade Z-Competent E. Coli Cells (ZYMO RESEARCH)

QIAquick PCR Purification and Gel Extraction Kit (Qiagen)

Qubit dsDNA HS Assay Kit (Invitrogen)

Qubit RNA Assay Kit (Invitrogen)

SYBRGreen I Mastermix (Roche)

SyBr Gold Nucleic acid gel stain (Invitrogen)

ULTRAhyb Ultrasensitive Hybridization Buffer (Ambion)

UTP Alpha 32P (Perkin Elmer)

2.1.6 Antibodies

Alexa Fluor® 488 conjugated BrdU Antibody (Ambion)

GAPDH Rabbit polyclonal Antibody (Santa Cruz)

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Goat anti-Mouse IgG (H+L) Secondary Antibody, Alexa Fluor® 568 conjugate (Ambion)

HA.11 mouse monoclonal Antibody (Novus Biologies)

HP1 Alpha Rabbit polyclonal Antibody (Cell signal)

H3K9me3 rabbit polyclonal Antibody (Abcam)

Monoclonal Anti-FLAG M2, Antibody Produced in mouse (Sigma-Aldrich)

MTA1 rabbit polyclonal Antibody (Abcam)

MTA2 rabbit polyclonal Antibody (Abcam)

RING1B rabbit polyclonal Antibody (Abcam)

TRIM28 rabbit polyclonal Antibody (Abcam)

ZBTB7A rabbit polyclonal Antibody (Novus Biologies)

2.1.7 Chemicals and other reagents

Chemicals used in experiments were purchased from the following companies: Roth, Sigma, Roche, Invitrogen, InvivoGen and MP Biomedicals. Other reagents not listed above are specified in the experimental methods, including siRNAs, solutions and buffers etc.

2.1.8 Major Equipments

Agarose gel electrophoresis equipment (Bio-Rad)

Agilent 2100 Bioanalyzer (Agilent Technologies)

BD LSR II Flow Cytometer (BD)

Bio-Rad Tetrad 2 Peltier Thermo Cycler (Bio-Rad)

Bioruptor PTMP sonication equipment (Diagnode)

Cell incubator (Hereaus Instruments)

Centrifuges: 5417R, 5804R (Eppendorf)

D-Tube Dialyzer Midi rack and tubes (EMD Biosciences)

Exposure Screen and Cassette (Kodak)

Fujifilm FAS 4000 (Fujifilm)

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Fujifilm FLA-7000 PhosphorImager (Fujifilm)
Illumina Genome Analyzer IIx (Illumina)
Illumina HiSeq 2000 (Illumina)
MilliQBiocel water purification system (Millipore)
NanoDrop ND-1000 (NanoDrop Technologies)
Owl P10DS Dual Gel Vertical Electrophoresis System (Bio-Rad)
PAGE electrophoreses equipment (Invitrogen)
pH Meter 537 (WTW)
Qubit Fluorometer (Invitrogen)
Roche LightCycler 480 Real-Time PCR System (Roche)
Shake 'n' Stack™ Hybridization Ovens (Thermo)
Thermomixer (Eppendorf)
Trans-Blot SD Semi-Dry Transfer Cell (Bio-Rad)
UV crosslinker (Hoefer)
Vortex-Genie 2 (Scientific Industries)
Western blotting equipment (BioRad)

2.2 EXPERIMENTAL METHODS

2.2.1 ZBTB24 overexpression vector construction

2.2.1.1 Total RNA extraction

Total RNA from HEK 293 Flp-In T-REx cells and patient lymphoblastoid cells were extracted by TRIzol according to invitrogen protocol. Briefly, resuspend and homogenize the cells in 1 ml TRIzol reagent (Invitrogen) (or up to 10 million cells). After homogenization, 0.2X volume of chloroform was added to cell lysate and mixed vigorously for 15 sec. After 2 min incubation, centrifuge at 12,000 x g for 15 min in 4°C to separate phases. Carefully remove upper aqueous phase to a fresh, nuclease-free tube. Then the total RNA was

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precipitated by adding equal volume of isopropanol. Finally, the RNA pellet was washed with 75% ethanol, air-dried and dissolved in nuclease-free water. The dissolved total RNA was quantified by NanoDrop (NanoDrop Technologies) and its quality was assessed by Agilent 2100 Bioanalyzer (Agilent Technologies).

2.2.1.2 Reverse transcription (RT) and PCR

Total RNA was treated with TURBO DNase (Ambion) following the manufacturer's protocol to remove genomic DNA contamination. Reverse transcription was performed as following procedures: 2 µg of DNase treated total RNA, 1 µl oligo (dT)20 primer (50 µM), 1 µl dNTPs (10 mM each, Fermentas) was mixed and incubated at 65 °C for 5 minutes to exclude secondary structure. Then the RNA was placed on ice immediately for at least 2 min. 4 µL First Strand (FS) buffer (Invitrogen), 1 µL DTT (0.1 M, Invitrogen), 1 µl RNaseOUT (40 U/µl, Invitrogen) and 1 µl Superscript III (200 U/ µl, Invitrogen), were added into mix accordingly. Finally, the prepared reaction mix was incubated under the following program: 50 °C 50 min, 70 °C 15 min, 4°C hold.

For PCR step, RT products were applied as template to amplify the full length of *ZBTB24* coding sequence (CDS) by using Phusion High-Fidelity DNA Polymerase (Finnzymes) in 50 µL reaction system as follows: 34.5 µl H₂O, 10 µL 5 x Phusion HF buffer, 1 µl dNTPs (10 mM each), 1 µL forward primer (10 µM), 1 µl reverse primer (10 µM), 0.5 µL Phusion Polymerase (2 U/µl) with PCR program: 98 °C 30 sec, (98 °C 10 sec, 60 °C 30 sec, 72 °C 2 min) x 35 cycles, 72 °C 10 min, 4 °C hold. The PCR product was finally detected by agarose gel electrophoresis. Target bands were cut and purified by QIAquick Gel Purification Kit (Qiagen). Nanodrop was then performed to quantify DNA concentration. The PCR primers (*ZBTB24_CDS_F*, *ZBTB24_CDS_R*) were listed in Table III.

2.2.1.3 ZBTB24 over expression vector construction by Gateway method

The purified full-length CDS fragments of wildtype and mutant *ZBTB24* were inserted into pENTR/D-TOPO vector flanked with attL sites respectively according to the manufacturer's

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protocol. The ligated product was then transformed into Premade Z-Competent E. Coli Cells following manufacturer's protocol. Bacteria colonies were picked and screened by colony PCR using Gotaq polymerase (Promega) to get positive clones. The positive clones were then expanded in LB medium supplemented with 50 µg/ml Kanamycin (Sigma). Plasmids were extracted using GeneJET Plasmid Miniprep Kit (Fermentas) and quantified by Nanodrop. After that, *ZBTB24* CDS region was shuffled from pENTR/D-TOPO to pFRT/DEST FLAG-HA and pFRT/TO/DEST FLAG-HA overexpression vector flanked with attR sites by LR reaction using Gateway LR Clonase II enzyme mix (Invitrogen) and transformed into Premade Z-Competent E. Coli Cells. Multi-directional Sanger sequencing validation using vector and *ZBTB24* gene specific sequencing primers (T7-Pro/ M13F, *ZBTB24* seq and *ZBTB24_CDS_R*) was performed to confirm the sequences.

2.2.2 Stable *ZBTB24* over expression HEK cell lines establishment

Stable HEK293 T-REx Flp-In cell lines constitutively or inducibly expressing FLAG/HA tagged wild-type or mutant *ZBTB24*, and wild-type HEK293 T-REx Flp-In cells were constructed and maintained as described before (Spitzer, Landthaler, & Tuschl, 2013; Wang et al., 2013). 3.6 µg pOG44 and 0.4 µg pFRT/DEST FLAG-HA-*ZBTB24* or pFRT/TO/DEST FLAG-HA-*ZBTB24* were mixed (maximum 3 µl) and transfected HEK 293 Flp-In T-REx cells using Lipofectamine 2000 following the manufacturer's instruction. pOG44 and pFRT/DEST FLAG-HA-GFP were transfected as negative and positive control respectively. After 24h, transfection efficiency was assessed by GFP expression and the cells were transferred to 10-cm cell culture plate containing antibiotic-free medium for another 24 hours until they attached. Then selective medium was added and changed every 2-3 days until the distinct cell foci can be identified. 5 separate single colonies were picked out by pipet tip, each of which was expanded from 96 wells plate to 15cm plates. During the expansion process, small fraction of cells were collected to validate the expression of target transcript

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and protein by q-PCR and western blot. Finally, stable cell lines were stored in Freezing medium and used for continuous experiments. The q-PCR primers for *ZBTB24* (*ZBTB24* q-F and *ZBTB24* q-R) were listed in Table III.

2.2.3 Immunofluorescence

The cover slides seeded with wild type (Wt) and mutant (Mt) *ZBTB24* constitutively overexpressed HEK cell lines were gently washed with 1xDPBS and fixed with 4% Paraformaldehyde (PFA) (ROTH) for 20min under room temperature. Then the fixed cells were washed with PBS and permeabilized with 0.1% TritonX-100 in room temperature for 15min. After permeabilization, the cells were washed with PBS, blocked by 5% BSA for 1h and incubated with primary antibody (HA.11 mouse monoclonal Antibody (Novus Biologies), 1:400) in 4 °C overnight. On the next day, after three times washing with PBS, the cells were re-blocked by 5% BSA for extra 20min in room temperature and incubated with secondary antibody (Goat anti-Mouse IgG (H+L) Secondary Antibody, Alexa Fluor® 568 conjugate (Ambion), 1:600) for 40min under room temperature. Ultimately, the cells were stained with 1:5000 DAPI (Invitrogen), washed with PBS and mounted with Prolong Gold Antifade Reagent (Invitrogen). The fluorescent signal was observed under.

2.2.4 Chromosome immunoprecipitation and deep-sequencing (ChIP-Seq)

2.2.4.1 Chromosome immunoprecipitation (ChIP)

ChIP experiment was performed in wild type *ZBTB24* overexpression HEK cell lines according to Transcription Factor ChIP Kit (Diagenode) manufacture's protocol as follows:

Firstly, 5×10^7 cells was trypsinized and resuspended in 10ml cell culture medium. The crosslinking reagent containing 300 μ L 37% Formaldehyde and 700 μ L BufferA was added and incubated for 10min in room temperature with rotation. After crosslinking, 1100 μ L 1.25M Glycine was added to stop reaction and cross linked cells were pelleted and washed with ice cold PBS. The cell pellets could be snap frozen and stored in -80°C for up to one

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month. Secondly, cells pellet was lysed with ice cold Buffer B for 10min under 4°C and further washed with Buffer C for another 10min in 4°C according to the manual. Then, 5×10^6 lysed cells were resuspended in 150 μ L Sonication Buffer D supplemented with 1x Proteinase inhibitor (supplied by the Kit) inside and sheared using Bioruptor™ from Diagenode for 20 cycles (30 seconds"ON"/30seconds"OFF"). A small aliquot of the sheared sample was used to validate sonication quality. After shearing, immunoprecipitation was performed as following system per IP: 6 μ L 5%BSA, 10 μ L P.I., 60 μ L Buffer E, 30 μ L Beads, 5 μ g HA antibody, H₂O (supplemented to 300 μ L total volume) and 30 μ L sheared chromatin (correspond to 1×10^6 cells). Then the IP reactions were incubated on rotating wheel overnight at 4°C and 100 μ L sheared chromatin was kept as input. When immunoprecipitation was finished, the beads were pelleted and washed with Buffer 1-4 as described in manufacture's instruction. The DNA-Protein-Antibody complex was then eluted by 400 μ L Buffer F and the input volume was adjusted to 400 μ L by Buffer F as well. After adding 16 μ L 5M NaCl, the cell elute was reverse crosslinked for 4h under 65°C. Then the ChIP DNA was extracted by phenol/chloroform/isoamyl alcohol (25:24:1) and Chloroform/isoamyl alcohol (24:1) respectively and precipitated by ethanol. After centrifuging, the DNA pellets were washed by 70% Ethanol and dissolved in water.

2.2.4.2 TruSeq ChIP DNA library Preparation

According to Truseq protocol, 15-20ng ChIP DNA and input DNA was used for ChIP DNA library preparation. The original DNA was firstly gone through end repair and purified with Ampure XP beads. Then, a single 'A' nucleotide was added to the 3' ends of the blunt DNA fragments and ligation procedure which ligated multiple indexing adapters to the ends of the DNA fragments was followed. When ligation was finished, after two steps of purification, the DNA was detected by 2% SYBR Gold agrose gel running. The bands ranged from 200-400bp were cutted and purified by MinElute Gel Extraction Kit. Finally, PCR was performed by using common primer cocktail as described by Truseq protocol. The purified ChIP library was

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then quantified by Qubit and the length was assessed by Bioanalyzer DNA 1000 chip Kit. The libraries were sequenced in 1 x 50 nt and 1 x 150 nt manner on HiSeq 2000 platform (Illumina).

2.2.4.3 Computational analysis of ChIP-seq data

The sequencing reads was aligned to reference human genome (GRC38) using Bowtie2 with default parameters (Langmead & Salzberg, 2012). The alignment results, including both unique mapped reads and multiple mapped reads were used to identify peaks using MACS2 (Yong Zhang et al., 2008) (-q 0.01). The multiple mapped reads was assigned to the position by randomly selecting one with the best alignment score. We divided human genome into 5 distinct sections, including centromere, pericentromere, genic, intergenic and subtelomere. 109 centromere fragments from 24 chromosomes were derived from UCSC centromere track (Karolchik D, Hinrichs AS, 2012). 56 genomic fragments from the region between the centromere boundary and its neighboring gene were defined as pericentromere. If the region is larger than 10Mb, only 10Mb of region around centromere was defined as pericentromere. Similarly, subtelomere was the regions between telomere gap and its neighboring gene. If the region is larger than 500kb, only 500kb region around telomere were defined as subtelomere. The remaining regions were classified into gene and intergenic regions based on GENCODE (V23). The number of ZBTB24 binding sites within each section was then counted. A background distribution of binding sites was generated by randomly selecting 4040 regions with the same length distribution as ZBTB24 peaks identified in the human genome. For the enriched sections, we further classified them into different repeats according to the sequence features derived from repeat mask in UCSC genome browser (Karolchik D, Hinrichs AS, 2012), including ALR (alpha satellite repeat), Sat2/3 (combining 459 repeat elements containing GAATG/CATTC motif), LINE, SINE and other repeats.

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2.2.5 siRNA-mediated knockdown of ZBTB24 and TRIM28

siRNAs against ZBTB24 (Ambion, s19038) and TRIM28 (Ambion, s19780) were reverse transfected into HEK293 Flp-In T-REx cells at a final concentration 10 nM with Lipofectamine RNAiMAX (Invitrogen) following the manufacturer's protocol. Cells transfected with siRNA or only transfection reagents (mock) were collected at indicated time points. Then the knockdown efficiency was analyzed by qRT-PCR. Total RNA was extracted as described and treated with TURBO DNase kit (Ambion) following the manufacturer's protocol. Reverse transcription was performed using 2 µg of DNase treated total RNA, random hexamer and Superscript III reverse transcriptase (Invitrogen) according to manufacturer's protocol described before. First stranded cDNA was diluted 1:5 and 1 µl was used as template in a 10 µl qPCR reaction system. qPCR was carried out using SYBRGreen Masrermix I (Roche) on LightCycler 480 (Roche) according to manufacturer's instruction. The data generated from RT-qPCR was calculated by $2^{-\Delta\Delta Ct}$ method. GAPDH was considered as endogenous control. All assays were performed in 3 independent biological replicates (n=3). Every biological experiment contained three technical triplicates. siRNA and qPCR primer sequences for *ZBTB24* and *TRIM28* were listed in Table III.

2.2.6 Total RNA sequencing

2.2.6.1 Truseq Stranded Total RNA library preparation

At the beginning, according to the protocol, ERCC RNA Spike-In Control Mix was added inside 100ng total RNA (Turbo DNase treated) which were extracted from 6 normal control and one patient lymphoblastoid cell lines as well as Control and ZBTB24 Knocked down HEK cells in 48h and 72h respectively, total RNA sequencing library was constructed following TruSeq Stranded Total RNA Sample Preparation Guide: The ribosomal RNA inside input total RNA was firstly removed by Ribo-Zero procedure following the protocol. First strand cDNA was synthesized by using SuperScript II and First Strand Synthesis Act D Mix.

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After gotten single stranded cDNA, second strand was synthesized. After end repairing and A-tailing, the double stranded cDNA was ligated by indexing adaptors and amplified. Qubit and Bioanalyzer DNA 1000 chip were performed to assess the purified library quality.

2.2.6.2 Computational analysis of RNA-seq data

The sequencing reads was mapped to human genome reference (GRC38) using bowtie2 with default setting. We used all the mapped reads to quantify the expression level for centromere and pericentromere at each of the 22 autosomes and only unique mapped reads for the 60155 genes (GENCODE V23). DEseq (Anders & Huber, 2010) was used to normalize the raw reads counts and estimate the expression fold changes between HEK293 cells with and without ZBTB24 knockdown as well as the lymphocyte derived from ICF patient and healthy control. The significant difference of the fold change between different categories: centromere, pericentromere, gene was assessed by Wilcox test.

2.2.7 Expression profiling by qRT-PCR

To assess the transcription changes of centromeric and pericentromeric satellites in ZBTB24 and TRIM28 deficient HEK cells. Total RNA from Mock control, ZBTB24 24h/48h/72h Knock down and TRIM28 48h/72h/96h Knock down HEK cells was isolated and reverse transcribed as mentioned above. The data generated from RT-qPCR was calculated as described. All assays were performed in 4 independent biological replicates (n=4). Every biological experiment contained three technical triplicates. For expression quantification, the average fold change was calculated by normalizing to GAPDH. The qPCR primer corresponded to target satellite repeats (Chr1 ALR, Chr6 ALR, Chr11 ALR, Chr16 Sat 2/3a, Chr16 Sat 2/3b) were listed in Table III.

2.2.8 ChIP q-PCR validation

To increase the amount of ChIP DNA used for qPCR to get valid signal, ChIP was carried out in HA-FLAG tagged wild type/mutant ZBTB24 overexpressed HEK cells as reported

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(<http://www.epigenesys.eu/en/protocols/chromatin-immunoprecipitation-chip/219-phospho-sensitive-chromatin-immunoprecipitation-of-rna-polymerase-ii>). Flag antibody (Sigma, F1804) was used for IP. Due to indirect binding of TRIM28 and genomic DNA, the TRIM28 ChIP between control and ZBTB24 deficient HEK cells was performed by using iDeal ChIP Kit for transcription factors (Diagenode, C01010055), TRIM28 endogenous antibody (Ambion, ab10483) was used for IP. Meanwhile, iDeal ChIP Kit for Histones (Diagenode, C01010051) was used for H3K9me3 (Ambion, ab8898) among control and TRIM28/ZBTB24 knocked down HEK cells. The ChIP DNA was then used as qPCR template to detect the enrichment of different ALR and Sat2/3 repeat regions. qPCR was carried out using SYBR Green I Mastermix (Roche) on LightCycler 480 (Roche) according to manufacturer's instruction. All assays were performed in independent biological triplicates (n=3). Every biological experiment contained three technical triplicates. Relative enrichment of different target proteins was calculated over IP mock control by $2^{\Delta C_t}$ method and then compared with the IP in HEK293 cells expressing wild type ZBTB24 or without knockdown, which was normalized to 1. The qPCR primer corresponded to target loci (Chr1 ALR, Chr6 ALR, Chr11 ALR, Chr16 Sat 2/3a, Chr16 Sat 2/3b) were listed in Table III.

2.2.9 Northern Blot

20 μ g of denatured RNA from HEK293 cells with or without ZBTB24 knockdown was separated on 10% urea gel and transferred to a Hybond-N+ membrane (Amersham Pharmacia). After ultraviolet cross-linking, the membranes were pre-hybridized with ULTRAhyb® Hybridization Buffer (Ambion) for 1 h, and hybridized overnight at 68 °C with [α -³²P] UTP totally-labeled RNA probes that are specific to sense or antisense transcripts from ALR on Chromosome 1. After hybridization, membranes were washed at 68 °C twice for 10 min with 5 \times SSC and once for 10 min with 1 \times SSC. The radioisotopic images were

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recorded using phosphorimaging screen on FLA 7000 imager (FujiFilm). The membranes were then stripped with boiled stripping buffer containing 0.5% SDS at 80 °C three times for 10min and hybridized with the [γ - ^{32}P]-ATP end-labeled DNA probe specific for U6 snRNA which was considered as loading control (Zou et al., 2011). The probe sequences were listed in Table III.

2.2.10 Identification of ZBTB24 protein interaction partners by Stable Isotope Labeling by Amino Acids in Cell Culture (SILAC) based quantitative mass spectrometry

To identify protein interaction partner of ZBTB24, HEK293 cells with or without expressing FLAG/HA-tagged ZBTB24 were labeled by light SILAC medium containing non-labeled amino acids ($^{12}\text{C}_6^{14}\text{N}_4$ L- arginine and $^{12}\text{C}_6^{14}\text{N}_2$ L-lysine (Sigma-Aldrich)) and heavy SILAC medium containing heavy-labeled amino acids ($^{13}\text{C}_6^{15}\text{N}_4$ L-arginine and $^{13}\text{C}_6^{15}\text{N}_2$ L-lysine (Cambridge Isotope Laboratories)) for 2 weeks respectively and then mixed in equal amount. For each experiment, approximately 1×10^9 cells were used. The expression of ZBTB24 was induced for 16 h by adding 20 ng/ml Doxycycline. Cells were lysed in 3 times the cell pellet volume of low salt NP-40 lysis buffer (50 mM Tris-HCl [pH 7.5], 150 mM KCl, 2 mM EDTA, 0.5% (v/v) NP-40, 1 mM NaF, 1 mM DTT, complete EDTA-free protease inhibitor cocktail (Roche)) and incubated for 30 min at 4 °C. Lysates were cleared by centrifugation at 15,000 g for 20 min. Cell lysates were treated with 1 U/ μl Benzonase (Sigma) to remove DNA and RNA. Immunoprecipitation using FLAG-conjugated Protein G Dynabeads (Invitrogen) and subsequent mass spectrometry analysis were performed as described before (Gregersen et al., 2014). Reverse experiment with cross over labeling was performed in parallel.

Quantification of proteins was performed using MaxQuant (Cox & Mann, 2008). Peptide and protein false discovery rates were set to 0.01. Only proteins with a minimum ratio count of two unique peptides were considered for quantification. Proteins with the enrichment ratios above 1.25 in both labeling-swap experiments were considered to be interaction partners of

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ZBTB24. The protein-protein interaction network was constructed based on STRING database (Szklarczyk et al., 2015) with medium confidence (0.4).

2.2.11 Immunoprecipitation and Western Blot

The HEK293 cells expressing FLAG/HA-tagged ZBTB24 were lysed in NP-40 lysis buffer (50mM TRIS-HCl pH=7.5, 150mM KCl, 2 mM EDTA pH=8.0, 0.5% NP-40, and complete EDTA-free protease inhibitor cocktail) and then treated with $0.2 \text{ U}/10^7$ cells (Hubner et al., 2010) at 4 °C for 30 min. Protein G beads (50µl/ml cell lysate) was washed by 2 times of PBST. The FLAG antibody (Sigma) was then added to a final concentration of 0.25 µg/µl and incubated with beads at room temperature for 1 h on rotation. At the same time the cell lysate was cleared at 15,000g for 20 min and incubated with FLAG conjugated beads in 4 °C overnight. After IP, the immunoprecipitants were washed 4 times with lysis buffer, resuspended in 2xprotein loading dye and denatured in 95 °C for 10 min. Cell lysate immunoprecipitated with empty beads was considered as IP negative control (Mock). After denaturing, the beads eluted supernatants and input were loaded and separated on 10% SDS-PAGE-gel, transferred to PVDF western blot membranes (Roche) and incubated with primary antibody against TRIM28 (1:1000, Abcam, ab10483), MTA1 (1:1000, Abcam, ab71153), MTA2 (1:1000, Abcam, ab8106) and ZBTB7A (1:1000, Novus Biologies, NB 100-762), as well as the antibody against GAPDH (1:1000, Santa Cruz, sc 25778), which serves as negative control. Then the membranes were washed three times with PBST and incubated with respective secondary antibodies with HRP conjugation (1:2000, Santa Cruz). After incubation, the membranes were washed again and developed by using LAS4000 (GE Healthcare).

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2.2.12 Cell proliferation assay and Cell cycle analysis

After ZBTB24 knocking down, the cells were harvested and counted by adding Blue stain to distinguish alive cells under different timelines (24h/48h/72h) and the cell proliferation curve was formulated according to the change of cell number in different time points.

The flow cytometric assay was performed by labeling the cells with 10 μ M BrdU for 60 min at 37 °C and fixed overnight in 70% EtOH. The labeled genomic DNA was denatured by treatment with 2 M HCl /0.5% Triton X-100 for 30 min and neutralized with 0.1 M Na₂B₄O₇ buffer (pH8.5). After neutralization, the cells were incubated in PBST (PBS/0.5% Tween-20 + 0.5% BSA) supplemented with 10% Alexa Fluor® 488 conjugated BrdU Antibody (Ambion, B35130) for 30 min at room temperature in the dark and washed three times in PBST. Cells were resuspended in 500 μ l PBS containing 25 μ l RNaseA (10mg/ml) and incubated for 30 min at 37°C in the dark. Finally, 15 μ l 1mg/ml Propidium iodide (Life technologies, P3566) were added and the measurement was carried out on a LSR II from BD.

The 2-D cell cycle distribution was then analyzed by software Flow Jo 7.6.5 according to the manufacturer's instruction. Every group of samples were performed in three biological triplicates.

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Primer Name	Primer Sequence (5'-3')
<i>ZBTB24</i> CDS-F	CACCATGGCAGAAACATCGCCAGAGCCTTC
<i>ZBTB24</i> CDS-R	TCAGCTCTGCTCCTGGCCAAGTGGC
<i>ZBTB24</i> q-F	CTCTGACCACCAAGCACTC
<i>ZBTB24</i> q-R	GCCTGTATGAACTCGGTAATGG
<i>TRIM28</i> q-F	ACCATACTGTGCGCTCTACTG
<i>TRIM28</i> q-R	GGGGTTCATGCTTGTGTACG
Chr1 ALR q-F	GCAAGTGGAGATTTTCAGCCG
Chr1 ALR q-R	GAACGCACACATCACAAAGGAG
Chr6 ALR q-F	TCACCTAAAACCTAGACAGAAGC
Chr6 ALR q-R	GGAAAGTTCCACTCTGTGAGTTG
Chr11 ALR q-F	TGCTCCATCAACAGGAGTGTTTC
Chr11 ALR q-R	ACCACTTTGTGGCCTTCCTTC
Chr16 Sat2/3 a q-F	ATCATCATCGAATGGAGTCG
Chr16 Sat2/3 a q-R	TCATTCCATTTGATTCAATTCGGTG
Chr16 Sat2/3 b q-F	TGAGCCCACTCAATGCTTC
Chr16 Sat2/3 b q-R	AATAGAATCTTCTAACGGACTCAAG
Chr1 ALR p-F	GGGTAATACGACTCACTATAGGGTCGTTGGAAAC GGGATTTCTTC
Chr1 ALR p-R	GGGTAATACGACTCACTATAGGGCGAAGGCCTCA AGGAGGTCTG
T7-Pro	GGGTAATACGACTCACTATAGGG
<i>GAPDH</i> q-F	AGCCACATCGCTCAGACAC
<i>GAPDH</i> q-R	GCCAATACGACCAAATCC
U6 antisense probe	CACGAATTTGCGTGTTCATCCTT
M13F	GTAAAACGACGGCCAG
T7-Pro	ATTAACCCTCACTAAAGGGA
<i>ZBTB24</i> seq	TCGGAGCCTACTTGTGAGCCA
<i>ZBTB24</i> _CDS_Rev	TCAGCTCTGCTCCTGGCCAAGTGGC
<i>ZBTB24</i> -siRNA-Sense	GGAAUAUUCUUCAGCUACAtt
<i>ZBTB24</i> -siRNA-Antisense	UGUAGCUGAAGAAUAUUCctg
<i>TRIM28</i> -siRNA-Sense	GCAACAUUGCAGAAGAGCAtt
<i>TRIM28</i> -siRNA-Antisense	UGCUCUUCUGCAAUGUUGCat

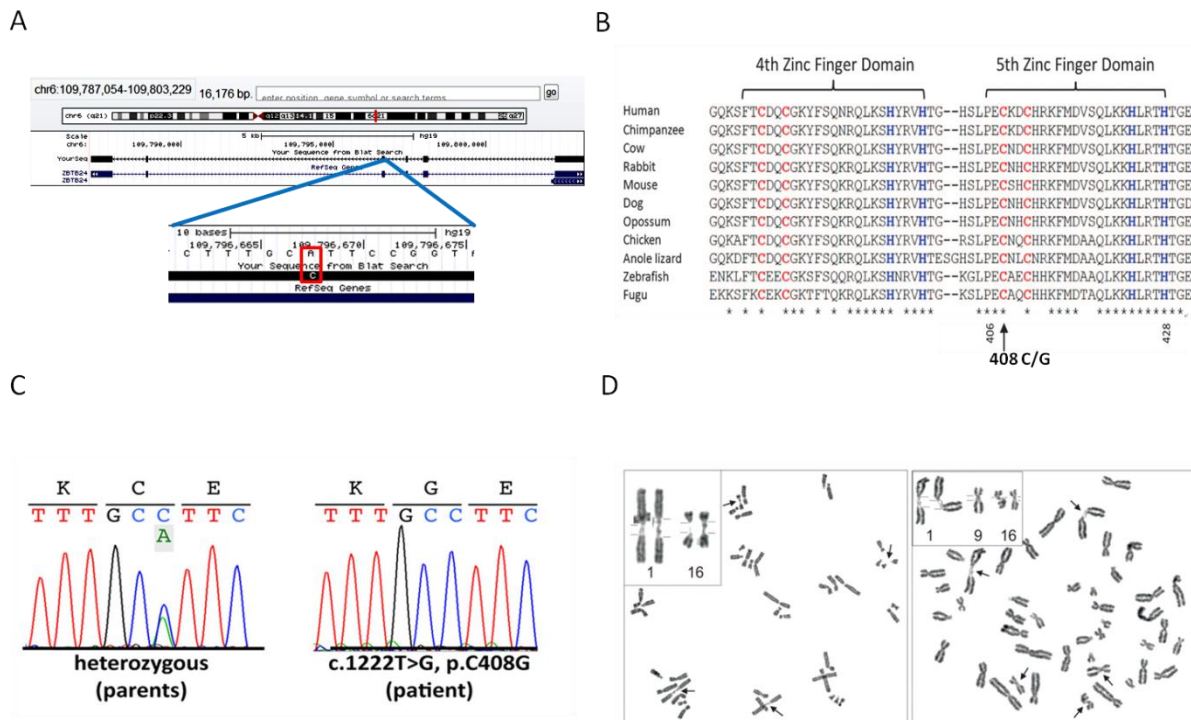
Table III: Primers, probes and siRNA list

3. Results

3. Results

3.1 Identification of an ICF patient who harbors missense mutation in *ZBTB24*

By using exome sequencing, in a female ICF patient, we identified a missense mutation in *ZBTB24* (c.1222T>G, p.Cys408Gly; NM_014797.2 and NP_055612.2) which caused a Cys to Gly conversion in the fifth zinc-finger domain (Figure 3.1A) (von Bernuth et al., 2014). Sequence comparison showed the mutated site was highly conserved across species (Figure 3.1B). Sanger sequencing showed this homozygous mutation was inherited from both parents who were heterozygous carrier (Figure 3.1C). The Giemsa staining of metaphase chromosomes in patient lymphocytes revealed spontaneous decondensation of centromeric and pericentromeric constitutive heterochromatin on chromosomes 1, 16, and to a less extent on 9 (Figure 3.1D) (von Bernuth et al., 2014). It was further increased upon exposure of cultures to 5-azacytidine. This indicated that *ZBTB24* might regulate structural stability and functional formation of human centromeric and pericentromeric heterochromatin.



3. Results

Figure 3.1 - Genotype and phenotype of the patient with *ZBTB24* mutation. (von Bernuth et al., 2014)

- (A) The homozygous missense mutation was identified in the patient on *ZBTB24* (c.1222T>G, p.Cys408Gly; NM_014797.2 and NP_055612.2).
- (B) The mutation was located in 5th zinc finger domain of *ZBTB24* and the site is highly conserved across species.
- (C) Sanger sequencing confirmation among the parents (heterozygous) and the patient (homozygous), the homozygous mutation is inherited from both of parental alleles.
- (D) Giemsa staining showed spontaneous decondensation of centromeric and pericentromeric constitutive heterochromatin of chromosome 1,16 and 9 in the patient.

3.2 Flag-HA tagged *ZBTB24* overexpression vector construction and stable transfected HEK293 cell line establishment

The commercially available antibody against *ZBTB24* was not good enough and the expression level of *ZBTB24* in HEK293 was relatively low. Therefore, in this project, for ChIP as well as protein immunoprecipitation experiments, we overexpress Flag-HA tagged *ZBTB24* in HEK293 cells and use the antibody against Flag/HA tag to perform immunoprecipitation.

For this purpose, firstly, we amplified CDS fragments of wild type and mutant *ZBTB24* from normal individual and patient-derived cDNA. Sanger sequencing confirmed the missense mutation identified from the patient (Figure 3.2A). Then the CDS fragments of wild type/ mutant *ZBTB24* was integrated into constitutive (pFRT _DEST_FLAG_HA) or Doxycycline inducible overexpression vectors (pFRT _TO_DEST_FLAG_HA) containing FRT site to facilitate recombination between plasmid and the genome as described in materials and methods (Figure 3.2B). The plasmids were then transfected into HEK 293 Flp-In T-REx Cell

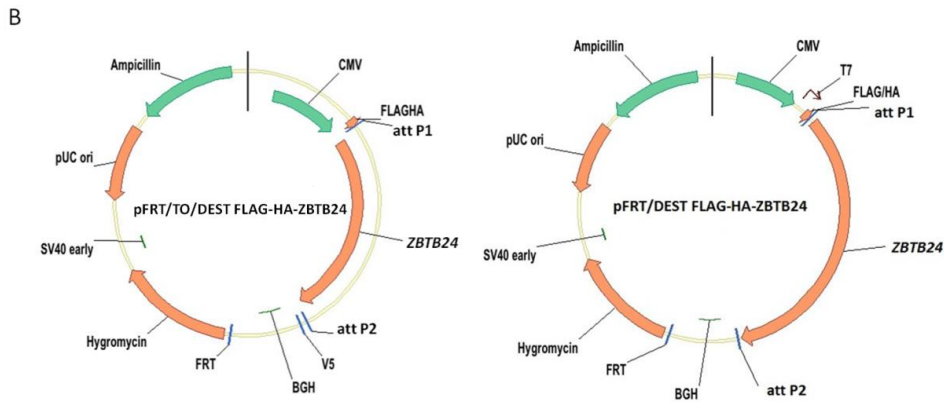
3. Results

Line together with POG44, which encodes Flp-recombinase to mediate recombination. With several rounds of selection, the stable transfected cell lines were established.

As shown in Figure 3.2C and 3.2D, the expression of exogenous Flag-HA tagged ZBTB24 could be efficiently detected by RT-qPCR and western-blot either constitutively or induced by Doxycycline. The abundance of wild type and mutant ZBTB24 were similar.

A

mutant ZBTB24	ATGCGAAGAACATCGCCAGAGCCTTCTGGCAGCTTGTGTACACTCAGACGCTCACAGTGCACCTGTCTGGCCAGTTTGGAGATCAGAGAAAGAAAGCTTCTCTGTGCATTACT	120
wild-type ZBTB24	ATGCGAAGAACATCGCCAGAGCCTTCTGGCAGCTTGTGTACACTCAGACGCTCACAGTGCACCTGTCTGGCCAGTTTGGAGATCAGAGAAAGAAAGCTTCTCTGTGCATTACT	120
zbtb24 cds	ATGCGAAGAACATCGCCAGAGCCTTCTGGCAGCTTGTGTACACTCAGACGCTCACAGTGCACCTGTCTGGCCAGTTTGGAGATCAGAGAAAGAAAGCTTCTCTGTGCATTACT	120
mutant ZBTB24	TTAATCGTGGAGAAATGTACATTTCGGGCCCCACAAGCCCTTACTTCTGCCAGTAGTGAATACCTTCTCAATGATGTTTGCAGAAAGAGGGGAAATCGGCCAATCCATTTATATGCTGGAA	240
wild-type ZBTB24	TTAATCGTGGAGAAATGTACATTTCGGGCCCCACAAGCCCTTACTTCTGCCAGTAGTGAATACCTTCTCAATGATGTTTGCAGAAAGAGGGGAAATCGGCCAATCCATTTATATGCTGGAA	240
zbtb24 cds	TTAATCGTGGAGAAATGTACATTTCGGGCCCCACAAGCCCTTACTTCTGCCAGTAGTGAATACCTTCTCAATGATGTTTGCAGAAAGAGGGGAAATCGGCCAATCCATTTATATGCTGGAA	240
mutant ZBTB24	GGCATGGTTCGACAGCCTTGGTATCTCTGCTGGAATTTATCTACAGAGTTATCTCCATGCCAGTGAAGAAATCAGAACAAATCTGGCTACTGCTCAGTCTTAAAAGCTATAGC	360
wild-type ZBTB24	GGCATGGTTCGACAGCCTTGGTATCTCTGCTGGAATTTATCTACAGAGTTATCTCCATGCCAGTGAAGAAATCAGAACAAATCTGGCTACTGCTCAGTCTTAAAAGCTATAGC	360
zbtb24 cds	GGCATGGTTCGACAGCCTTGGTATCTCTGCTGGAATTTATCTACAGAGTTATCTCCATGCCAGTGAAGAAATCAGAACAAATCTGGCTACTGCTCAGTCTTAAAAGCTATAGC	360
mutant ZBTB24	CTGGTAAAGGCTTACACAGACTTCCAAAATAATCATAGCTCCCAAGGCCAACACTTGAACACTGCTGGTGGCCAGTGGTGTATCTCTAATAAGAAAAGCATCTCCAAAGCGG	480
wild-type ZBTB24	CTGGTAAAGGCTTACACAGACTTCCAAAATAATCATAGCTCCCAAGGCCAACACTTGAACACTGCTGGTGGCCAGTGGTGTATCTCTAATAAGAAAAGCATCTCCAAAGCGG	480
zbtb24 cds	CTGGTAAAGGCTTACACAGACTTCCAAAATAATCATAGCTCCCAAGGCCAACACTTGAACACTGCTGGTGGCCAGTGGTGTATCTCTAATAAGAAAAGCATCTCCAAAGCGG	480
mutant ZBTB24	AAAGGGGAGAGCAAAAAGATCAATCAATTCAGAGAGGAAATCAGACTGGCTGCAGAGGAAATACAGTTAAGAGTGAACAAATCAGTTTCAAGATAGCAAAATCTTGTGGTT	600
wild-type ZBTB24	AAAGGGGAGAGCAAAAAGATCAATCAATTCAGAGAGGAAATCAGACTGGCTGCAGAGGAAATACAGTTAAGAGTGAACAAATCAGTTTCAAGATAGCAAAATCTTGTGGTT	600
zbtb24 cds	AAAGGGGAGAGCAAAAAGATCAATCAATTCAGAGAGGAAATCAGACTGGCTGCAGAGGAAATACAGTTAAGAGTGAACAAATCAGTTTCAAGATAGCAAAATCTTGTGGTT	600
mutant ZBTB24	AAAGGGAGCAGTGGTACTCAATGAGCAATTCAGCAAAAAGAAAGAAAGTTCGGAGCCTACTTGTAGCCAAAGTAGAGAGGAGAAATGCCAGTTGAAAAGATGAGAACTATGAT	720
wild-type ZBTB24	AAAGGGAGCAGTGGTACTCAATGAGCAATTCAGCAAAAAGAAAGAAAGTTCGGAGCCTACTTGTAGCCAAAGTAGAGAGGAGAAATGCCAGTTGAAAAGATGAGAACTATGAT	720
zbtb24 cds	AAAGGGAGCAGTGGTACTCAATGAGCAATTCAGCAAAAAGAAAGAAAGTTCGGAGCCTACTTGTAGCCAAAGTAGAGAGGAGAAATGCCAGTTGAAAAGATGAGAACTATGAT	720
mutant ZBTB24	CCAGCCCGGAGTGCACAGCAAGCCCTGAGGCCCTGAGGCCCTGTAAGAAGCTGTGGCAAGGCTTTAAGTACAATCACTTTTAGCAATCCACACAGAGAGCCACACAGGGGAGCGA	840
wild-type ZBTB24	CCAGCCCGGAGTGCACAGCAAGCCCTGAGGCCCTGAGGCCCTGTAAGAAGCTGTGGCAAGGCTTTAAGTACAATCACTTTTAGCAATCCACACAGAGAGCCACACAGGGGAGCGA	840
zbtb24 cds	CCAGCCCGGAGTGCACAGCAAGCCCTGAGGCCCTGAGGCCCTGTAAGAAGCTGTGGCAAGGCTTTAAGTACAATCACTTTTAGCAATCCACACAGAGAGCCACACAGGGGAGCGA	840
mutant ZBTB24	AGGATCTGTGGAGGAAAGCGCCCTGAGGCCCTGAGGCCCTGTAAGAAGCTGTGGCAAGGCTTTAAGTACAATCACTTTTAGCAATCCACACAGAGAGCCACACAGGGGAGCGA	960
wild-type ZBTB24	AGGATCTGTGGAGGAAAGCGCCCTGAGGCCCTGAGGCCCTGTAAGAAGCTGTGGCAAGGCTTTAAGTACAATCACTTTTAGCAATCCACACAGAGAGCCACACAGGGGAGCGA	960
zbtb24 cds	AGGATCTGTGGAGGAAAGCGCCCTGAGGCCCTGAGGCCCTGTAAGAAGCTGTGGCAAGGCTTTAAGTACAATCACTTTTAGCAATCCACACAGAGAGCCACACAGGGGAGCGA	960
mutant ZBTB24	CTTTCAAAAGTAAAGCTGGTAAAGGCTTTGGCCAGAGCACTGCTACAGGTCACACAGAGATGCACACAGGAGCCGCGTACACTCTGACCTGTGCGAGCAAGGCTCTGACC	1080
wild-type ZBTB24	CTTTCAAAAGTAAAGCTGGTAAAGGCTTTGGCCAGAGCACTGCTACAGGTCACACAGAGATGCACACAGGAGCCGCGTACACTCTGACCTGTGCGAGCAAGGCTCTGACC	1080
zbtb24 cds	CTTTCAAAAGTAAAGCTGGTAAAGGCTTTGGCCAGAGCACTGCTACAGGTCACACAGAGATGCACACAGGAGCCGCGTACACTCTGACCTGTGCGAGCAAGGCTCTGACC	1080
mutant ZBTB24	ACCAGCAGCTCACTCTGGAGCAGATGAGCCTGCACTCAGGACAGAAAGCTTTTACCTGTGATCAATGGGAAAATATTTCCAGCAGAACAGACAGCTAAAGAGCCATTACCGAGTTCAAT	1200
wild-type ZBTB24	ACCAGCAGCTCACTCTGGAGCAGATGAGCCTGCACTCAGGACAGAAAGCTTTTACCTGTGATCAATGGGAAAATATTTCCAGCAGAACAGACAGCTAAAGAGCCATTACCGAGTTCAAT	1200
zbtb24 cds	ACCAGCAGCTCACTCTGGAGCAGATGAGCCTGCACTCAGGACAGAAAGCTTTTACCTGTGATCAATGGGAAAATATTTCCAGCAGAACAGACAGCTAAAGAGCCATTACCGAGTTCAAT	1200
mutant ZBTB24	CCAGGCGCTCAATTCGGGAAAGCTGGCAAGAGCTGCCAATTCAGTGAATGCTCTCAGCTAAAGAAACATCTGGCAACACACAGCTGGAGAGCCATTACTGTGAAATCTGTGGC	1320
wild-type ZBTB24	CCAGGCGCTCAATTCGGGAAAGCTGGCAAGAGCTGCCAATTCAGTGAATGCTCTCAGCTAAAGAAACATCTGGCAACACACAGCTGGAGAGCCATTACTGTGAAATCTGTGGC	1320
zbtb24 cds	CCAGGCGCTCAATTCGGGAAAGCTGGCAAGAGCTGCCAATTCAGTGAATGCTCTCAGCTAAAGAAACATCTGGCAACACACAGCTGGAGAGCCATTACTGTGAAATCTGTGGC	1320
mutant ZBTB24	AAATCTTTCACAGAAAGAGTTCCTCTCAGACCCACATCAGAATCCATCGAGGAGAAAGCCATACCTCTGTGGCATTGTGGCAATCTTCTCTGACTCCAGTCCCAAAAGGAGACAC	1440
wild-type ZBTB24	AAATCTTTCACAGAAAGAGTTCCTCTCAGACCCACATCAGAATCCATCGAGGAGAAAGCCATACCTCTGTGGCATTGTGGCAATCTTCTCTGACTCCAGTCCCAAAAGGAGACAC	1440
zbtb24 cds	AAATCTTTCACAGAAAGAGTTCCTCTCAGACCCACATCAGAATCCATCGAGGAGAAAGCCATACCTCTGTGGCATTGTGGCAATCTTCTCTGACTCCAGTCCCAAAAGGAGACAC	1440
mutant ZBTB24	GGCATCTACAGCTGGCAGAGCCCTTCTCTGCCCTGAGTGAATACAGTTTCTCTGCTAGACACTTGAAGGCTCACTTGAAGAAATCATAGCAAGAGAGCAGTCTCAGAT	1560
wild-type ZBTB24	GGCATCTACAGCTGGCAGAGCCCTTCTCTGCCCTGAGTGAATACAGTTTCTCTGCTAGACACTTGAAGGCTCACTTGAAGAAATCATAGCAAGAGAGCAGTCTCAGAT	1560
zbtb24 cds	GGCATCTACAGCTGGCAGAGCCCTTCTCTGCCCTGAGTGAATACAGTTTCTCTGCTAGACACTTGAAGGCTCACTTGAAGAAATCATAGCAAGAGAGCAGTCTCAGAT	1560
mutant ZBTB24	CGCCAGCAGTATTCGGCAGTAGTAATACAGAGAGGTCAGGAATTTCTCAGCTACAGCCATCAACTCTCTACTCGGGAGAGCAGGAAATCAGCTTCTCGTAACGGATTCTGTGA	1680
wild-type ZBTB24	CGCCAGCAGTATTCGGCAGTAGTAATACAGAGAGGTCAGGAATTTCTCAGCTACAGCCATCAACTCTCTACTCGGGAGAGCAGGAAATCAGCTTCTCGTAACGGATTCTGTGA	1680
zbtb24 cds	CGCCAGCAGTATTCGGCAGTAGTAATACAGAGAGGTCAGGAATTTCTCAGCTACAGCCATCAACTCTCTACTCGGGAGAGCAGGAAATCAGCTTCTCGTAACGGATTCTGTGA	1680
mutant ZBTB24	CTAAACATCAATTTCTGCCCCGCTCTACAGGAAATCAGCTTGTGACTGCGAGAGTCCCAAAACATGACTGCAGACAGGCTCTAATCTTACCTGCTCCAGCAGCCAGAG	1800
wild-type ZBTB24	CTAAACATCAATTTCTGCCCCGCTCTACAGGAAATCAGCTTGTGACTGCGAGAGTCCCAAAACATGACTGCAGACAGGCTCTAATCTTACCTGCTCCAGCAGCCAGAG	1800
zbtb24 cds	CTAAACATCAATTTCTGCCCCGCTCTACAGGAAATCAGCTTGTGACTGCGAGAGTCCCAAAACATGACTGCAGACAGGCTCTAATCTTACCTGCTCCAGCAGCCAGAG	1800
mutant ZBTB24	CAACTCGAGAATTTAATCTTTCAGCTCAACAGGAGCAACAGACACATTCAGAGCCTCAATATGATTGAAAGCCAGATGGGCCCCACAAAACAGAGCCAGTGCAGTACTCTGTG	1920
wild-type ZBTB24	CAACTCGAGAATTTAATCTTTCAGCTCAACAGGAGCAACAGACACATTCAGAGCCTCAATATGATTGAAAGCCAGATGGGCCCCACAAAACAGAGCCAGTGCAGTACTCTGTG	1920
zbtb24 cds	CAACTCGAGAATTTAATCTTTCAGCTCAACAGGAGCAACAGACACATTCAGAGCCTCAATATGATTGAAAGCCAGATGGGCCCCACAAAACAGAGCCAGTGCAGTACTCTGTG	1920
mutant ZBTB24	TCCCAAGAAACACTGGAACATCTTCAATGCCATCAAGAGCAACAGAGGAGCTCCATTTAGCTACAAGTACTCAGATCCAGCTCAGCACTGCACTGACAGAGGCTGTCCGCCA	2040
wild-type ZBTB24	TCCCAAGAAACACTGGAACATCTTCAATGCCATCAAGAGCAACAGAGGAGCTCCATTTAGCTACAAGTACTCAGATCCAGCTCAGCACTGCACTGACAGAGGCTGTCCGCCA	2040
zbtb24 cds	TCCCAAGAAACACTGGAACATCTTCAATGCCATCAAGAGCAACAGAGGAGCTCCATTTAGCTACAAGTACTCAGATCCAGCTCAGCACTGCACTGACAGAGGCTGTCCGCCA	2040
mutant ZBTB24	CCACCCTCAGCAGTGGCCAGCCAGCCACTTGGCCAGGAGCAGAGCTG	2093
wild-type ZBTB24	CCACCCTCAGCAGTGGCCAGCCAGCCACTTGGCCAGGAGCAGAGCTG	2093
zbtb24 cds	CCACCCTCAGCAGTGGCCAGCCAGCCACTTGGCCAGGAGCAGAGCTG	2093



3. Results

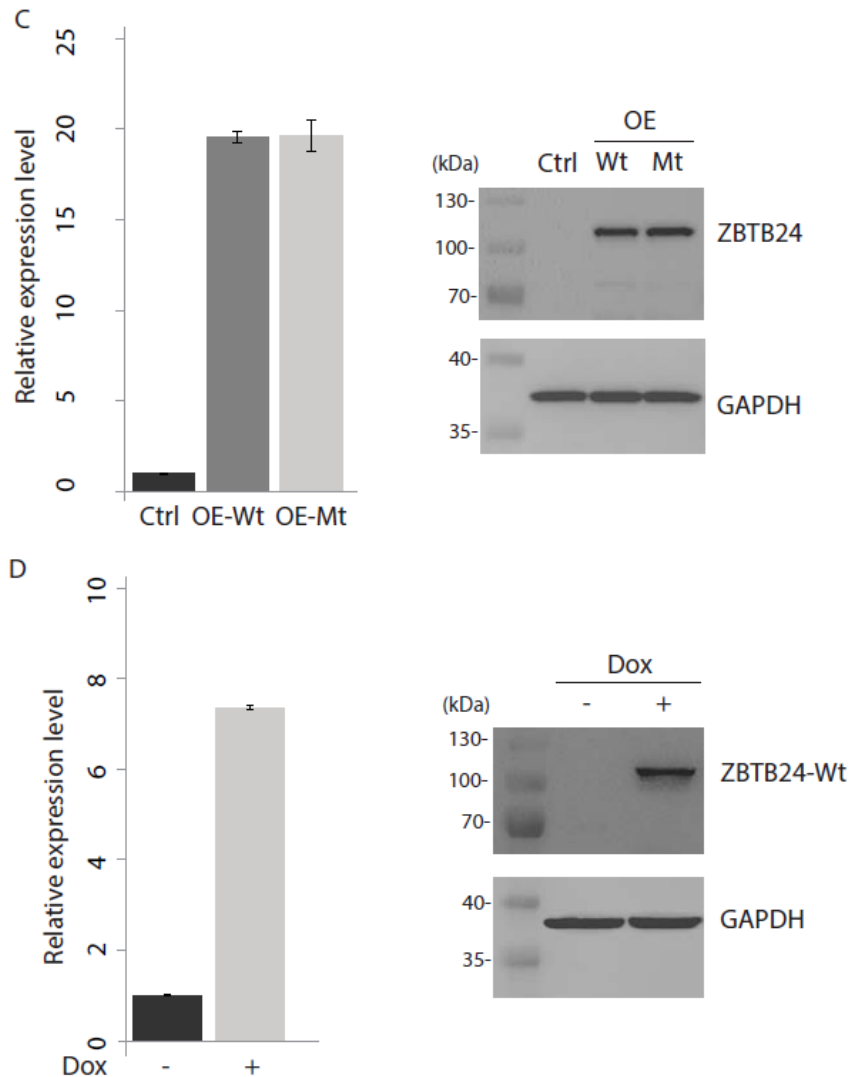


Fig 3.2 - Flag-HA tagged ZBTB24 overexpression vector construction and stable transfected HEK293 cell line establishment

- (A) Sanger sequencing confirmed the CDS of mutant *ZBTB24* and wild-type *ZBTB24* amplified from normal people and patient cDNA. The mutation site was indicated.
- (B) The scheme of pFRT _TO_DEST_FLAG_HA (left) and pFRT _DEST_FLAG_HA overexpression vectors.
- (C) Validation of overexpression of FLAG/HA tagged wild type and mutant ZBTB24 in HEK293 cells constitutively overexpressing ZBTB24 by qRT-PCR (left) and western blot (right). Wild type HEK293 cells without any transfection was considered

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as negative control. Ctrl, Wild type HEK293; OE-Wt, HEK293 with wild type ZBTB24 overexpression; OE-Mt, HEK293 with mutant ZBTB24 overexpression. Mouse monoclonal antibody against HA tag (Novus Biologies, mms-101p) was used for western blot.

- (D) Validation of overexpression of FLAG/HA tagged wild type ZBTB24 in HEK293 cells inducibly overexpressing ZBTB24 by qRT-PCR (left) and western blot (right). qRT-PCR and western blot were performed in HEK293 cells without (Dox-) or with (Dox+) 20ng/ml Doxycycline induction for 16h. Error bars, s.e.m.

3.3 Knockdown efficiency of indicated genes at different transfection time points in HEK293 cells

As described in materials and methods, we knocked down ZBTB24 and TRIM28 in HEK293 cells and validated expression level of corresponded genes at 48, 72 and 96 hours after transfection respectively. Meanwhile, ZBTB24-TRIM28 double knock down efficiency was also validated by RT-qPCR. The results showed both ZBTB24 and TRIM28 could be efficiently down-regulated. The expression level was around 20% of wild type control with only transfection reagent. (Figure 3.3)

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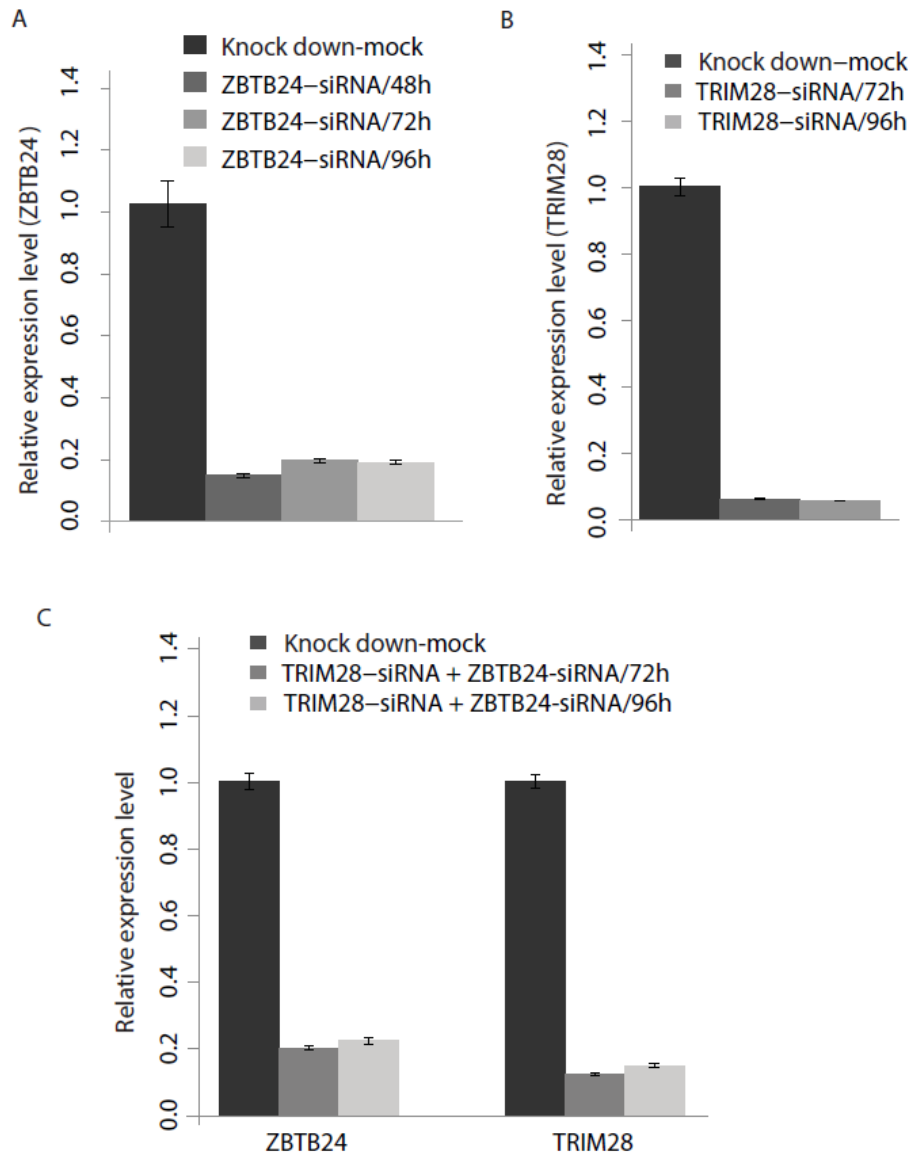


Figure 3.3 - qRT-PCR validation for knockdown efficiency of indicated genes at different transfection time points in HEK293 cells.

- (A) ZBTB24 knockdown validation.
- (B) TRIM28 knockdown validation.
- (C) ZBTB24 and TRIM28 double knockdown validation. Relative expression level (normalized to GAPDH) over control cells was indicated. Error bar, s.e.m.

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3.4 Sub-cellular localization of ZBTB24 proteins in stable overexpression HEK293 cell lines

To understand the sub-cellular localization of ZBTB24 and whether it could be interfered by the missense mutation identified in patient, immuno-fluorescent staining using anti-HA antibody for overexpressed Flag-HA tagged wild type/ mutant ZBTB24 was performed in stable transfected HEK293 cell lines. The microscope image data showed significant fluorescent signal for both wild type or mutant ZBTB24 overlaid with DAPI staining, which was considered as exclusive fluorescent dye for cell nucleus. This indicated that ZBTB24 was predominantly localized in cell nucleus and the homozygous missense mutation identified in patient did not affect its subcellular localization (Figure 3.4).

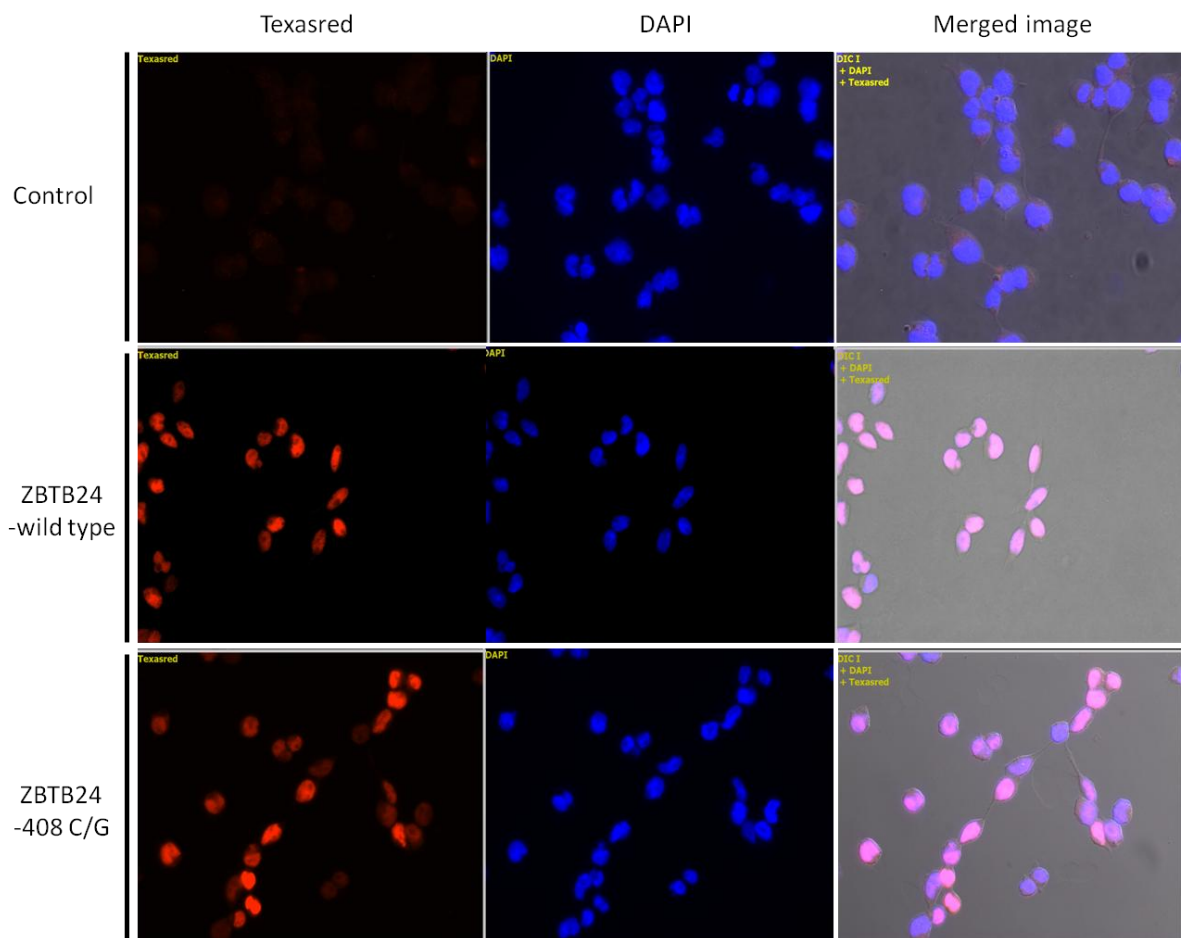


Figure 3.4 - Sub-cellular localization of wild type and mutant ZBTB24. Immuno-fluorescent was performed using the antibody against HA tag in stable HEK293 cell lines

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overexpressing wild type and mutant ZBTB24. Both wild type and mutant ZBTB24 was predominantly localized in cell nucleus. DAPI staining was used to indicate cell nucleus.

3.5 ZBTB24 binds to pericentromeric and centromeric satellite repeats

In order to identify ZBTB24 potential binding sites genome wide, especially in centromeric and pericentromeric heterochromatic region which was decondensed in ICF patients, we performed chromatin immunoprecipitation followed by deep sequencing (ChIP-seq) in HEK293 cells expressing FLAG/HA-tagged ZBTB24. Approximately 17 million (17,202,601) reads could be mapped to human genome, where 4040 peaks were identified using MACS2.0. To further investigate the distribution of these binding sites across the human genome, the genome was sorted into 5 distinct sections (centromere, pericentromere, genic region, intergenic region and subtelomere) and the peaks were relocated into these five regions in term of their genomic coordinates (Figure 3.5A). Very strikingly, 3177 (80.1%) were aligned within (3005, 75.8%) or adjacent to (172, 4.3%, pericentromere) centromeres, which was around 40 times (in centromere) and three times (in pericentromere) higher than expected by chance, whereas only 783 peaks (19.6%) were located in genic and intergenic regions, respectively (Figure 3.5B and 3.5C). Within centromere, the most majority of identified binding sites were completely overlapping with ALR repeats, whereas about 40% of the peaks were overlapping with Sat2/3 repeats which existed in pericentromeric region. The binding of ZBTB24 at corresponded ALR repeats on chromosome 1, 6, 11 as well as two distinct Sat2/3 repeats on chromosome 16 could be validated using ChIP followed by qPCR (ChIP-qPCR) and there it showed significant enrichment of ZBTB24 compared with control (Figure 3.5D).

Because Zinc finger domain usually mediates binding between proteins and DNA, the 408th G to C conversion of ZBTB24 from our ICF patient was speculated to disrupted C2H2 zinc

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finger structure. To investigate whether the mutant ZBTB24 could interfere the binding to centromeric and pericentromeric repeats, we performed ChIP-qPCR to analyze the binding of mutant ZBTB24 on different satellite repeats. Compared with wild type ZBTB24, the binding of mutant ZBTB24 on centromeric and pericentromeric region was significantly decreased (Figure 3.5D).

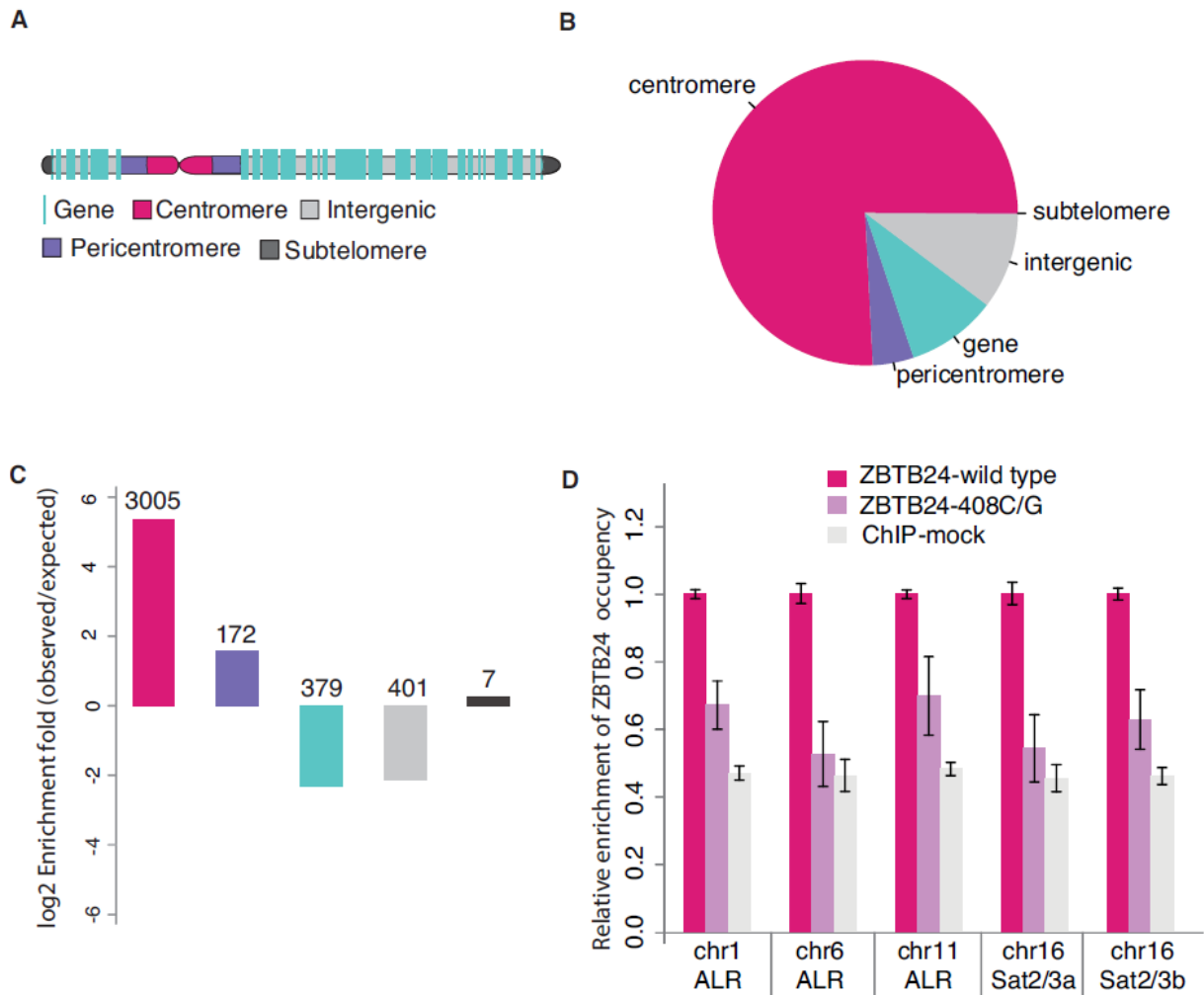


Figure 3.5 - ZBTB24 binds to human centromere and pericentromere repetitive regions.

- (A) Schematic representation of five distinct sections of human genome (see Materials and Methods).
- (B) Distribution of ZBTB24 binding sites in each section. 3964 out of 4040 peaks identified could be assigned into these five regions according to their genome coordinates.

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- (C) Relative enrichment or depletion of ZBTB24 binding sites in each section. Here the distribution of ZBTB24 binding sites in different sections were compared to a background distribution of binding sites generated by randomly selecting in the human genome 4040 regions with the same length distribution. The number of ZBTB24 binding sites identified in the different sections was indicated above the bar.
- (D) ChIP-qPCR analysis showed the binding of ZBTB24 at ALR repeats on chromosome 1, 6, 11 (Chr1 ALR, Chr6 ALR, Chr11 ALR) as well as two distinct Sat2/3 repeats on chromosome 16 (Chr16 Sat2/3a, Chr16 Sat2/3b). Mutant ZBTB24 harboring the missense mutation identified in ICF patient showed a significantly reduced binding affinity at both ALR and Sat2/3 repeats. Relative occupancy was calculated over IP mock control and then compared with Wild type ZBTB24 group, which was normalized to 1. n=3; Error bar, s.e.m.

3.6 ZBTB24 is required for heterochromatin formation in pericentromeric and centromeric region

The DNA binding profile of ZBTB24 and decondensation of ALR and Sat2/3 heterochromatins in ICF patients with ZBTB24 mutation implied that ZBTB24 might directly regulate heterochromatin formation and regulation on pericentromeric and centromeric region. To address this hypothesis, we sought to characterize two defining features of heterochromatin at these regions following ZBTB24 depletion. One is transcription silencing and the other is repressive Histone epigenetic marker.

Firstly, given the transcriptional RNA output was usually repressed in heterochromatic regions (Bulut-Karslioglu et al., 2012), we tested RNA expression level among these regions upon ZBTB24 knocking down. By using genome wide RNA sequencing, we globally quantified RNA output in HEK293 cells with or without ZBTB24 depletion (Figure 3.6A).

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There were average 33 million 51nt sequencing reads generated for each of the six samples (two 48h, one 72h collected after ZBTB24 siRNA knockdown together with corresponding controls), of which 94.1-96.8% could be mapped to human genome references. Then we compared the number of sequencing reads derived from centromere, pericentromere or genes (GENCODE, v23) at each of the 22 autosomes between control cells and cells with reduced abundance of ZBTB24. In contrast to genes, where the median expression fold change is nearly one, the transcription from both centromeric (48h, 1.47 fold change, $p = 3.57 \times 10^{-9}$; 72h, 3.66 fold change, $p = 2.22 \times 10^{-10}$) and pericentromeric regions (48h, 1.41 fold change, $p = 1.62 \times 10^{-11}$; 72h 1.96 fold change, $p = 2.43 \times 10^{-13}$) was apparently upregulated upon ZBTB24 knockdown. It was important that such trend became more significant in cells harvested at 72h after siRNA transfection (Figure 3.6A).

To further understand whether heterochromatin silencing was also disrupted in the ICF patient. RNA-seq was performed to quantify the transcription changes at centromere and pericentromere on lymphocytes derived from the ICF2 patient and healthy controls. By comparing transcription levels between these two, we observed the transcriptions of both regions were also dramatically elevated in ICF2 lymphocytes for 4-8 folds (p value < 0.001) (Figure 3.6A).

Using qRT-PCR, we could validate derepressed RNA output at ALR and Sat2/3 in chromosome 1, 6, 11 and 16 (Figure 3.6B). It has been reported before that in mouse embryonic fibroblast, disruption of heterochromatin at pericentromeric region could lead to up-regulated transcription from both DNA strands of major satellite repeats (Bulut-Karslioglu et al., 2012). To check whether the same phenomenon existed for human ALR, we performed Northern blot using strand-specific RNA probes targeted to human ALR on Chromosome 1. As shown in Figure 3.6C, both forward and reverse transcripts were substantially more abundant in ZBTB24-deficient cells, demonstrating intact ZBTB24 could repress transcription from both strands of ALR at human centromeres. In addition, the length of the transcripts

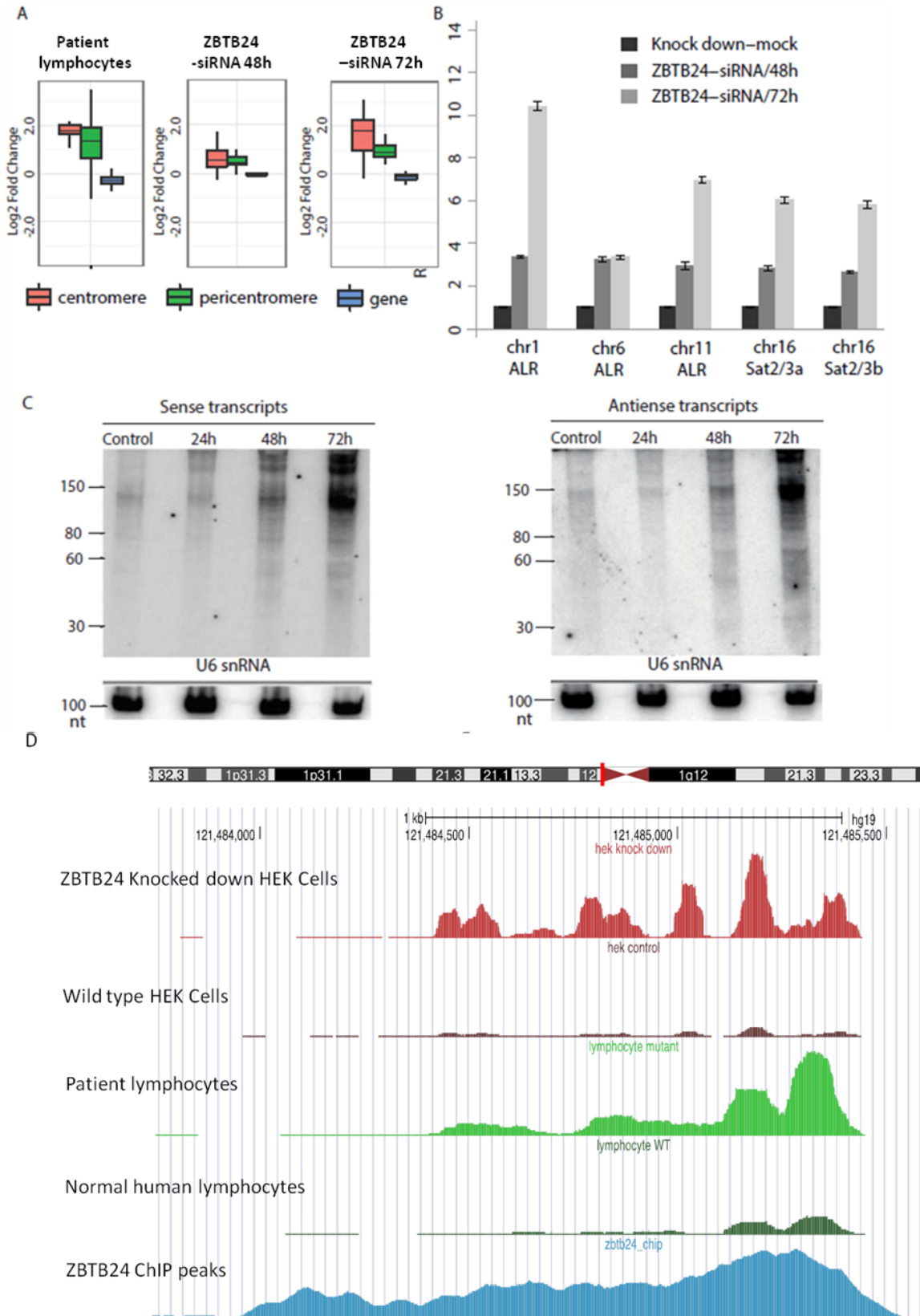
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could be ranged from 30nt to over 150nt. This was consistent with previous studies on mouse major satellites, where they observed divergent centromeric transcripts with different size (Bulut-Karslioglu et al., 2012). Figure 3.6D showed an example to compare the RNA-Seq data from different cells (ZBTB24 with/ without knock down HEK cells and lymphocytes from patient/ normal people) and ChIP-Seq data from ZBTB24 overexpressed HEK cells on ALR repeats of Chromosome 1. As shown there, the transcriptional up regulated centromeric and pericentromeric regions in ZBTB24 deficient cells overlapped with the ZBTB24 binding sites, indicating ZBTB24 could bind to centromeric and pericentromeric repeat region and repress local transcription.

To check whether deficiency of ZBTB24 could disrupt the epigenetic signature of heterochromatin at and in the vicinity of centromere, we analyzed variation of H3K9me3 enrichment at ALR and Sat2/3 between wild type and ZBTB24 deficient HEK293 cells using ChIP-qPCR with H3K9me3 specific antibody. As shown in Figure 3.6E, upon ZBTB24 depletion, the occupancy of H3K9me3 was reduced to 45-65% at different centromeric and pericentromeric repeats.

Taken together, besides the DNA binding pattern of ZBTB24, the transcriptional silencing disruption and impaired H3K9me3 signature at centromeric and pericentromeric heterochromatic region upon ZBTB24 depletion strongly suggested that ZBTB24 is a direct regulator for heterochromatin formation in human centromeric and pericentromeric regions.

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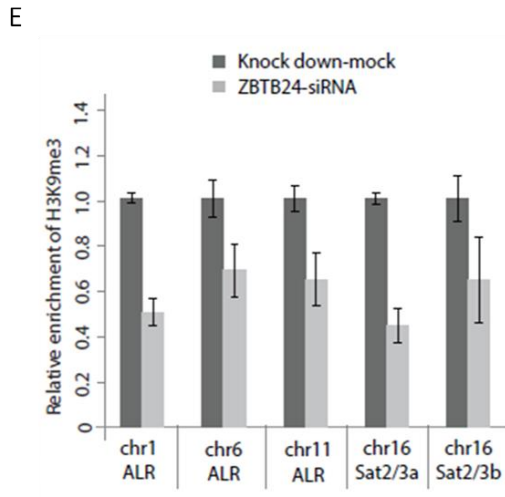


Figure 3.6 - ZBTB24 is required for transcription repression and H3K9me3 signature at centromeric and pericentromeric heterochromatin.

- (A) RNA-seq analysis showed that the transcription at centromeric and pericentromeric heterochromatin were derepressed in patient lymphocytes and ZBTB24 knockdown HEK293 cells. Boxplot showed the comparison of the fold change of transcription from the centromere, pericentromere or genes regions at each of the 22 autosomes between Normal people lymphocytes and patient lymphocytes or the control cells and ZBTB24 knockdown cells. In contrast to genes, where the median expression does not change, the transcription from both centromeric and pericentromeric regions were apparently derepressed upon ZBTB24 knockdown and importantly, such trend became more profound in the cells harvested 72h after siRNA transfection. ***, $p < 10^{-9}$; $n = 22$; Error bar, s.e.m; Wilcox test.
- (B) qRT-PCR analysis validated the derepressed RNA expression at ALR and Sat2/3 in chromosome 1, 6, 11 and 16 (Chr1 ALR, Chr6 ALR, Chr11 ALR, Chr16 Sat2/3a, Chr16 Sat2/3b). Fold change of expression level (normalized to GAPDH) over control cells was indicated. $n=4$; Error bar, s.e.m.
- (C) Northern blot analysis using stand-specific probes targeted at the ALR on

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Chromosome 1 detected the increased transcription from both strand of ALR in cells with ZBTB24 knockdown. U6 snRNA was considered as loading control.

- (D) An example showed the correlation between ZBTB24 binding sites and transcriptional derepression loci of ALR repeats on Chromosome 1. The RNA-Seq or ChIP-Seq data in different cell lines were indicated in the chart. The transcriptional up-regulated region could be covered and occupied by ZBTB24 binding sites.
- (E) ChIP-qPCR analysis showed the enrichment of H3K9me3 was reduced at ALR repeats on chromosome 1, 6, 11 as well as two distinct Sat2/3 repeats on chromosome 16 (Chr1 ALR, Chr6 ALR, Chr11 ALR, Chr16 Sat2/3a, Chr16 Sat2/3b) in cells with ZBTB24 knockdown. Relative enrichment of H3K9me3 at indicated regions was calculated as described in Figure 3.5D. n=3; Error bar, s.e.m.

3.7 The deficiency of ZBTB24 causes cell proliferation blocking and cell cycle arrest in late S and G2/M phase

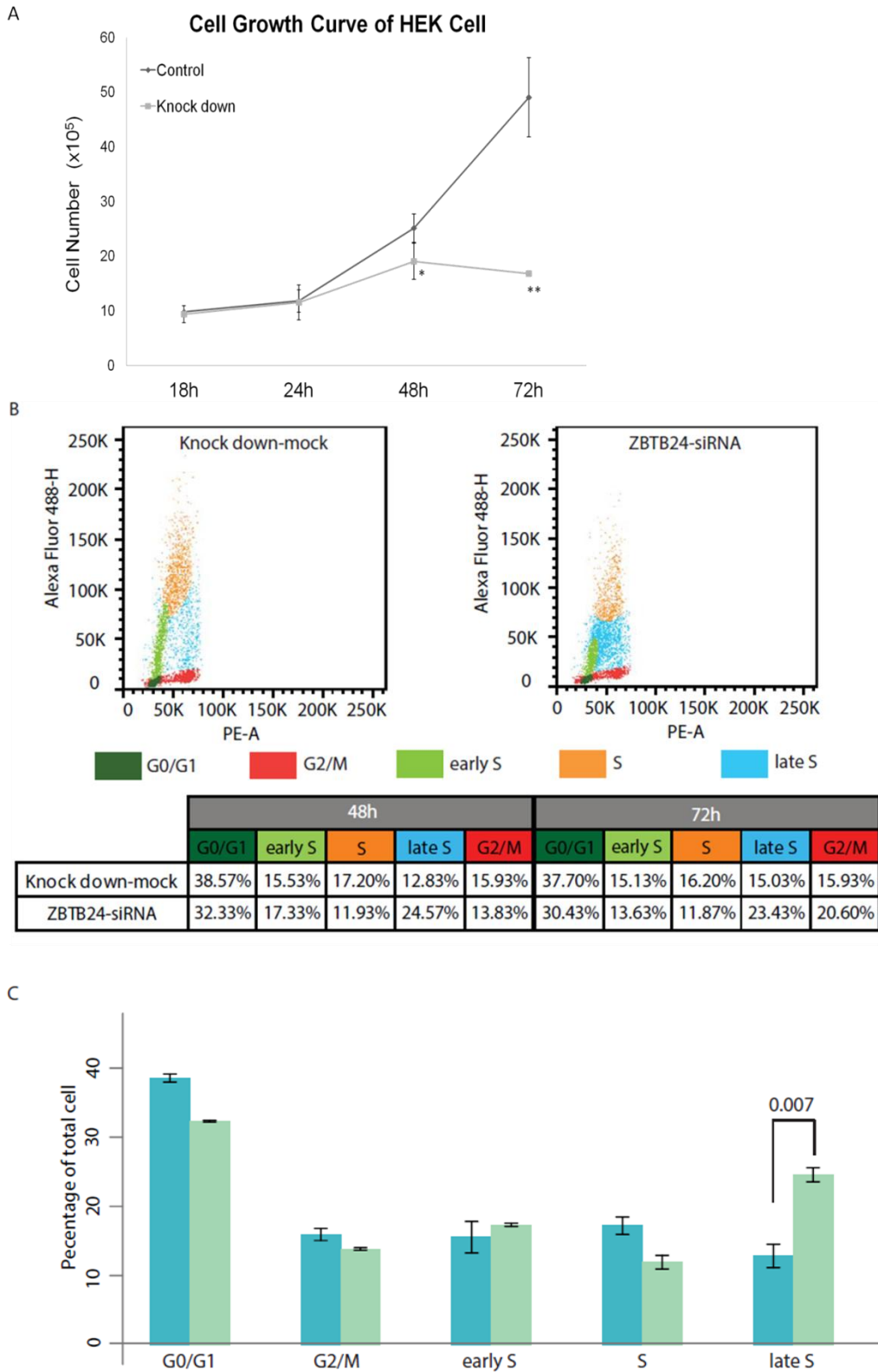
The cell proliferation blocking were observed in ICF2 lymphocytes (von Bernuth et al., 2014). To understand whether ZBTB24 knock down could impede cell proliferation in HEK293 cells as well, we harvested the cells with or without ZBTB24 depletion and calculated the cell number. As shown in Figure 3.7A, the cell proliferation began to reduce at 48h, whereas at 72h, the cell number from knock down group was almost 2 folds lower than control group. This revealed a severe interference of cell proliferation upon ZBTB24 knocking down.

Since it has been reported that the transcripts from centromere are relevant to cell cycle regulation (Zhu et al., 2011) and the cell proliferation blocking had been observed not only in ICF2 lymphocytes but also in ZBTB24 knocked down cells as previously described, to understand such defect in a more mechanistic detail, we analyzed cell cycle distribution in HEK293 cells with and without ZBTB24 depletion using flow cytometry assay. Based on

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Propidium iodide (PI) and Bromdesoxyuridin (BrdU) double staining profile (Figure 3.7B), we observed that in contrast to control cells with mock transfection, the cells depleted with ZBTB24 were already dramatically blocked in late S phase at 48 h after siRNA transfection (91.5% increase, p value 0.007) (Figure 3.7C). However, after another 24 h (72 h), in addition to late S phase, cell cycle arrest from knock down group was also apparently observed in G2-M phase (29.3% increase, p value 0.03) (Figure 3.7D). As the replication of centromere or pericentromere embedded in heterochromatin occurred mostly in late S phase (Lima-de-Faria & Jaworska, 1968; Weidtkamp-Peters, Rahn, Cardoso, & Hemmerich, 2006), and lower DNA synthesis efficiency indicated by Brdu labeling was also observed in ZBTB24 deficient cells (Figure 3.7B), the cell cycle arrest at late S phase resulted from ZBTB24 depletion could be due to aberrant replication of disrupted centromeric and pericentromeric heterochromatin. Further G2-M stalling at the later time point could be resulted from disrupted centromere heterochromatin structure causing disability of kinetochore assembly in mitosis (Kanellopoulou et al., 2005). Taken them together, it revealed ZBTB24-maintained centromeric and pericentromeric heterochromatin has significant functional relevance in controlling the cell cycle.

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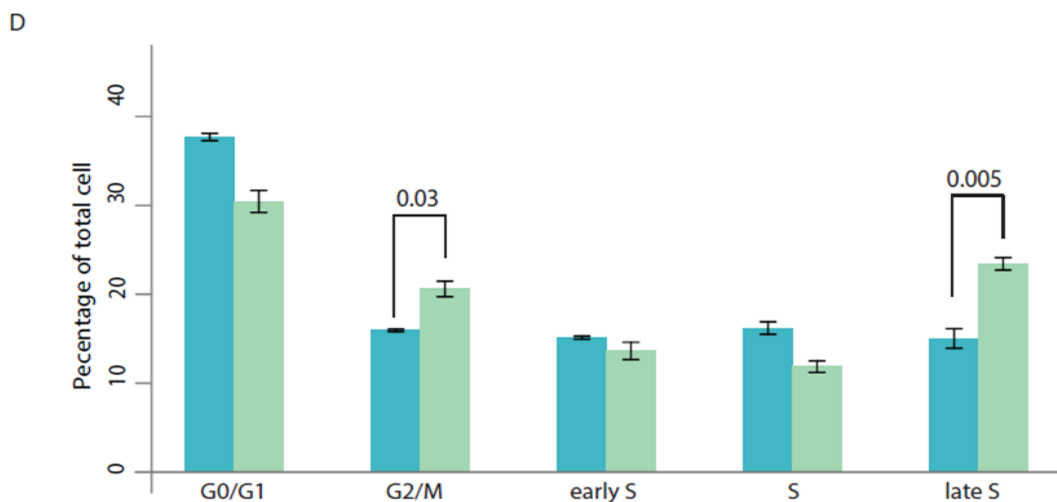


Figure 3.7 - ZBTB24 deficiency caused cell proliferation blocking and cell cycle arrest in late S and G2/M phase.

- (A) Cell growth curve in HEK293 cells with or without ZBTB24 at different timelines. The cell number was calculated by mean value from three independent biological triplicates. * $P < 0.05$, ** $P < 0.01$; $n = 3$; Error bar, s.e.m; t test.
- (B) Flow cytometry -based cell cycle analysis of cells with (right) and without (left) ZBTB24 knockdown. Based on Propidium iodide (X axis) and Bromdesoxyuridin (Y axis) double staining, cells at distinct phases could be assigned. The mean percentages of cells in each cell-cycle phase (G0/G1, early S, S, late S and G2/M) from cells without or with ZBTB24 knockdown at different time points were listed in the table below. $n = 3$.
- (C) Percentage of cells at distinct cell cycle phases in cells with (green) and without (blue) ZBTB24 knockdown collected at 48h after siRNA transfection. P value was shown in the chart; $n = 3$; Error bar, s.e.m; t test.
- (D) Percentage of cells at distinct cell cycle phases in cells with (green) and without (blue) ZBTB24 knockdown collected at 72h after siRNA transfection. P value was shown in the chart; $n = 3$; Error bar, s.e.m; t test.

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3.8 Proteomics characterization of ZBTB24 interaction partners

Recent researches revealed some transcription factors binding to centromere and telomere repressed transcription and regulated chromatin high order structure through interacting with other epigenetic modification factors (Conomos, Reddel, & Pickett, 2014). Moreover, the BTB/POZ domain harbored by ZBTB family proteins is a versatile protein-protein interaction domain (Perez-Torrado et al., 2006; Stogios et al., 2005) and several BTB domain-containing zinc finger proteins are known to regulate transcription through their interaction with transcriptional co-factors (H. Kim et al., 2014; Licchesi et al., 2010). We hypothesized that ZBTB24 might bind to centromeric or pericentromeric repeats and then recruit other co-factors to mediate heterochromatin formation and regulate transcriptional silencing. To investigate this hypothesis, we sought to identify the proteins bound to/interacted with ZBTB24 in proteomics level. For this purpose, we performed immunoprecipitation using FLAG antibody conjugated Protein G Dynabeads in HEK293 cells with and without expressing FLAG/HA-tagged ZBTB24 and then compared the abundance of precipitated proteins by stable isotope labeling by amino acids in cell culture (SILAC)-based quantitative mass spectrometry to identify proteins that specifically co-immunoprecipitated with ZBTB24. As a biological replicate, a crossover label-swap experiment with reversed light/heavy isotope labeling was performed. In totally, our analysis identified 79 proteins with enrichments in both of experiments (Figure 3.8A), of which, very strikingly, we identified 17 zinc finger proteins interacting with ZBTB24 (Table IV). Among them, 6 were zinc finger proteins with KRAB domain which was usually considered to mediate transcription repression, 4 of them had only Zinc fingers and only 1 consisted of SCAN box and Zinc fingers. The other zinc finger proteins all belonged to the same ZBTB protein family, consistent with the previous observation that BTB domain can promote homo- and hetero- dimerization. Particularly, we could validate interaction between ZBTB24 and ZBTB7A/LRF/Pokemon/FBI1 (Figure 3.8B),

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one of ZBTB family proteins known to play an important role in determining B versus T lymphoid lineage fate. ZBTB7A could also repress gene expression by recruiting the nucleosome remodeling and deacetylation complex (NuRD) and mediating DNA methylation. Several other putative interacting proteins, including USP9X29, KLHL21 and KLHL26 were known to associate with chromosome passenger complex (Maerki et al., 2009; Vong, Cao, Li, Iglesias, & Zheng, 2005), which played a key role in mitotic checkpoint maintenance and chromosomal condensation. In addition, Pericentriolar Material 1 (PCM1) was responsible for centrosome assembly (Dammermann & Merdes, 2002). The observed interactions with these proteins were consistent with the localization of ZBTB24 at centromere regions.

Based on known protein-protein interactions annotated in String database (Szklarczyk et al., 2015), 55 identified proteins could be classified into several functional clusters, 12 proteins of which were known to function in transcriptional regulation and histone modification (Figure 3.8C). For instance, MTA1, MTA2, RBBP4, RBBP7 and HDAC2 composing the NuRD complex, were responsible for chromatin remodeling and functioned as transcriptional co-repressors essential for homeostasis of both hematopoietic and epithelial stem cells (Fujita et al., 2004; Kashiwagi, Morgan, & Georgopoulos, 2007; Williams et al., 2004). It has also been reported that NuRD complex was required for proper heterochromatin formation in the pericentromeric region (Helbling Chadwick, Chadwick, Jaye, & Wade, 2009; J. Kim et al., 1999; Sims & Wade, 2011). RING1 and RNF2/RING1B, are the core components of Polycomb Repression Complex 1 (PRC1), which represses transcription through facilitating chromatin compaction and has been observed at paternal constitutive heterochromatin of early mouse embryos (Puschendorf et al., 2008). As shown in Figure 3.8B, direct interactions between ZBTB24 and MTA1/MTA2 as well as RNF2/RING1B were validated by coimmunoprecipitations of epitope-tagged ZBTB24 from HEK293 cell extracts followed by western blot analysis.

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Figure 3.8 - Genome-wide characterization of ZBTB24 interaction partners.

- (A) Scatterplot of SILAC ratios from the crossover label-swap experiments to identify proteins interacted with ZBTB24. In total, 79 proteins (dark circles) with the ratio above 1.25 in both labeling-swap experiments were considered as candidate interaction partners of ZBTB24.
- (B) Immunoprecipitations of epitope-tagged ZBTB24 from HEK293 cell extracts followed by western analysis validated the interaction between ZBTB24 and ZBTB7A, MTA1, MTA2, as well as RNF2/RING1B.
- (C) Based on known protein-protein interaction annotated in String database (Szkarczyk et al, 2015), 55 candidate interaction partners could be grouped into several functional clusters. 12 proteins marked with yellow were known to function in transcriptional regulation and histone modification.

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Gene names	Protein names	Functional Domains	Functions and Putative Functions
PATZ1	POZ-, AT hook-, and zinc finger-containing protein 1	A.T hook DNA-binding domain; BTB (POZ) domain; C2H2-type zinc fingers	Transcription repression; ESC pluripotency; Tumour suppression; Lymphomagenesis
ZBTB1	Zinc finger and BTB domain-containing protein 1	BTB (POZ) domain; C2H2-type zinc fingers	lymphoid lineage commitment and differentiation; Early lymphoid progenitors development into T-cell lineage; Transcription repression; Chromatin remodeling and DNA repair
ZBTB11	Zinc finger and BTB domain-containing protein 11	BTB (POZ) domain; C2H2-type zinc fingers	May be involved in transcriptional regulation
ZBTB17	Zinc finger and BTB domain-containing protein 17	BTB (POZ) domain; C2H2-type zinc fingers	Cancer cell proliferation and tumorigenesis; cell growth; cell cycle regulation; Transcription regulation; Early lymphocyte development; cell apoptosis; CpG methylation of promoter; early embryonic development; neuroblastoma gene
ZBTB3	Zinc finger and BTB domain-containing protein 3	BTB (POZ) domain; C2H2-type zinc fingers	Cancer cell growth; Cell apoptosis; May be involved in transcriptional regulation
ZBTB7A	Zinc finger and BTB domain-containing protein 7A	BTB (POZ) domain; C2H2-type zinc fingers	Cancer oncogenesis; Tumor suppressor; Transcription repression; Lymphoid progenitors development to B-cell lineage
ZKSCAN8	Zinc finger protein with KRAB and SCAN domains 8	KRAB domain; SCAN box domain; C2H2-type zinc fingers	May be involved in transcriptional regulation
ZNF136	Zinc finger protein 136	KRAB domain; C2H2-type zinc fingers	Transcription repression
ZNF146	Zinc finger protein OZF	C2H2-type zinc fingers	May be linked to Telomere regulation and Cancer
ZNF324	Zinc finger protein 324A	KRAB domain; C2H2-type zinc fingers	May be involved in transcriptional regulation
ZNF324B	Zinc finger protein 324B	KRAB domain; C2H2-type zinc fingers	May be involved in transcriptional regulation
ZNF408	Zinc finger protein 408	C2H2-type zinc fingers	Familial exudative vitreoretinopathy (FEVR); retinal vasculature development
ZNF574	Zinc finger protein 574	C2H2-type zinc fingers	Unknown
ZNF768	Zinc finger protein 768	C2H2-type zinc fingers	Unknown
ZNF845	Zinc finger protein 845	KRAB domain; C2H2-type zinc fingers	Unknown
ZNF320	Zinc finger protein 320	KRAB domain; C2H2-type zinc fingers	Unknown
ZSCAN25	Zinc finger and SCAN domain-containing protein 25	SCAN box domain; C2H2-type zinc fingers	Unknown

Table IV - Zinc finger Proteins among identified ZBTB24 interaction partners.

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3.9 ZBTB24 and TRIM28 could regulate centromeric and pericentromeric heterochromatin formation synergistically

Among all potential interaction partners we have identified, TRIM28 caught our special attention. It has been reported that TRIM28 can interact with HP1 directly and function as a scaffold to repress transcription through DNA methylation, H3K9 methylation and histone deacetylation by recruiting DNA methyltransferase (DNMT3A and DNMT3B), Histone lysine methyltransferase (SETDB1) and Histone deacetylase (NuRD) (Doerks et al., 2002; Quenneville et al., 2011; Schultz et al., 2002). It can be tethered by Krüppel-associated box zinc finger proteins (KRAB-ZFPs) to mediate heterochromatin formation at the endogenous retrovirus (ERV) elements, promoters and imprinted regions (Quenneville et al., 2011; Schultz et al., 2002; Turelli et al., 2014). Although TRIM28 has been observed to associate with centromere heterochromatin (Cammass et al., 2002), its role in centromere/pericentromere heterochromatin formation remains unclear. Given the observed interaction between TRIM28 and ZBTB24, it is plausible that ZBTB24 could tether TRIM28 to centromere/pericentromere, which then further recruits other co-factors to regulate heterochromatin formation.

To investigate functional relevance of the interaction between ZBTB24 and TRIM28 in centromere/pericentromere heterochromatin, we first validated their direct interaction by performing immunoprecipitation followed by western analysis (Figure 3.9A). Second, we sought to check whether TRIM28 could also bind to centromere and pericentromere region. Using ChIP-qPCR, we could demonstrate that TRIM28 indeed bound to both ALR and Sat2/3 (Figure 3.9B). To further address whether the binding of TRIM28 at centromere and pericentromere was dependent on ZBTB24, we compared TRIM28 occupancy at ALR and Sat2/3 between wild type and ZBTB24 deficient cells. As shown in Figure 3.9B, the binding of TRIM28 at these regions were moderately reduced (~35%) upon ZBTB24 depletion (Figure 3.9B), indicating that the binding of TRIM28 to centromeric and pericentromeric

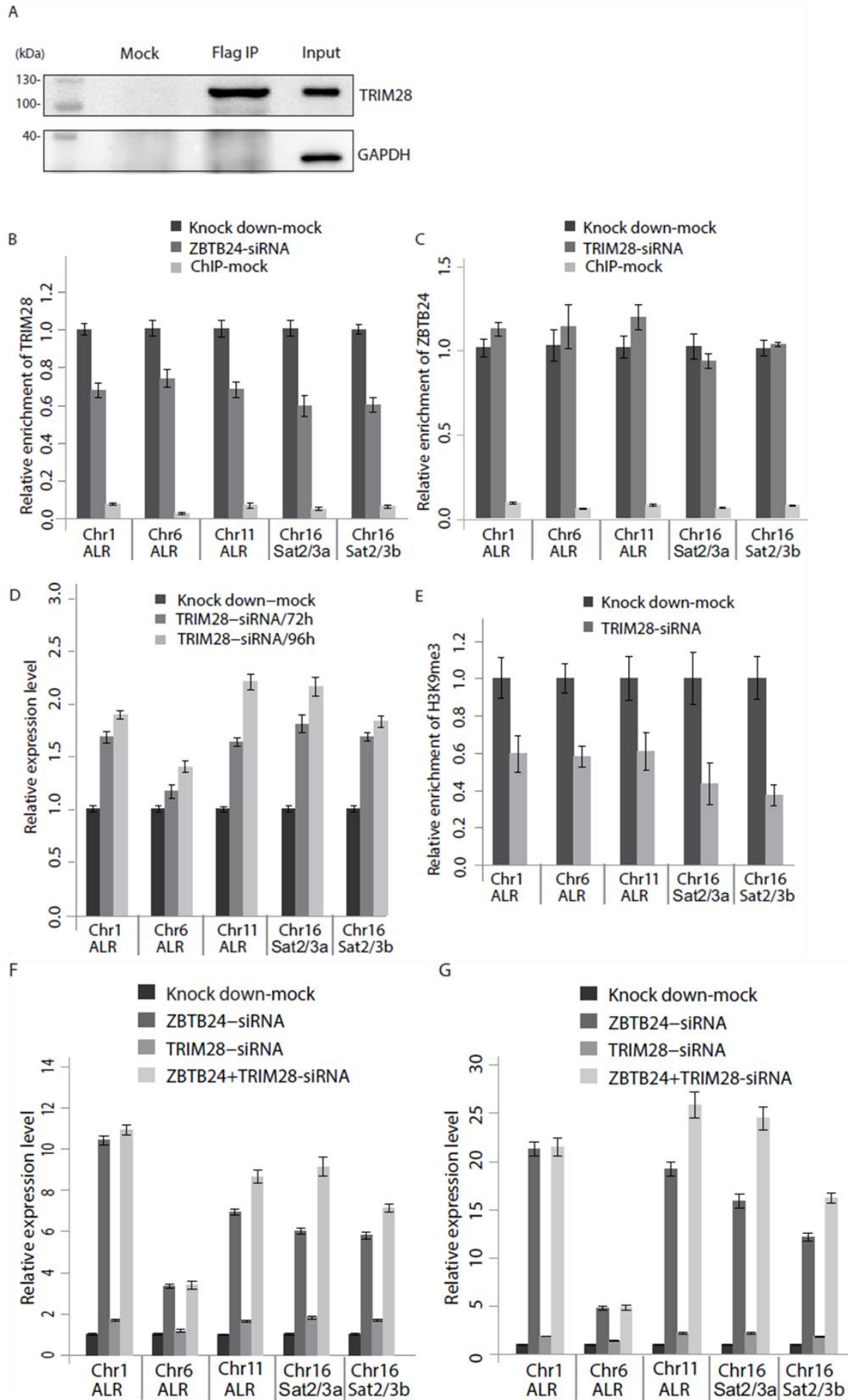
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regions were partially dependent on ZBTB24. Reciprocally, by comparing the ZBTB24 occupancy between wild type and TRIM28 deficient cells, we showed that the binding of ZBTB24 at ALR and Sat2/3 was not affected by TRIM28 (Figure 3.9C).

Next, we asked whether TRIM28 was essential for maintaining centromeric and pericentromeric heterochromatin. To this end, we analyzed RNA expression in these regions upon TRIM28 depletion. As shown in Figure 3.9D, based on qRT-PCR, the transcription from both ALR and Sat2/3 were significantly increased upon TRIM28 knockdown, suggesting the defective heterochromatin at centromeric and pericentromeric region (Figure 3.9D). Consistent with this, we also observed a significantly reduced enrichment of H3K9me3 at both ALR and Sat2/3, with a stronger effect at Sat2/3 (~40% and 60% reduction in ALR and Sat2/3, respectively) (Figure 3.9E).

Finally, we examined whether ZBTB24 and TRIM28 could act on centromeric and pericentromeric heterochromatin formation synergistically. For this purpose, we compared the transcription of ALR and Sat 2/3 in wild type HEK293 cells, HEK293 cells with ZBTB24 or TRIM28 depletion alone, and HEK293 cells with both ZBTB24 and TRIM28 depleted. As shown in Figure 3.9F, the effect of depleting ZBTB24 on both ALR and Sat2/3 transcript derepression was much stronger than that of TRIM28, suggesting the more important role of ZBTB24 in repressing the centromeric and pericentromeric transcription. Interestingly, compared to depletion of ZBTB24 alone, whereas the depletion of both proteins did not induce stronger transcriptional derepression at ALRs (1.1 fold change, double knockdown *vs.* ZBTB24 knockdown $p=0.3$, t test), it did enhance additional transcription at Sat2/3 (1.37 fold change, double knockdown *vs.* ZBTB24 knockdown $p=3.91 \times 10^{-7}$, t test). This pattern persisted at 96h after siRNA transfection (Figure 3.9G). Such observation indicated that the repressive effect of TRIM28 at centromere ALR was fully dependent on ZBTB24, while at the pericentromere Sat2/3, TRIM28 acted with ZBTB24 more synergistically.

3. Results



3. Results

Figure 3.9 - ZBTB24 and TRIM28 regulate heterochromatin formation at human centromere and pericentromere synergistically.

- (A) Immunoprecipitation of epitope-tagged ZBTB24 from HEK293 cell extracts followed by western analysis validated the interaction between ZBTB24 and TRIM28.
- (B) ChIP-qPCR analysis showed the binding of TRIM28 at ALR repeats on chromosome 1, 6, 11 as well as two distinct Sat2/3 repeats on chromosome 16 (Chr1 ALR, Chr6 ALR, Chr11 ALR, Chr16 Sat2/3a, Chr16 Sat2/3b), which is reduced in cells with ZBTB24 knockdown. Relative enrichment was indicated. n=3; Error bar, s.e.m.
- (C) ChIP-qPCR analysis showed the binding of ZBTB24 at ALR repeats on chromosome 1, 6, 11 (Chr1 ALR, Chr6 ALR, Chr11 ALR) as well as two distinct Sat2/3 repeats on chromosome 16 (Chr16 Sat2/3a, Chr16 Sat2/3b), is not significantly affected in HEK293 cells with TRIM28 knockdown. Relative enrichment was indicated. n=3; Error bar, s.e.m.
- (D) qRT-PCR analysis showed the derepressed RNA expression at ALR and Sat2/3 in chromosome 1, 6, 11 and 16 (Chr1 ALR, Chr6 ALR, Chr11 ALR, Chr16 Sat2/3a, Chr16 Sat2/3b) upon TRIM28 Knockdown. Fold change of expression level (over GAPDH) over control cells was indicated. n=4; Error bar, s.e.m.
- (E) ChIP-qPCR analysis showed the enrichment of H3K9me3 was reduced at ALR repeats on chromosome 1, 6, 11 as well as two distinct Sat2/3 repeats on chromosome 16 (Chr1 ALR, Chr6 ALR, Chr11 ALR, Chr16 Sat2/3a, Chr16 Sat2/3b) in cells with TRIM28 knockdown. Relative enrichment was indicated. n=3; Error bar, s.e.m.
- (F) qRT-PCR analysis compared the derepressed transcription in HEK293 cells with ZBTB24 or TRIM28 depletion alone, and HEK293 cells with both ZBTB24 and TRIM28 depleted. The cells were harvest at 72 h after siRNA transfection. Fold

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change of expression level (over GAPDH) over control cells was indicated. The effect of depleting ZBTB24 on both ALR and Sat2/3 transcript derepression in chromosome 1, 6, 11 and 16 (Chr1 ALR, Chr6 ALR, Chr11 ALR, Chr16 Sat2/3a, Chr16 Sat2/3b) was much stronger than that of TRIM28. Compared to depletion of ZBTB24 alone, whereas the depletion of both proteins did not induce stronger transcriptional derepression at ALRs, it did enhance additional transcription at Sat2/3. n=4; Error bar, s.e.m.

- (G) qRT-PCR analysis compared the derepressed transcription in HEK293 cells with ZBTB24 or TRIM28 depletion alone, and HEK293 cells with both ZBTB24 and TRIM28 depleted. The cells were harvest at 96 h after siRNA transfection. ALR repeats on chromosome 1, 6, 11 (Chr1 ALR, Chr6 ALR, Chr11 ALR) and two distinct Sat2/3 repeats on chromosome 16 (Chr16 Sat2/3a, Chr16 Sat2/3b) were detected. n=3; Error bar, s.e.m.

4. Discussion

In this study, we revealed ZBTB24, a protein associated with human ICF syndrome, could bind at human centromere and pericentromere repetitive region and it is essential for heterochromatin formation at these regions. Through a global survey of proteins bound to ZBTB24, in addition to several known heterochromatin regulators, we identified TRIM28 as a potential interaction partner. Consistent with their physical interaction, we could demonstrate that TRIM28 also functions in regulating heterochromatin at centromeric/pericentromeric region, which is at least partially dependent on ZBTB24.

A recent study from Jenuwein lab has revealed a paradigm pathway, in which transcriptional repression of pericentromeric repeats by sequence-specific transcription factors, was essential for the integrity of heterochromatin. In that study, the authors have demonstrated with extensive evidence that Pax3 and Pax9 could act on mouse major satellite repeats in such manner, and proposed many other transcription factors, particularly large variety of zinc finger proteins could also function in transcriptional repression at highly divergent repeats in various eukaryotic genomes (Bulut-Karslioglu et al., 2012). Apparently, ZBTB24, as demonstrated in our study, regulated the heterochromatin formation at centromeric and pericentromeric regions at least in part with a similar mechanism. On one hand, it can bind at centromeric and pericentromeric repeats, likely mediated by its eight zinc-finger domains and AT-hook motif. Based on the ChIP-seq peaks, we could not identify a distinct sequence motif(s). Therefore, the observed binding might be facilitated also through its interaction partners, particularly zinc finger proteins given that six ZBTB proteins and 11 other zinc finger proteins were identified as potential interaction partners in this study (Figure 4). On the other hand, ZBTB24, via the BTB domain, could recruit other co-factors to fulfill its regulatory functions, as already shown for other members of the ZBTB family (Figure 4). For example, ZBTB16/PLZF interacts directly with the SMRT and N-CoR co-repressors, thereby

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mediating transcriptional repression (David et al., 1998; S. H. Hong et al., 1997). Indeed, among the potential ZBTB24 interaction partners, several are well-known transcriptional repressors, such as the core components of NuRD complex, which can mediate heterochromatin formation by inducing histones deacetylation and DNA methylation (Cai et al., 2014; Y Zhang et al., 1999). Importantly, NuRD has been shown associating with and is required for the assembly of pericentromeric heterochromatin (Sims & Wade, 2011). Inhibition of histone deacetylation could disrupt pericentromeric heterochromatin and centromere function (Taddei, Maison, Roche, & Almouzni, 2001).

TRIM28 is the most interesting interaction partner of ZBTB24 that we have identified. It is known as a scaffold protein that can establish local heterochromatin by recruiting multi-protein complexes, including DNMT3A/B, SETDB1, NuRD and HP1. It has been shown that sequence-specific KRAB-ZFPs can tether TRIM28 to gene promoters, endogenous retroelements as well as imprinting control regions, thereby repressing local transcription activity (Lechner, Schultz, Negorev, Maul, & Rauscher, 2005; Quenneville et al., 2011; Schultz et al., 2002; Turelli et al., 2014). Besides these extensively studied function in facultative heterochromatin, however, the role of TRIM28 in regulating constitutive heterochromatin remains largely unexplored, although it has been shown in mouse fibroblast NIH3T3 cells that TRIM28, together with two KRAB-ZFPs, KRAZ1 and KRAZ2, colocalized with HP1a-containing centromeric heterochromatin (Matsuda et al., 2001). Here for the first time, we revealed that similar as in other facultative heterochromatin regions, TRIM28 could also bind to centromeric and pericentromeric repetitive region, repress the transcription and was essential for the heterochromatic integrity. Moreover we found the binding and function of TRIM28 in these regions was at least partially dependent on ZBTB24. This is consistent with the observed interaction between TRIM28 and ZBTB24, although it remains unclear whether the two interact directly or indirectly through other proteins. Indeed, among the 79 potential interaction partners of ZBTB24, six are KRAB-ZFs. Given the

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different synergistic effects of the two proteins on centromeric and pericentromeric heterochromatin, it is plausible that different protein complexes comprising different additional cofactors act on the two regions. Moreover, while ZBTB24 can regulate heterochromatin formation through other partners independent of TRIM28, there may exist many other DNA binding proteins that can tether TRIM28 to the centromeric and pericentromeric regions, likely in cell type and condition-specific manner.

Mutations in the *ZBTB24* gene cause ICF syndrome with severe defects manifested in only distinct tissues. This is consistent with the differential expression of ZBTB24 across different tissues. Its high expression in naïve B cell may explain the severe B cell defects observed in ICF patients (Cerbone et al., 2012). It is conceivable that large variety of DNA binding proteins could mediate heterochromatin formation with a similar mechanism as ZBTB24 and many of them act in tissue/cell type-specific manner. Therefore only those tissues/cells in which ZBTB24 is essential are affected. The defective heterochromatin at centromeric/pericentromeric regions could on one hand directly disrupt the basic cellular process such as cell cycle progress. On the other hand, altered heterochromatin structure may also lead to high-order change in nuclear architecture and thereby indirectly the aberrant gene expression. Here, we for the first time unambiguously established ZBTB24 as an important centromeric/ pericentromeric heterochromatin regulator. Our study provides a first mechanistic insight into the ZBTB24-mediated heterochromatin regulation. How the heterochromatin defects contribute to the pathophysiology of ICF syndrome will await future studies in more disease-relevant cells/tissues.

Overall, our study represented a direct investigation of centromeric/pericentromeric heterochromatin formation in human (Figure 4). We for the first time unambiguously established a zinc-finger protein as an important regulator of human centromeric/pericentromeric heterochromatin. Our results provided the mechanistic insight

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into ZBTB24-mediated heterochromatin regulation and extended the function of TRIM28 to the regulation of constitutive heterochromatin.

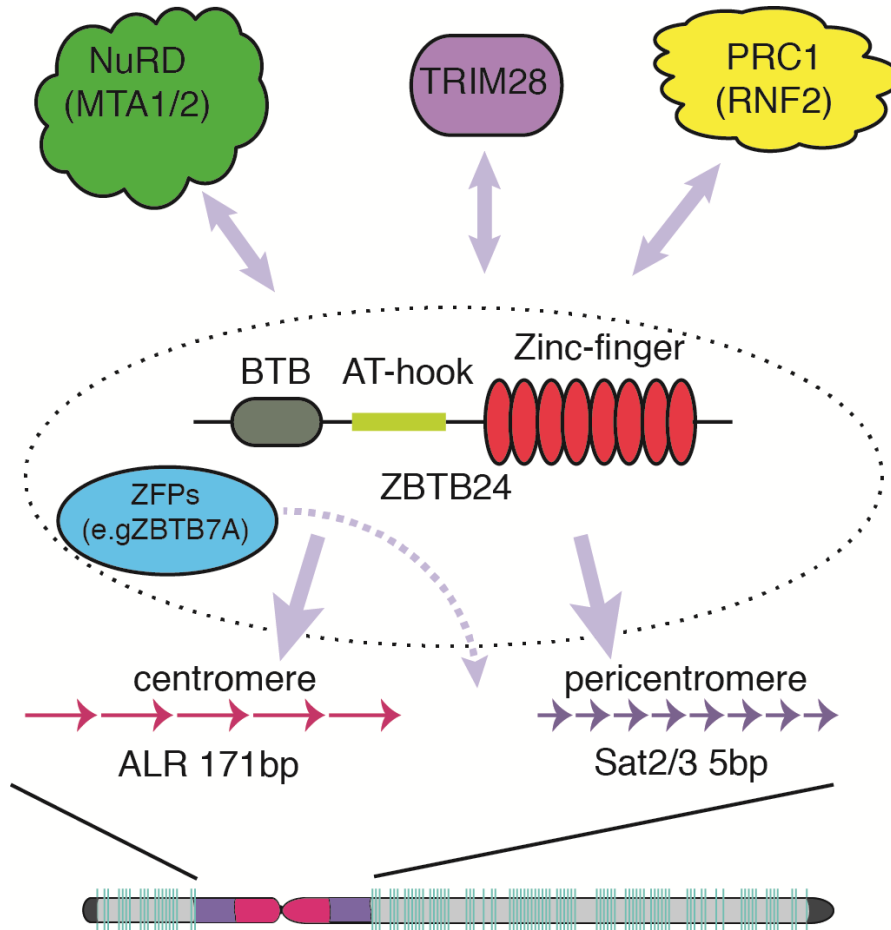


Figure 4 - Mechanistic model for ZBTB24-mediated human centromeric and pericentromeric heterochromatin regulation.

ZBTB24 can bind at human centromeric and pericentromeric repeats, directly mediated by its eight zinc-finger domains and AT-hook motif and/or indirectly facilitated through its interaction partners, particularly other zinc finger proteins. Then, it can further recruit co-factors to fulfill its regulatory functions, including well-known transcriptional repressors, such as the core components of NuRD complex and PRC1 complex. In addition, it can tether TRIM28 to centromeric and pericentromeric region, which can function as a scaffold protein in regulating local heterochromatin formation.

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6. Appendix

6. Appendix

6.1 Putative ZBTB24 binding sites identified by ChIP-Seq

genomic_loci	genomic_region	repeat_name	repeat_family	repeat_class
chr1:113501739-113501895	intergenic	L1PA2	LINE	L1
chr1:118283085-118283261	gene	L1PA3	LINE	L1
chr1:120461434-120461590	centromere	ALR/Alpha	Satellite	centr
chr1:120836393-120836549	gene	L1PA2	LINE	L1
chr1:121755226-121755400	intergenic	L1PB	LINE	L1
chr1:121764818-121764974	gene	L1PA2	LINE	L1
chr1:121773466-121773672	gene	MamRep137	DNA	TcMar? ¹ TcMar-Tigger
chr1:121774863-121775118	intergenic	L1PA3	LINE	L1
chr1:121968499-121968682	intergenic	L1PA3	LINE	L1
chr1:122238572-122238728	gene	L1PA2	LINE	L1
chr1:122395878-122396121	gene	L1PA2	LINE	L1
chr1:122429527-122429683	intergenic	L1MD	LINE	L1
chr1:122457785-122457941	centromere	ALR/Alpha	Satellite	centr
chr1:122502385-122502556	gene	L1PA4	LINE	L1
chr1:122505784-122505954	gene	L1HS	LINE	L1
chr1:122511324-122511480	gene	L1PA2	LINE	L1
chr1:122520261-122520492	Unplaced_chr	L1PA3	LINE	L1
chr1:122528420-122528576	intergenic	L1PA3	LINE	L1
chr1:122539733-122539889	intergenic	L1PA3	LINE	L1
chr1:122540460-122540686	intergenic	L1PA10	LINE	L1
chr1:122547093-122547249	gene	L1PA6	LINE	L1
chr1:122553811-122554008	gene	L1PA3	LINE	L1
chr1:122557347-122557518	centromere	ALR/Alpha	Satellite	centr
chr1:122566063-122566233	centromere	ALR/Alpha	Satellite	centr
chr1:122587655-122587850	intergenic	norepeat	nofamily	noclass
chr1:122590292-122590448	intergenic	(TTCCATTTCGAG) _n	Simple_repeat	Simple_repeat
chr1:122605124-122605280	intergenic	norepeat	nofamily	noclass
chr1:122625067-122625252	centromere	ALR/Alpha	Satellite	centr
chr1:122673694-122673850	centromere	ALR/Alpha	Satellite	centr
chr1:122680444-122680600	centromere	ALR/Alpha	Satellite	centr
chr1:122738815-122739062	centromere	ALR/Alpha	Satellite	centr
chr1:122760713-122760869	centromere	ALR/Alpha	Satellite	centr
chr1:122797030-122797207	centromere	ALR/Alpha	Satellite	centr
chr1:122818234-122818390	centromere	ALR/Alpha	Satellite	centr
chr1:122820516-122820732	centromere	ALR/Alpha	Satellite	centr
chr1:122822337-122822561	centromere	ALR/Alpha	Satellite	centr
chr1:122827320-122827501	centromere	ALR/Alpha	Satellite	centr
chr1:122842595-122842855	centromere	ALR/Alpha	Satellite	centr
chr1:122850229-122850388	centromere	ALR/Alpha	Satellite	centr
chr1:122861091-122861256	centromere	ALR/Alpha	Satellite	centr
chr1:122865769-122865944	centromere	ALR/Alpha	Satellite	centr
chr1:122890021-122890177	centromere	ALR/Alpha	Satellite	centr
chr1:122890320-122890476	centromere	ALR/Alpha	Satellite	centr
chr1:122902397-122902644	centromere	ALR/Alpha	Satellite	centr
chr1:122911318-122911474	centromere	ALR/Alpha	Satellite	centr
chr1:122913442-122913623	centromere	ALR/Alpha	Satellite	centr
chr1:122918778-122918934	centromere	ALR/Alpha	Satellite	centr
chr1:122929264-122929486	centromere	ALR/Alpha	Satellite	centr
chr1:122943967-122944197	centromere	ALR/Alpha	Satellite	centr
chr1:122948062-122948218	centromere	ALR/Alpha	Satellite	centr
chr1:122949321-122949477	centromere	ALR/Alpha	Satellite	centr
chr1:122952911-122953067	centromere	ALR/Alpha	Satellite	centr
chr1:122970041-122970212	centromere	ALR/Alpha	Satellite	centr
chr1:122989037-122989193	centromere	ALR/Alpha	Satellite	centr
chr1:123001226-123001457	centromere	ALR/Alpha	Satellite	centr
chr1:123004120-123004276	centromere	ALR/Alpha	Satellite	centr
chr1:123006643-123006799	centromere	ALR/Alpha	Satellite	centr
chr1:123007429-123007677	centromere	ALR/Alpha	Satellite	centr
chr1:123019785-123019954	centromere	ALR/Alpha	Satellite	centr
chr1:123035976-123036298	centromere	ALR/Alpha	Satellite	centr
chr1:123081907-123082063	centromere	ALR/Alpha	Satellite	centr
chr1:123098304-123098498	centromere	ALR/Alpha	Satellite	centr
chr1:123099603-123099863	centromere	ALR/Alpha	Satellite	centr
chr1:123107222-123107384	centromere	ALR/Alpha	Satellite	centr
chr1:123119888-123120044	centromere	ALR/Alpha	Satellite	centr
chr1:123158721-123158877	centromere	ALR/Alpha	Satellite	centr
chr1:123168640-123168828	centromere	ALR/Alpha	Satellite	centr
chr1:123194213-123194403	centromere	ALR/Alpha	Satellite	centr
chr1:123225816-123226057	centromere	ALR/Alpha	Satellite	centr
chr1:123259552-123259842	centromere	ALR/Alpha	Satellite	centr
chr1:123264383-123264539	centromere	ALR/Alpha	Satellite	centr
chr1:123274458-123274614	centromere	ALR/Alpha	Satellite	centr
chr1:123288838-123289037	centromere	ALR/Alpha	Satellite	centr
chr1:123290514-123290670	centromere	ALR/Alpha	Satellite	centr
chr1:123297617-123297773	centromere	ALR/Alpha	Satellite	centr
chr1:123337998-123338182	centromere	ALR/Alpha	Satellite	centr
chr1:123344974-123345166	centromere	ALR/Alpha	Satellite	centr
chr1:123349144-123349366	centromere	ALR/Alpha	Satellite	centr
chr1:123351445-123351622	centromere	ALR/Alpha	Satellite	centr
chr1:123372512-123372668	centromere	ALR/Alpha	Satellite	centr
chr1:123388729-123388885	centromere	ALR/Alpha	Satellite	centr
chr1:123403333-123403502	centromere	ALR/Alpha	Satellite	centr
chr1:123433449-123433614	centromere	ALR/Alpha	Satellite	centr
chr1:123447442-123447635	centromere	ALR/Alpha	Satellite	centr
chr1:123468697-123468873	centromere	ALR/Alpha	Satellite	centr
chr1:123486280-123486436	centromere	ALR/Alpha	Satellite	centr

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chr1:123487595-123487801	centromere	ALR/Alpha	Satellite	centr
chr1:123503891-123504109	centromere	ALR/Alpha	Satellite	centr
chr1:123507776-123507932	centromere	ALR/Alpha	Satellite	centr
chr1:123510871-123511027	centromere	ALR/Alpha	Satellite	centr
chr1:123527853-123528009	centromere	ALR/Alpha	Satellite	centr
chr1:123536560-123536826	centromere	ALR/Alpha	Satellite	centr
chr1:123551580-123551736	centromere	ALR/Alpha	Satellite	centr
chr1:123556423-123556596	centromere	ALR/Alpha	Satellite	centr
chr1:123609565-123609721	centromere	ALR/Alpha	Satellite	centr
chr1:123623793-123623949	centromere	ALR/Alpha	Satellite	centr
chr1:123628096-123628300	centromere	ALR/Alpha	Satellite	centr
chr1:123665172-123665328	centromere	ALR/Alpha	Satellite	centr
chr1:123707357-123707513	intergenic	L1PA5	LINE	L1
chr1:123734376-123734536	centromere	ALR/Alpha	Satellite	centr
chr1:123741399-123741555	centromere	ALR/Alpha	Satellite	centr
chr1:123745329-123745488	centromere	ALR/Alpha	Satellite	centr
chr1:123775430-123775620	centromere	ALR/Alpha	Satellite	centr
chr1:123790198-123790354	centromere	ALR/Alpha	Satellite	centr
chr1:123798424-123798628	centromere	ALR/Alpha	Satellite	centr
chr1:123803519-123803692	centromere	ALR/Alpha	Satellite	centr
chr1:123819585-123819815	centromere	ALR/Alpha	Satellite	centr
chr1:123821574-123821762	centromere	ALR/Alpha	Satellite	centr
chr1:123829808-123830084	centromere	ALR/Alpha	Satellite	centr
chr1:123849225-123849579	centromere	ALR/Alpha	Satellite	centr
chr1:123856703-123856859	centromere	ALR/Alpha	Satellite	centr
chr1:123919351-123919515	centromere	ALR/Alpha	Satellite	centr
chr1:123924488-123924685	centromere	ALR/Alpha	Satellite	centr
chr1:123927609-123927765	centromere	ALR/Alpha	Satellite	centr
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chr1:123970075-123970231	centromere	ALR/Alpha	Satellite	centr
chr1:123979908-123980064	centromere	ALR/Alpha	Satellite	centr
chr1:123999728-123999884	centromere	ALR/Alpha	Satellite	centr
chr1:124000115-124000317	centromere	ALR/Alpha	Satellite	centr
chr1:124003404-124003560	centromere	ALR/Alpha	Satellite	centr
chr1:124023542-124023720	centromere	ALR/Alpha	Satellite	centr
chr1:124026150-124026413	centromere	ALR/Alpha	Satellite	centr
chr1:124061900-124062103	centromere	ALR/Alpha	Satellite	centr
chr1:124068541-124068740	centromere	ALR/Alpha	Satellite	centr
chr1:124072242-124072398	centromere	ALR/Alpha	Satellite	centr
chr1:124080209-124080365	centromere	ALR/Alpha	Satellite	centr
chr1:124089172-124089328	centromere	ALR/Alpha	Satellite	centr
chr1:124105146-124105363	centromere	ALR/Alpha	Satellite	centr
chr1:124117201-124117357	centromere	ALR/Alpha	Satellite	centr
chr1:124137790-124138035	centromere	ALR/Alpha	Satellite	centr
chr1:124178430-124178586	centromere	ALR/Alpha	Satellite	centr
chr1:124181201-124181362	centromere	ALR/Alpha	Satellite	centr
chr1:124186797-124186979	centromere	ALR/Alpha	Satellite	centr
chr1:124199148-124199354	centromere	ALR/Alpha	Satellite	centr
chr1:124216400-124216556	centromere	ALR/Alpha	Satellite	centr
chr1:124221297-124221453	centromere	ALR/Alpha	Satellite	centr
chr1:124234673-124234905	centromere	ALR/Alpha	Satellite	centr
chr1:124237614-124237770	centromere	ALR/Alpha	Satellite	centr
chr1:124246485-124246797	centromere	ALR/Alpha	Satellite	centr
chr1:124261067-124261223	centromere	ALR/Alpha	Satellite	centr
chr1:124301737-124301901	centromere	ALR/Alpha	Satellite	centr
chr1:124306723-124306929	centromere	ALR/Alpha	Satellite	centr
chr1:124307889-124308062	centromere	ALR/Alpha	Satellite	centr
chr1:124328939-124329095	centromere	ALR/Alpha	Satellite	centr
chr1:124338393-124338620	centromere	ALR/Alpha	Satellite	centr
chr1:124377112-124377358	centromere	ALR/Alpha	Satellite	centr
chr1:124390305-124390506	centromere	ALR/Alpha	Satellite	centr
chr1:124407656-124407851	centromere	ALR/Alpha	Satellite	centr
chr1:124416643-124416804	centromere	ALR/Alpha	Satellite	centr
chr1:124422754-124422910	centromere	ALR/Alpha	Satellite	centr
chr1:124435223-124435434	centromere	ALR/Alpha	Satellite	centr
chr1:124439839-124439995	centromere	ALR/Alpha	Satellite	centr
chr1:124448193-124448431	centromere	ALR/Alpha	Satellite	centr
chr1:124453347-124453569	centromere	ALR/Alpha	Satellite	centr
chr1:124465602-124465789	centromere	ALR/Alpha	Satellite	centr
chr1:124480017-124480173	centromere	ALR/Alpha	Satellite	centr
chr1:124482422-124482578	centromere	ALR/Alpha	Satellite	centr
chr1:124485883-124486080	centromere	ALR/Alpha	Satellite	centr
chr1:124517822-124517978	centromere	ALR/Alpha	Satellite	centr
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chr1:124614947-124615207	centromere	ALR/Alpha	Satellite	centr
chr1:124639245-124639401	centromere	ALR/Alpha	Satellite	centr
chr1:124661990-124662172	centromere	ALR/Alpha	Satellite	centr
chr1:124671660-124671816	centromere	ALR/Alpha	Satellite	centr
chr1:124686302-124686458	centromere	ALR/Alpha	Satellite	centr
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chr1:124713726-124713930	centromere	ALR/Alpha	Satellite	centr
chr1:124714870-124715102	centromere	ALR/Alpha	Satellite	centr
chr1:124722133-124722295	centromere	ALR/Alpha	Satellite	centr
chr1:124737176-124737332	centromere	ALR/Alpha	Satellite	centr
chr1:124740227-124740440	centromere	ALR/Alpha	Satellite	centr
chr1:124741294-124741502	centromere	ALR/Alpha	Satellite	centr
chr1:124742395-124742551	centromere	ALR/Alpha	Satellite	centr

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chr1:124747559-124747715	centromere	ALR/Alpha	Satellite	centr
chr1:124749587-124749746	centromere	ALR/Alpha	Satellite	centr
chr1:124756355-124756531	centromere	ALR/Alpha	Satellite	centr
chr1:124756824-124757013	centromere	ALR/Alpha	Satellite	centr
chr1:124770969-124771171	centromere	ALR/Alpha	Satellite	centr
chr1:125166177-125166453	centromere	ALR/Alpha	Satellite	centr
chr1:125166845-125167327	centromere	ALR/Alpha	Satellite	centr
chr1:125167694-125168040	centromere	ALR/Alpha	Satellite	centr
chr1:125168178-125168350	centromere	ALR/Alpha	Satellite	centr
chr1:125169873-125170142	centromere	ALR/Alpha	Satellite	centr
chr1:125173933-125174262	centromere	ALR/Alpha	Satellite	centr
chr1:125175350-125175579	centromere	ALR/Alpha	Satellite	centr
chr1:125175935-125176198	centromere	ALR/Alpha	Satellite	centr
chr1:125176967-125177221	centromere	ALR/Alpha	Satellite	centr
chr1:125177660-125177858	centromere	ALR/Alpha	Satellite	centr
chr1:125178126-125178500	centromere	ALR/Alpha	Satellite	centr
chr1:125178802-125180996	centromere	ALR/Alpha	Satellite	centr
chr1:125181417-125181973	centromere	ALR/Alpha	Satellite	centr
chr1:125182054-125183242	centromere	ALR/Alpha	Satellite	centr
chr1:125183468-125183875	centromere	ALR/Alpha	Satellite	centr
chr1:125184395-125184597	centromere	ALR/Alpha	Satellite	centr
chr1:12846354-12846510	centromere	ALR/Alpha	Satellite	centr
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chr1:143185629-143186464	centromere	ALR/Alpha	Satellite	centr
chr1:143186689-143188026	centromere	ALR/Alpha	Satellite	centr
chr1:143188241-143188411	centromere	ALR/Alpha	Satellite	centr
chr1:143189825-143190168	centromere	ALR/Alpha	Satellite	centr
chr1:143190246-143190837	centromere	ALR/Alpha	Satellite	centr
chr1:143190998-143191311	centromere	ALR/Alpha	Satellite	centr
chr1:143191475-143191718	centromere	ALR/Alpha	Satellite	centr
chr1:143191855-143195842	centromere	ALR/Alpha	Satellite	centr
chr1:143199602-143200919	centromere	ALR/Alpha	Satellite	centr
chr1:143201084-143201295	centromere	ALR/Alpha	Satellite	centr
chr1:143201446-143202074	centromere	ALR/Alpha	Satellite	centr
chr1:143202373-143202965	centromere	ALR/Alpha	Satellite	centr
chr1:143203174-143203878	centromere	ALR/Alpha	Satellite	centr
chr1:143205559-143205847	centromere	ALR/Alpha	Satellite	centr
chr1:143206012-143207266	centromere	ALR/Alpha	Satellite	centr
chr1:143208353-143208606	centromere	ALR/Alpha	Satellite	centr
chr1:143210823-143211204	centromere	ALR/Alpha	Satellite	centr
chr1:143211662-143212038	centromere	ALR/Alpha	Satellite	centr
chr1:143212353-143213390	centromere	ALR/Alpha	Satellite	centr
chr1:143213448-143214010	centromere	ALR/Alpha	Satellite	centr
chr1:143214166-143216134	centromere	ALR/Alpha	Satellite	centr
chr1:143216194-143218567	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr1:143218698-143219308	pericentromere	norepeat	nofamily	noclass
chr1:143219466-143221726	pericentromere	norepeat	nofamily	noclass
chr1:143221930-143223553	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr1:143223631-143223985	gene	L1PA2	LINE	L1
chr1:143224536-143224776	centromere	ALR/Alpha	Satellite	centr
chr1:143225028-143225263	gene	L1PA2	LINE	L1
chr1:143226131-143226295	gene	L1PA4	LINE	L1
chr1:143227313-143228154	gene	L1PA2	LINE	L1
chr1:143228571-143229117	gene	L1PA5	LINE	L1
chr1:143229176-143229743	intergenic	norepeat	nofamily	noclass
chr1:143229950-143230679	gene	L1PA2	LINE	L1
chr1:143230870-143231945	gene	L1PA3	LINE	L1
chr1:143232270-143233717	gene	norepeat	nofamily	noclass
chr1:143235640-143236306	Unplaced_chr	L1PA3	LINE	L1
chr1:143236926-143238549	centromere	ALR/Alpha	Satellite	centr
chr1:143238616-143240697	gene	L1PA7	LINE	L1
chr1:143240771-143241953	centromere	ALR/Alpha	Satellite	centr
chr1:143242993-143243230	centromere	ALR/Alpha	Satellite	centr
chr1:143243294-143243450	centromere	ALR/Alpha	Satellite	centr
chr1:143243769-143244005	centromere	ALR/Alpha	Satellite	centr
chr1:143244418-143244683	centromere	ALR/Alpha	Satellite	centr
chr1:143245364-143246295	centromere	ALR/Alpha	Satellite	centr
chr1:143246757-143247077	centromere	ALR/Alpha	Satellite	centr
chr1:143247137-143247510	centromere	ALR/Alpha	Satellite	centr
chr1:143248568-143249131	centromere	ALR/Alpha	Satellite	centr
chr1:143249573-143250126	centromere	ALR/Alpha	Satellite	centr
chr1:143250247-143250561	centromere	ALR/Alpha	Satellite	centr
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chr1:143256249-143257019	centromere	ALR/Alpha	Satellite	centr
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chr1:143264339-143265060	centromere	ALR/Alpha	Satellite	centr
chr1:143265402-143266140	centromere	ALR/Alpha	Satellite	centr
chr1:143266410-143267660	centromere	ALR/Alpha	Satellite	centr
chr1:143268489-143268656	centromere	ALR/Alpha	Satellite	centr
chr1:143269476-143269757	centromere	ALR/Alpha	Satellite	centr
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chr1:145350807-145350963	centromere	ALR/Alpha	Satellite	centr
chr1:145374547-145374734	centromere	ALR/Alpha	Satellite	centr
chr1:145392322-145392576	centromere	ALR/Alpha	Satellite	centr
chr1:146068736-146068947	centromere	ALR/Alpha	Satellite	centr
chr1:146087657-146087868	centromere	ALR/Alpha	Satellite	centr
chr1:146092430-146092586	centromere	ALR/Alpha	Satellite	centr
chr1:146097152-146097333	centromere	ALR/Alpha	Satellite	centr
chr1:146101874-146102030	centromere	ALR/Alpha	Satellite	centr

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chr1:146988943-146989099	centromere	ALR/Alpha	Satellite	centr
chr1:148563785-148563943	centromere	ALR/Alpha	Satellite	centr
chr1:152434418-152434582	centromere	ALR/Alpha	Satellite	centr
chr1:157344244-157344464	centromere	ALR/Alpha	Satellite	centr
chr1:158958157-158958390	centromere	ALR/Alpha	Satellite	centr
chr1:159326607-159326763	centromere	ALR/Alpha	Satellite	centr
chr1:165968139-165968299	centromere	ALR/Alpha	Satellite	centr
chr1:172059396-172059669	centromere	ALR/Alpha	Satellite	centr
chr1:174235346-174235502	centromere	ALR/Alpha	Satellite	centr
chr1:174236956-174237112	centromere	ALR/Alpha	Satellite	centr
chr1:174610314-174610470	centromere	ALR/Alpha	Satellite	centr
chr1:174781487-174781643	centromere	ALR/Alpha	Satellite	centr
chr1:175436646-175436802	centromere	ALR/Alpha	Satellite	centr
chr1:185888101-185888257	gene	MSR1	Satellite	Satellite
chr1:194017529-194017685	gene	MSR1	Satellite	Satellite
chr1:194260210-194260366	intergenic	L1PA3	LINE	L1
chr1:197447861-197448017	gene	L1PA7	LINE	L1
chr1:204471170-204471651	gene	L1PA3	LINE	L1
chr1:207721936-207722092	gene	L1PA2	LINE	L1
chr1:218011284-218011440	Unplaced_chr	(TTCCA)n	Simple_repeat	Simple_repeat
chr1:221260362-221260518	Unplaced_chr	(TTCCA)n	Simple_repeat	Simple_repeat
chr1:222352941-222353097	gene	L1P1	LINE	L1
chr1:222355361-222355517	centromere	ALR/Alpha	Satellite	centr
chr1:224378667-224378827	Unplaced_chr	(TTCCA)n	Simple_repeat	Simple_repeat
chr1:225103402-225103558	Unplaced_chr	(GAATG)n	Satellite/Simple_repeat	Satellite/Simple_repeat
chr1:228486910-228487358	Unplaced_chr	(GAATG)n	Satellite/Simple_repeat	Satellite/Simple_repeat
chr1:231995740-231995945	intergenic	BSR/Beta	Satellite	Satellite
chr1:238717130-238717292	gene	L1PA3	LINE	L1
chr1:248070221-248070377	intergenic	L1PA2	LINE	L1
chr1:248764445-248764601	gene	norepeat	nofamily	noclass
chr1:33768411-33768569	centromere	ALR/Alpha	Satellite	centr
chr1:34956099-34956255	centromere	ALR/Alpha	Satellite	centr
chr1:35260256-35260412	centromere	ALR/Alpha	Satellite	centr
chr1:41854830-41854986	centromere	ALR/Alpha	Satellite	centr
chr1:47169026-47169182	centromere	ALR/Alpha	Satellite	centr
chr1:48461376-48461660	centromere	ALR/Alpha	Satellite	centr
chr1:49832268-49832424	centromere	ALR/Alpha	Satellite	centr
chr1:52173611-52173767	centromere	ALR/Alpha	Satellite	centr
chr1:58961716-58961878	centromere	ALR/Alpha	Satellite	centr
chr1:68895476-68895632	centromere	ALR/Alpha	Satellite	centr
chr1:70098927-70099274	centromere	ALR/Alpha	Satellite	centr
chr1:70099461-70099617	centromere	ALR/Alpha	Satellite	centr
chr1:74235-74391	centromere	ALR/Alpha	Satellite	centr
chr1:74448335-74448512	centromere	ALR/Alpha	Satellite	centr
chr1:83975909-83976065	centromere	ALR/Alpha	Satellite	centr
chr1:85644038-85644194	centromere	ALR/Alpha	Satellite	centr
chr1:86612698-86612854	centromere	ALR/Alpha	Satellite	centr
chr1:91387221-91387393	centromere	ALR/Alpha	Satellite	centr
chr1:98161134-98161290	centromere	ALR/Alpha	Satellite	centr
chr1:98212642-98212798	centromere	ALR/Alpha	Satellite	centr
chr1_K1270709v1_random:10675-11094	centromere	ALR/Alpha	Satellite	centr
chr1_K1270709v1_random:11191-11537	centromere	ALR/Alpha	Satellite	centr
chr1_K1270709v1_random:11777-12263	centromere	ALR/Alpha	Satellite	centr
chr1_K1270709v1_random:12330-12933	centromere	ALR/Alpha	Satellite	centr
chr1_K1270709v1_random:1-290	centromere	ALR/Alpha	Satellite	centr
chr1_K1270709v1_random:13342-14299	centromere	ALR/Alpha	Satellite	centr
chr1_K1270709v1_random:14936-15281	centromere	ALR/Alpha	Satellite	centr
chr1_K1270709v1_random:15521-16876	centromere	ALR/Alpha	Satellite	centr
chr1_K1270709v1_random:17076-17678	centromere	ALR/Alpha	Satellite	centr
chr1_K1270709v1_random:2333-2880	centromere	ALR/Alpha	Satellite	centr
chr1_K1270709v1_random:3586-3953	centromere	ALR/Alpha	Satellite	centr
chr1_K1270709v1_random:4076-4366	centromere	ALR/Alpha	Satellite	centr
chr1_K1270709v1_random:4433-5048	centromere	ALR/Alpha	Satellite	centr
chr1_K1270709v1_random:6453-6994	centromere	ALR/Alpha	Satellite	centr
chr1_K1270709v1_random:662-1070	centromere	ALR/Alpha	Satellite	centr
chr1_K1270709v1_random:7142-7811	centromere	ALR/Alpha	Satellite	centr
chr1_K1270709v1_random:7864-8463	centromere	ALR/Alpha	Satellite	centr
chr1_K1270709v1_random:8553-8827	centromere	ALR/Alpha	Satellite	centr
chr1_K1270709v1_random:9708-10165	centromere	ALR/Alpha	Satellite	centr
chr10:10062-10422	centromere	ALR/Alpha	Satellite	centr
chr10:109831382-109831538	centromere	ALR/Alpha	Satellite	centr
chr10:111587285-111587441	centromere	ALR/Alpha	Satellite	centr
chr10:112780178-112780334	centromere	ALR/Alpha	Satellite	centr
chr10:12775285-12775639	centromere	ALR/Alpha	Satellite	centr
chr10:12775747-12776002	centromere	ALR/Alpha	Satellite	centr
chr10:1306852-1307016	centromere	ALR/Alpha	Satellite	centr
chr10:132158643-132158828	centromere	ALR/Alpha	Satellite	centr
chr10:14991025-14991194	centromere	ALR/Alpha	Satellite	centr
chr10:18725647-18725803	centromere	ALR/Alpha	Satellite	centr
chr10:20539537-20539839	centromere	ALR/Alpha	Satellite	centr
chr10:30952755-30952911	centromere	ALR/Alpha	Satellite	centr
chr10:31284894-31285050	centromere	ALR/Alpha	Satellite	centr
chr10:32637803-32637959	centromere	ALR/Alpha	Satellite	centr
chr10:32667456-32667612	centromere	ALR/Alpha	Satellite	centr
chr10:39938795-39938968	centromere	ALR/Alpha	Satellite	centr
chr10:39969710-39969877	centromere	ALR/Alpha	Satellite	centr
chr10:39985650-39985913	centromere	ALR/Alpha	Satellite	centr
chr10:39994118-39994274	centromere	ALR/Alpha	Satellite	centr
chr10:39998126-39998315	centromere	ALR/Alpha	Satellite	centr
chr10:40011014-40011337	centromere	ALR/Alpha	Satellite	centr
chr10:40024566-40024884	centromere	ALR/Alpha	Satellite	centr
chr10:40047627-40047908	centromere	ALR/Alpha	Satellite	centr
chr10:40060748-40060933	centromere	ALR/Alpha	Satellite	centr
chr10:40070443-40070646	centromere	ALR/Alpha	Satellite	centr
chr10:40073208-40073364	centromere	ALR/Alpha	Satellite	centr
chr10:40077041-40077207	centromere	ALR/Alpha	Satellite	centr
chr10:40078353-40078544	centromere	ALR/Alpha	Satellite	centr
chr10:40085792-40085948	centromere	ALR/Alpha	Satellite	centr
chr10:40086487-40086661	centromere	ALR/Alpha	Satellite	centr

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chr10:40100583-40100739	centromere	ALR/Alpha	Satellite	centr
chr10:40120541-40120721	centromere	ALR/Alpha	Satellite	centr
chr10:40200675-40200831	centromere	ALR/Alpha	Satellite	centr
chr10:40201206-40201432	centromere	ALR/Alpha	Satellite	centr
chr10:40206703-40206952	centromere	ALR/Alpha	Satellite	centr
chr10:40207005-40207169	centromere	ALR/Alpha	Satellite	centr
chr10:40217337-40217493	centromere	ALR/Alpha	Satellite	centr
chr10:40219415-40219571	centromere	ALR/Alpha	Satellite	centr
chr10:40246266-40246525	centromere	ALR/Alpha	Satellite	centr
chr10:40267438-40267715	centromere	ALR/Alpha	Satellite	centr
chr10:40277079-40277541	centromere	ALR/Alpha	Satellite	centr
chr10:40279281-40279546	centromere	ALR/Alpha	Satellite	centr
chr10:40284372-40284528	centromere	ALR/Alpha	Satellite	centr
chr10:40286250-40286552	centromere	ALR/Alpha	Satellite	centr
chr10:40287871-40288033	centromere	ALR/Alpha	Satellite	centr
chr10:40290195-40290398	centromere	ALR/Alpha	Satellite	centr
chr10:40336865-40337021	centromere	ALR/Alpha	Satellite	centr
chr10:40346220-40346403	centromere	ALR/Alpha	Satellite	centr
chr10:40366110-40366266	centromere	ALR/Alpha	Satellite	centr
chr10:40366762-40366930	centromere	ALR/Alpha	Satellite	centr
chr10:40367651-40367893	centromere	ALR/Alpha	Satellite	centr
chr10:40389428-40389711	centromere	ALR/Alpha	Satellite	centr
chr10:40390580-40390736	centromere	ALR/Alpha	Satellite	centr
chr10:40399542-40399736	centromere	ALR/Alpha	Satellite	centr
chr10:40408151-40408561	centromere	ALR/Alpha	Satellite	centr
chr10:40436866-40437022	centromere	ALR/Alpha	Satellite	centr
chr10:40455618-40455810	gene	LIP1	LINE	L1
chr10:40461990-40462297	centromere	ALR/Alpha	Satellite	centr
chr10:40467086-40467424	centromere	ALR/Alpha	Satellite	centr
chr10:40476275-40476431	centromere	ALR/Alpha	Satellite	centr
chr10:40486373-40486599	centromere	ALR/Alpha	Satellite	centr
chr10:40488797-40489017	centromere	ALR/Alpha	Satellite	centr
chr10:40489933-40490143	centromere	ALR/Alpha	Satellite	centr
chr10:40497746-40497945	centromere	ALR/Alpha	Satellite	centr
chr10:40507538-40507870	centromere	ALR/Alpha	Satellite	centr
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chr10:40543515-40543942	centromere	ALR/Alpha	Satellite	centr
chr10:40578711-40579008	centromere	ALR/Alpha	Satellite	centr
chr10:40582363-40582519	centromere	ALR/Alpha	Satellite	centr
chr10:40601698-40601894	centromere	ALR/Alpha	Satellite	centr
chr10:40619564-40619809	centromere	ALR/Alpha	Satellite	centr
chr10:40646806-40646962	centromere	ALR/Alpha	Satellite	centr
chr10:40647481-40647637	centromere	ALR/Alpha	Satellite	centr
chr10:40668330-40668742	centromere	ALR/Alpha	Satellite	centr
chr10:40671171-40671327	centromere	ALR/Alpha	Satellite	centr
chr10:40682412-40682656	centromere	ALR/Alpha	Satellite	centr
chr10:40687967-40688168	centromere	ALR/Alpha	Satellite	centr
chr10:40726771-40726927	centromere	ALR/Alpha	Satellite	centr
chr10:40736692-40737016	centromere	ALR/Alpha	Satellite	centr
chr10:40756093-40756286	intergenic	LIPA2	LINE	L1
chr10:40774120-40774347	intergenic	LIPA3	LINE	L1
chr10:40786604-40786894	gene	LIPA3	LINE	L1
chr10:40804382-40804579	intergenic	LIHS	LINE	L1
chr10:40807571-40807816	centromere	ALR/Alpha	Satellite	centr
chr10:40814518-40814688	intergenic	LIPA2	LINE	L1
chr10:40816560-40816716	intergenic	LIPA3	LINE	L1
chr10:40817666-40817822	intergenic	LIHS	LINE	L1
chr10:40818205-40818411	subtelomere	(GTTAGG)n	Simple_repeat	Simple_repeat
chr10:40834299-40834486	Unplaced_chr	LIPA2	LINE	L1
chr10:40834680-40834836	gene	norepeat	nofamily	noclass
chr10:40834936-40835101	intergenic	LIPA2	LINE	L1
chr10:40836252-40836408	centromere	ALR/Alpha	Satellite	centr
chr10:40844931-40845300	centromere	ALR/Alpha	Satellite	centr
chr10:40848155-40848367	centromere	ALR/Alpha	Satellite	centr
chr10:40852903-40853093	centromere	ALR/Alpha	Satellite	centr
chr10:40860474-40860697	centromere	ALR/Alpha	Satellite	centr
chr10:40870868-40871048	centromere	ALR/Alpha	Satellite	centr
chr10:40875317-40875473	centromere	ALR/Alpha	Satellite	centr
chr10:40882701-40882910	centromere	ALR/Alpha	Satellite	centr
chr10:40891926-40892113	centromere	ALR/Alpha	Satellite	centr
chr10:40896265-40896470	centromere	ALR/Alpha	Satellite	centr
chr10:40896725-40896881	centromere	ALR/Alpha	Satellite	centr
chr10:40918008-40918178	centromere	ALR/Alpha	Satellite	centr
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chr10:40947068-40947251	centromere	ALR/Alpha	Satellite	centr
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chr10:41057118-41057340	centromere	ALR/Alpha	Satellite	centr
chr10:41061865-41062033	centromere	ALR/Alpha	Satellite	centr
chr10:41130065-41130357	centromere	ALR/Alpha	Satellite	centr
chr10:41135908-41136064	centromere	ALR/Alpha	Satellite	centr
chr10:41170319-41170475	centromere	ALR/Alpha	Satellite	centr
chr10:41175039-41175195	centromere	ALR/Alpha	Satellite	centr
chr10:41178224-41178440	centromere	ALR/Alpha	Satellite	centr
chr10:41181805-41181961	centromere	ALR/Alpha	Satellite	centr
chr10:41194325-41194481	centromere	ALR/Alpha	Satellite	centr
chr10:41204216-41204375	centromere	ALR/Alpha	Satellite	centr
chr10:41204957-41205142	centromere	ALR/Alpha	Satellite	centr
chr10:41210356-41210761	centromere	ALR/Alpha	Satellite	centr
chr10:41225902-41226111	centromere	ALR/Alpha	Satellite	centr
chr10:41248381-41248677	centromere	ALR/Alpha	Satellite	centr
chr10:41255558-41255729	centromere	ALR/Alpha	Satellite	centr

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chr10:41268357-41268532	centromere	ALR/Alpha	Satellite	centr
chr10:41270339-41270495	centromere	ALR/Alpha	Satellite	centr
chr10:41279427-41279590	centromere	ALR/Alpha	Satellite	centr
chr10:41304128-41304421	centromere	ALR/Alpha	Satellite	centr
chr10:41306778-41306945	centromere	ALR/Alpha	Satellite	centr
chr10:41310127-41310283	centromere	ALR/Alpha	Satellite	centr
chr10:41310781-41311040	centromere	ALR/Alpha	Satellite	centr
chr10:41311854-41312010	centromere	ALR/Alpha	Satellite	centr
chr10:41321452-41321608	centromere	ALR/Alpha	Satellite	centr
chr10:41350933-41351189	centromere	ALR/Alpha	Satellite	centr
chr10:41353336-41353770	centromere	ALR/Alpha	Satellite	centr
chr10:41354544-41354813	centromere	ALR/Alpha	Satellite	centr
chr10:41413468-41413653	centromere	ALR/Alpha	Satellite	centr
chr10:41415389-41415545	centromere	ALR/Alpha	Satellite	centr
chr10:41416360-41416657	centromere	ALR/Alpha	Satellite	centr
chr10:41429147-41429303	centromere	ALR/Alpha	Satellite	centr
chr10:41432221-41432381	centromere	ALR/Alpha	Satellite	centr
chr10:41441007-41441175	centromere	ALR/Alpha	Satellite	centr
chr10:41446675-41446889	centromere	ALR/Alpha	Satellite	centr
chr10:41456420-41456576	centromere	ALR/Alpha	Satellite	centr
chr10:41472975-41473255	centromere	ALR/Alpha	Satellite	centr
chr10:41475982-41476148	centromere	ALR/Alpha	Satellite	centr
chr10:41488193-41488349	centromere	ALR/Alpha	Satellite	centr
chr10:41494319-41494643	centromere	ALR/Alpha	Satellite	centr
chr10:41503789-41504031	centromere	ALR/Alpha	Satellite	centr
chr10:41506180-41506431	centromere	ALR/Alpha	Satellite	centr
chr10:41513036-41513192	centromere	ALR/Alpha	Satellite	centr
chr10:41536108-41536264	centromere	ALR/Alpha	Satellite	centr
chr10:41540724-41541038	centromere	ALR/Alpha	Satellite	centr
chr10:41543162-41543338	gene	LIPA2	LINE	L1
chr10:41543707-41543921	centromere	ALR/Alpha	Satellite	centr
chr10:41545176-41545477	centromere	ALR/Alpha	Satellite	centr
chr10:41562422-41562578	centromere	ALR/Alpha	Satellite	centr
chr10:41589586-41589742	centromere	ALR/Alpha	Satellite	centr
chr10:41592361-41592517	centromere	ALR/Alpha	Satellite	centr
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chr10:41851740-41851994	centromere	ALR/Alpha	Satellite	centr
chr10:41852879-41853188	centromere	ALR/Alpha	Satellite	centr
chr10:41854489-41855375	centromere	ALR/Alpha	Satellite	centr
chr10:41859798-41859964	centromere	ALR/Alpha	Satellite	centr
chr10:41860169-41860331	centromere	ALR/Alpha	Satellite	centr
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chr10:41899171-41899426	centromere	ALR/Alpha	Satellite	centr
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chr10:42066552-42066827	centromere	ALR/Alpha	Satellite	centr
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chr10:42068380-42068645	centromere	ALR/Alpha	Satellite	centr
chr10:42070716-42070970	centromere	ALR/Alpha	Satellite	centr
chr10:42071172-42071454	centromere	ALR/Alpha	Satellite	centr
chr10:42073071-42073266	centromere	ALR/Alpha	Satellite	centr
chr10:42073985-42074609	centromere	ALR/Alpha	Satellite	centr
chr10:42074791-42075080	centromere	ALR/Alpha	Satellite	centr
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chr10:42077940-42078180	centromere	ALR/Alpha	Satellite	centr
chr10:42079721-42080639	centromere	ALR/Alpha	Satellite	centr
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chr10:42083455-42083611	centromere	ALR/Alpha	Satellite	centr
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chr10:42086208-42086457	centromere	ALR/Alpha	Satellite	centr
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chr10:42091685-42092104	centromere	ALR/Alpha	Satellite	centr
chr10:42092438-42092803	centromere	ALR/Alpha	Satellite	centr
chr10:42094335-42094609	centromere	ALR/Alpha	Satellite	centr
chr10:42095372-42095619	centromere	ALR/Alpha	Satellite	centr
chr10:42097157-42097411	centromere	ALR/Alpha	Satellite	centr
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chr10:42099708-42100249	centromere	ALR/Alpha	Satellite	centr
chr10:42101557-42101724	centromere	ALR/Alpha	Satellite	centr
chr10:42103554-42103887	centromere	ALR/Alpha	Satellite	centr
chr10:42104179-42104482	centromere	ALR/Alpha	Satellite	centr
chr10:58655526-58655682	centromere	ALR/Alpha	Satellite	centr
chr10:61334339-61334495	centromere	ALR/Alpha	Satellite	centr
chr10:61901233-61901639	centromere	ALR/Alpha	Satellite	centr
chr10:67555936-67556096	centromere	ALR/Alpha	Satellite	centr
chr10:7061198-7061354	centromere	ALR/Alpha	Satellite	centr
chr10:96181316-96181472	centromere	ALR/Alpha	Satellite	centr
chr10:98055845-98056001	centromere	ALR/Alpha	Satellite	centr
chr10:99155446-99155602	centromere	ALR/Alpha	Satellite	centr
chr10_KI270824v1_alt:297-637	centromere	ALR/Alpha	Satellite	centr
chr10_KI270824v1_alt:920-1267	centromere	ALR/Alpha	Satellite	centr
chr11:10249609-10249858	centromere	ALR/Alpha	Satellite	centr
chr11:110210587-110210785	centromere	ALR/Alpha	Satellite	centr
chr11:112325632-112325870	centromere	ALR/Alpha	Satellite	centr
chr11:113432162-113432318	centromere	ALR/Alpha	Satellite	centr
chr11:114488833-114488989	centromere	ALR/Alpha	Satellite	centr
chr11:114841632-114841788	centromere	ALR/Alpha	Satellite	centr
chr11:121752195-121752351	centromere	ALR/Alpha	Satellite	centr
chr11:127288710-127288866	centromere	ALR/Alpha	Satellite	centr

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chr11:127872216-127872373	centromere	ALR/Alpha	Satellite	centr
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chr11:133642439-133642595	centromere	ALR/Alpha	Satellite	centr
chr11:14666667-14666823	centromere	ALR/Alpha	Satellite	centr
chr11:14800061-14800217	centromere	ALR/Alpha	Satellite	centr
chr11:16720301-16720457	centromere	ALR/Alpha	Satellite	centr
chr11:16915703-16915859	centromere	ALR/Alpha	Satellite	centr
chr11:17028871-17029027	centromere	ALR/Alpha	Satellite	centr
chr11:23316462-23316618	centromere	ALR/Alpha	Satellite	centr
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chr11:29417780-29417936	centromere	ALR/Alpha	Satellite	centr
chr11:30966867-30967060	centromere	ALR/Alpha	Satellite	centr
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chr11:4004602-4004758	centromere	ALR/Alpha	Satellite	centr
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chr11:50816508-50816667	centromere	ALR/Alpha	Satellite	centr
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chr11:51122637-51122826	centromere	ALR/Alpha	Satellite	centr
chr11:51158938-51159102	centromere	ALR/Alpha	Satellite	centr
chr11:51217742-51217930	centromere	ALR/Alpha	Satellite	centr
chr11:51234648-51234824	centromere	ALR/Alpha	Satellite	centr
chr11:51234895-51235056	centromere	ALR/Alpha	Satellite	centr
chr11:51273093-51273249	centromere	ALR/Alpha	Satellite	centr
chr11:51315022-51315178	centromere	ALR/Alpha	Satellite	centr
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chr11:51498826-51498982	centromere	ALR/Alpha	Satellite	centr
chr11:51536768-51536969	centromere	ALR/Alpha	Satellite	centr
chr11:51562196-51562352	centromere	ALR/Alpha	Satellite	centr
chr11:51575872-51576149	centromere	ALR/Alpha	Satellite	centr
chr11:51595159-51595594	centromere	ALR/Alpha	Satellite	centr
chr11:51628379-51628537	centromere	ALR/Alpha	Satellite	centr
chr11:51655785-51655998	centromere	ALR/Alpha	Satellite	centr
chr11:51669383-51669539	gene	MER112	DNA	hAT-Charlie
chr11:51696749-51696928	centromere	ALR/Alpha	Satellite	centr
chr11:51724616-51724772	centromere	ALR/Alpha	Satellite	centr
chr11:51769528-51769714	centromere	ALR/Alpha	Satellite	centr
chr11:51777540-51777726	centromere	ALR/Alpha	Satellite	centr
chr11:51795413-51795569	centromere	ALR/Alpha	Satellite	centr
chr11:51856495-51856651	centromere	ALR/Alpha	Satellite	centr
chr11:52023817-52024012	centromere	ALR/Alpha	Satellite	centr
chr11:52082430-52082586	centromere	ALR/Alpha	Satellite	centr
chr11:52094518-52094686	centromere	ALR/Alpha	Satellite	centr
chr11:52159637-52159906	centromere	ALR/Alpha	Satellite	centr
chr11:52169626-52169818	centromere	ALR/Alpha	Satellite	centr
chr11:52315959-52316115	centromere	ALR/Alpha	Satellite	centr
chr11:52333563-52333750	centromere	ALR/Alpha	Satellite	centr
chr11:52344387-52344543	centromere	ALR/Alpha	Satellite	centr
chr11:52465678-52465834	centromere	ALR/Alpha	Satellite	centr
chr11:52467131-52467287	centromere	ALR/Alpha	Satellite	centr
chr11:52506145-52506301	centromere	ALR/Alpha	Satellite	centr
chr11:52583501-52583664	centromere	ALR/Alpha	Satellite	centr
chr11:52665045-52665201	centromere	ALR/Alpha	Satellite	centr
chr11:52700900-52701056	centromere	ALR/Alpha	Satellite	centr
chr11:52755161-52755337	centromere	ALR/Alpha	Satellite	centr
chr11:52774984-52775233	centromere	ALR/Alpha	Satellite	centr
chr11:52807465-52807663	centromere	ALR/Alpha	Satellite	centr
chr11:52840470-52840626	centromere	ALR/Alpha	Satellite	centr
chr11:52843944-52844100	centromere	ALR/Alpha	Satellite	centr
chr11:52875383-52875539	centromere	ALR/Alpha	Satellite	centr
chr11:52908107-52908263	centromere	ALR/Alpha	Satellite	centr
chr11:52971635-52971877	centromere	ALR/Alpha	Satellite	centr
chr11:53045897-53046053	centromere	ALR/Alpha	Satellite	centr
chr11:53196633-53196789	centromere	ALR/Alpha	Satellite	centr
chr11:53222893-53223049	centromere	ALR/Alpha	Satellite	centr
chr11:53301043-53301234	Unplaced_chr	L1PA2	LINE	L1
chr11:53321656-53321812	Unplaced_chr	norepeat	nofamily	noclass
chr11:53351426-53351614	centromere	ALR/Alpha	Satellite	centr
chr11:53390962-53391118	Unplaced_chr	(GATTCATTC)n	Simple_repeat	Simple_repeat
chr11:53449057-53449213	Unplaced_chr	(ATTCCATTCG)n	Simple_repeat	Simple_repeat
chr11:53461893-53462049	Unplaced_chr	norepeat	nofamily	noclass
chr11:53586312-53586468	Unplaced_chr	norepeat	nofamily	noclass
chr11:53615263-53615419	Unplaced_chr	norepeat	nofamily	noclass
chr11:53640935-53641091	Unplaced_chr	(ATTCCATTCG)n	Simple_repeat	Simple_repeat
chr11:53647580-53647736	Unplaced_chr	norepeat	nofamily	noclass
chr11:53655980-53656136	centromere	ALR/Alpha	Satellite	centr
chr11:53662400-53662569	Unplaced_chr	(ATTCCATTCG)n	Simple_repeat	Simple_repeat
chr11:53709605-53709761	Unplaced_chr	norepeat	nofamily	noclass
chr11:53745658-53745956	Unplaced_chr	norepeat	nofamily	noclass
chr11:53747737-53747948	Unplaced_chr	norepeat	nofamily	noclass
chr11:53830005-53830161	Unplaced_chr	norepeat	nofamily	noclass
chr11:53838720-53838876	Unplaced_chr	(GATTCATTC)n	Simple_repeat	Simple_repeat
chr11:53852633-53852789	Unplaced_chr	(ATTCCATTCG)n	Simple_repeat	Simple_repeat
chr11:53862268-53862471	Unplaced_chr	(ATTCCATTCG)n	Simple_repeat	Simple_repeat
chr11:53868350-53868553	Unplaced_chr	norepeat	nofamily	noclass
chr11:53976972-53977128	Unplaced_chr	(GATTCATTC)n	Simple_repeat	Simple_repeat
chr11:54087928-54088084	centromere	ALR/Alpha	Satellite	centr
chr11:54156558-54156767	Unplaced_chr	norepeat	nofamily	noclass
chr11:54243333-54243489	gene	L1PA2	LINE	L1
chr11:54257108-54257264	intergenic	L1HS	LINE	L1
chr11:56717226-56717382	gene	L1PA5	LINE	L1

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chr11:60603728-60603921	intergenic	L1PA2	LINE	L1
chr11:60886618-60886774	gene	HAL1	LINE	L1
chr11:7359938-7360107	intergenic	L1PA2	LINE	L1
chr11:83592829-83593061	gene	(G)n	Simple_repeat	Simple_repeat
chr11:84752847-84753003	intergenic	L1PA4	LINE	L1
chr11:87269962-87270155	centromere	ALR/Alpha	Satellite	centr
chr11:91681981-91682137	gene	L1PA2	LINE	L1
chr11:97142800-97142986	gene	L1PA2	LINE	L1
chr11:98436165-98436321	gene	L1PA2	LINE	L1
chr12:10093-10356	intergenic	L1PA3	LINE	L1
chr12:118357414-118357635	intergenic	L1PA3	LINE	L1
chr12:125482010-125482166	intergenic	L1PA2	LINE	L1
chr12:129340637-129340793	gene	L1PA2	LINE	L1
chr12:129803299-129803493	intergenic	L1PA3	LINE	L1
chr12:131810194-131810387	gene	L1PA3	LINE	L1
chr12:131998638-131998902	intergenic	L1HS	LINE	L1
chr12:133264920-133265364	centromere	ALR/Alpha	Satellite	centr
chr12:17563261-17563463	intergenic	L1PA3	LINE	L1
chr12:2280469-2280718	intergenic	L1PA4	LINE	L1
chr12:23448928-23449084	intergenic	L1PA4	LINE	L1
chr12:29814027-29814183	gene	L1HS	LINE	L1
chr12:30036912-30037068	intergenic	(ATTCC)n	Simple_repeat	Simple_repeat
chr12:34883338-34883494	intergenic	(TGGAA)n	Simple_repeat	Simple_repeat
chr12:34902768-34902924	pericentromere	norepeat	nofamily	noclass
chr12:34942871-34943044	pericentromere	(CAATGGAAAT)n	Simple_repeat	Simple_repeat
chr12:34946806-34946962	centromere	ALR/Alpha	Satellite	centr
chr12:34954166-34954389	centromere	ALR/Alpha	Satellite	centr
chr12:34960674-34960895	centromere	ALR/Alpha	Satellite	centr
chr12:35001378-35001608	centromere	ALR/Alpha	Satellite	centr
chr12:35020289-35020456	centromere	ALR/Alpha	Satellite	centr
chr12:35023773-35023978	centromere	ALR/Alpha	Satellite	centr
chr12:35026243-35026591	centromere	ALR/Alpha	Satellite	centr
chr12:35028634-35028790	centromere	ALR/Alpha	Satellite	centr
chr12:35038107-35038263	centromere	ALR/Alpha	Satellite	centr
chr12:35068946-35069166	centromere	ALR/Alpha	Satellite	centr
chr12:35088703-35089043	centromere	ALR/Alpha	Satellite	centr
chr12:35103834-35104046	centromere	ALR/Alpha	Satellite	centr
chr12:35125609-35125765	centromere	ALR/Alpha	Satellite	centr
chr12:35156842-35157108	centromere	ALR/Alpha	Satellite	centr
chr12:35167025-35167184	centromere	ALR/Alpha	Satellite	centr
chr12:35178092-35178248	centromere	ALR/Alpha	Satellite	centr
chr12:35189847-35190108	centromere	ALR/Alpha	Satellite	centr
chr12:35230199-35230512	centromere	ALR/Alpha	Satellite	centr
chr12:35278930-35279117	centromere	ALR/Alpha	Satellite	centr
chr12:35301867-35302035	centromere	ALR/Alpha	Satellite	centr
chr12:35304308-35304464	gene	L1PA3	LINE	L1
chr12:35306476-35306653	intergenic	L1PA4	LINE	L1
chr12:35307307-35307463	intergenic	L1PA3	LINE	L1
chr12:35321897-35322107	centromere	ALR/Alpha	Satellite	centr
chr12:35376476-35376632	gene	L1PA4	LINE	L1
chr12:35378347-35378588	gene	norepeat	nofamily	noclass
chr12:35401773-35401929	gene	(AATGG)n	Simple_repeat	Simple_repeat
chr12:35417220-35417376	intergenic	L1PA3	LINE	L1
chr12:35433117-35433282	intergenic	L1PA3	LINE	L1
chr12:35453864-35454093	intergenic	L1PA4	LINE	L1
chr12:35468485-35468641	intergenic	L1PA4	LINE	L1
chr12:35516818-35516998	gene	L1HS	LINE	L1
chr12:35533162-35533318	intergenic	L1PA2	LINE	L1
chr12:35548486-35548705	intergenic	(CCTAT)n	Simple_repeat	Simple_repeat
chr12:35551432-35551634	centromere	ALR/Alpha	Satellite	centr
chr12:35554068-35554224	gene	L1PA2	LINE	L1
chr12:35664594-35664750	intergenic	L1HS	LINE	L1
chr12:35801623-35801779	gene	SSU-rRNA_Hsa	rRNA	rRNA
chr12:35803601-35803759	gene	L1PA2	LINE	L1
chr12:35895579-35895738	gene	L1PA4	LINE	L1
chr12:35942088-35942290	gene	L1PA4	LINE	L1
chr12:35981202-35981369	intergenic	L1PA3	LINE	L1
chr12:36009917-36010101	intergenic	L1PA3	LINE	L1
chr12:36019384-36019568	centromere	ALR/Alpha	Satellite	centr
chr12:36051942-36052098	gene	L1PA2	LINE	L1
chr12:36119614-36119770	gene	L1PA4	LINE	L1
chr12:36166616-36166772	intergenic	L1PA4	LINE	L1
chr12:36193390-36193546	intergenic	L1PA4	LINE	L1
chr12:36196424-36196648	intergenic	L1P3	LINE	L1
chr12:36245310-36245515	intergenic	L1PA3	LINE	L1
chr12:36249187-36249343	gene	L1PA4	LINE	L1
chr12:36257534-36257690	gene	L1HS	LINE	L1
chr12:36261857-36262013	intergenic	L1PA5	LINE	L1
chr12:36402528-36402684	gene	L1PA3	LINE	L1
chr12:36484034-36484199	centromere	ALR/Alpha	Satellite	centr
chr12:36514784-36514940	gene	norepeat	nofamily	noclass
chr12:36595685-36595852	gene	L1PA3	LINE	L1
chr12:36630879-36631093	gene	L1PA3	LINE	L1
chr12:36655044-36655200	intergenic	L1PA3	LINE	L1
chr12:36655516-36655677	intergenic	L1PA3	LINE	L1
chr12:36685809-36686028	intergenic	L1PA4	LINE	L1
chr12:36691757-36691950	intergenic	L1PA3	LINE	L1
chr12:36723366-36723563	intergenic	norepeat	nofamily	noclass
chr12:36744609-36744780	intergenic	L1PA3	LINE	L1
chr12:36748496-36748687	gene	MER5A	DNA	hAT-Charlie
chr12:36870001-36870157	centromere	ALR/Alpha	Satellite	centr
chr12:36871267-36871657	gene	L1PA4	LINE	L1
chr12:36895482-36895638	gene	L1PA3	LINE	L1
chr12:36949891-36950087	intergenic	L1PA3	LINE	L1
chr12:36960707-36960863	gene	L1PA2	LINE	L1
chr12:36967771-36967978	intergenic	L1P2	LINE	L1
chr12:36974972-36975143	intergenic	L1PA2	LINE	L1
chr12:37002545-37002701	gene	L1HS	LINE	L1
chr12:37020012-37020289	gene	L1PA2	LINE	L1

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chr12:37057408-37057634	intergenic	L1HS	LINE	L1
chr12:37084992-37085148	centromere	ALR/Alpha	Satellite	centr
chr12:37157980-37158136	gene	L1PA4	LINE	L1
chr12:41043726-41043882	gene	L1PA4	LINE	L1
chr12:4141050-4141206	gene	L1PA4	LINE	L1
chr12:43475306-43475676	intergenic	L1PA3	LINE	L1
chr12:44108496-44108652	intergenic	L1PA3	LINE	L1
chr12:45789-45945	intergenic	L1PA3	LINE	L1
chr12:48576881-48577152	centromere	ALR/Alpha	Satellite	centr
chr12:54638342-54638510	centromere	ALR/Alpha	Satellite	centr
chr12:54792198-54792465	centromere	ALR/Alpha	Satellite	centr
chr12:55349763-55349924	centromere	ALR/Alpha	Satellite	centr
chr12:56972360-56972546	centromere	ALR/Alpha	Satellite	centr
chr12:57894009-57894189	centromere	ALR/Alpha	Satellite	centr
chr12:57931617-57931773	centromere	ALR/Alpha	Satellite	centr
chr12:58994367-58994523	centromere	ALR/Alpha	Satellite	centr
chr12:61417070-61417226	centromere	ALR/Alpha	Satellite	centr
chr12:66057500-66057660	centromere	ALR/Alpha	Satellite	centr
chr12:67847445-67847631	centromere	ALR/Alpha	Satellite	centr
chr12:70897370-70897645	centromere	ALR/Alpha	Satellite	centr
chr12:73286424-73286580	centromere	ALR/Alpha	Satellite	centr
chr12:7333979-7334135	centromere	ALR/Alpha	Satellite	centr
chr12:79311352-79311508	centromere	ALR/Alpha	Satellite	centr
chr12:80247650-80247806	centromere	ALR/Alpha	Satellite	centr
chr12:80522965-80523121	centromere	ALR/Alpha	Satellite	centr
chr12:82181003-82181159	centromere	ALR/Alpha	Satellite	centr
chr12:82997025-82997181	centromere	ALR/Alpha	Satellite	centr
chr12:97652423-97652579	centromere	ALR/Alpha	Satellite	centr
chr12_GL383553v2_alt:114543-114699	centromere	ALR/Alpha	Satellite	centr
chr13:102526045-102526201	centromere	ALR/Alpha	Satellite	centr
chr13:16126286-16126442	centromere	ALR/Alpha	Satellite	centr
chr13:16145695-16145894	centromere	ALR/Alpha	Satellite	centr
chr13:16381167-16381323	centromere	ALR/Alpha	Satellite	centr
chr13:16385124-16385280	centromere	ALR/Alpha	Satellite	centr
chr13:16443082-16443238	centromere	ALR/Alpha	Satellite	centr
chr13:16487412-16487568	centromere	ALR/Alpha	Satellite	centr
chr13:16488854-16489161	centromere	ALR/Alpha	Satellite	centr
chr13:16515729-16515917	centromere	ALR/Alpha	Satellite	centr
chr13:16529985-16530191	centromere	ALR/Alpha	Satellite	centr
chr13:16534929-16535115	centromere	ALR/Alpha	Satellite	centr
chr13:16581422-16581583	centromere	ALR/Alpha	Satellite	centr
chr13:16605766-16605922	centromere	ALR/Alpha	Satellite	centr
chr13:16613759-16613950	centromere	ALR/Alpha	Satellite	centr
chr13:16647838-16648004	centromere	ALR/Alpha	Satellite	centr
chr13:16677841-16678033	centromere	ALR/Alpha	Satellite	centr
chr13:16757605-16757772	centromere	ALR/Alpha	Satellite	centr
chr13:16775841-16775997	centromere	ALR/Alpha	Satellite	centr
chr13:16807591-16807824	centromere	ALR/Alpha	Satellite	centr
chr13:16843870-16844242	centromere	ALR/Alpha	Satellite	centr
chr13:16862405-16862561	centromere	ALR/Alpha	Satellite	centr
chr13:16864328-16864662	centromere	ALR/Alpha	Satellite	centr
chr13:16923645-16923807	centromere	ALR/Alpha	Satellite	centr
chr13:16960639-16960823	centromere	ALR/Alpha	Satellite	centr
chr13:16984981-16985140	centromere	ALR/Alpha	Satellite	centr
chr13:17009577-17009740	centromere	ALR/Alpha	Satellite	centr
chr13:17061315-17061471	centromere	ALR/Alpha	Satellite	centr
chr13:17062192-17062348	gene	L1P2	LINE	L1
chr13:17096283-17096495	centromere	ALR/Alpha	Satellite	centr
chr13:17155849-17156005	centromere	ALR/Alpha	Satellite	centr
chr13:17228969-17229125	centromere	ALR/Alpha	Satellite	centr
chr13:17235045-17235201	centromere	ALR/Alpha	Satellite	centr
chr13:17245113-17245336	centromere	ALR/Alpha	Satellite	centr
chr13:17259680-17259836	centromere	ALR/Alpha	Satellite	centr
chr13:17267700-17267856	centromere	ALR/Alpha	Satellite	centr
chr13:17281502-17281697	centromere	ALR/Alpha	Satellite	centr
chr13:17309955-17310167	centromere	ALR/Alpha	Satellite	centr
chr13:17330006-17330162	centromere	ALR/Alpha	Satellite	centr
chr13:17368976-17369132	centromere	ALR/Alpha	Satellite	centr
chr13:17376901-17377070	centromere	ALR/Alpha	Satellite	centr
chr13:17378947-17379103	centromere	ALR/Alpha	Satellite	centr
chr13:17670617-17670773	centromere	ALR/Alpha	Satellite	centr
chr13:17704817-17704973	centromere	ALR/Alpha	Satellite	centr
chr13:17899241-17899411	centromere	ALR/Alpha	Satellite	centr
chr13:17980151-17980307	centromere	ALR/Alpha	Satellite	centr
chr13:18032048-18032204	centromere	ALR/Alpha	Satellite	centr
chr13:18044542-18044702	centromere	ALR/Alpha	Satellite	centr
chr13:18211873-18212074	centromere	ALR/Alpha	Satellite	centr
chr13:19213646-19213802	centromere	ALR/Alpha	Satellite	centr
chr13:24549375-24549555	centromere	ALR/Alpha	Satellite	centr
chr13:29219345-29219526	centromere	ALR/Alpha	Satellite	centr
chr13:30264889-30265045	centromere	ALR/Alpha	Satellite	centr
chr13:31305954-31306113	centromere	ALR/Alpha	Satellite	centr
chr13:39796379-39796535	centromere	ALR/Alpha	Satellite	centr
chr13:47603988-47604144	centromere	ALR/Alpha	Satellite	centr
chr13:47730958-47731114	centromere	ALR/Alpha	Satellite	centr
chr13:49015811-49015967	centromere	ALR/Alpha	Satellite	centr
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chr13:52270005-52270180	centromere	ALR/Alpha	Satellite	centr
chr13:59592511-59592667	centromere	ALR/Alpha	Satellite	centr
chr13:67992965-67993121	centromere	ALR/Alpha	Satellite	centr
chr13:69656077-69656233	centromere	ALR/Alpha	Satellite	centr
chr13:72705757-72705913	centromere	ALR/Alpha	Satellite	centr
chr13:74240676-74240853	centromere	ALR/Alpha	Satellite	centr
chr13:74495380-74495650	centromere	ALR/Alpha	Satellite	centr
chr13:74540034-74540190	centromere	ALR/Alpha	Satellite	centr
chr13:82048947-82049269	centromere	ALR/Alpha	Satellite	centr
chr13:83965332-83965520	centromere	ALR/Alpha	Satellite	centr
chr13:88683910-88684066	centromere	ALR/Alpha	Satellite	centr

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chr13:94067352-94067508	centromere	ALR/Alpha	Satellite	centr
chr13:97731369-97731525	centromere	ALR/Alpha	Satellite	centr
chr14:16055116-16055276	centromere	ALR/Alpha	Satellite	centr
chr14:16479170-16479326	centromere	ALR/Alpha	Satellite	centr
chr14:16535497-16535653	centromere	ALR/Alpha	Satellite	centr
chr14:16540952-16541108	centromere	ALR/Alpha	Satellite	centr
chr14:16561481-16561734	centromere	ALR/Alpha	Satellite	centr
chr14:16621649-16621805	centromere	ALR/Alpha	Satellite	centr
chr14:16637994-16638150	centromere	ALR/Alpha	Satellite	centr
chr14:16638666-16638822	centromere	ALR/Alpha	Satellite	centr
chr14:16655634-16655790	centromere	ALR/Alpha	Satellite	centr
chr14:16658293-16658449	centromere	ALR/Alpha	Satellite	centr
chr14:16665634-16665790	centromere	ALR/Alpha	Satellite	centr
chr14:16704689-16704845	centromere	ALR/Alpha	Satellite	centr
chr14:16770813-16770973	centromere	ALR/Alpha	Satellite	centr
chr14:16782814-16782970	centromere	ALR/Alpha	Satellite	centr
chr14:16798723-16798879	centromere	ALR/Alpha	Satellite	centr
chr14:16898929-16899169	centromere	ALR/Alpha	Satellite	centr
chr14:16936529-16936841	centromere	ALR/Alpha	Satellite	centr
chr14:16939239-16939398	centromere	ALR/Alpha	Satellite	centr
chr14:16984703-16984859	centromere	ALR/Alpha	Satellite	centr
chr14:16991298-16991490	centromere	ALR/Alpha	Satellite	centr
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chr14:17006569-17006728	centromere	ALR/Alpha	Satellite	centr
chr14:17032700-17032919	centromere	ALR/Alpha	Satellite	centr
chr14:17041912-17042068	centromere	ALR/Alpha	Satellite	centr
chr14:17042337-17042539	centromere	ALR/Alpha	Satellite	centr
chr14:17062489-17062707	centromere	ALR/Alpha	Satellite	centr
chr14:17095955-17096191	centromere	ALR/Alpha	Satellite	centr
chr14:17116592-17116789	intergenic	(TGGAA)n	Simple_repeat	Simple_repeat
chr14:17162494-17162669	intergenic	(TGGAA)n	Simple_repeat	Simple_repeat
chr14:17177772-17177928	intergenic	(GGAAT)n	Simple_repeat	Simple_repeat
chr14:17183590-17183749	intergenic	(AATGG)n	Simple_repeat	Simple_repeat
chr14:17202662-17202827	intergenic	norepeat	nofamily	noclass
chr14:17233506-17233662	intergenic	L1MA2	LINE	L1
chr14:17236606-17236833	centromere	ALR/Alpha	Satellite	centr
chr14:17305971-17306159	intergenic	L1PA5	LINE	L1
chr14:17324594-17324750	intergenic	L1HS	LINE	L1
chr14:17326518-17326674	intergenic	L1PA5	LINE	L1
chr14:17380678-17380834	intergenic	L1HS	LINE	L1
chr14:17417385-17417607	gene	LSU-rRNA_Hsa	rRNA	rRNA
chr14:17462221-17462398	intergenic	LSU-rRNA_Hsa	rRNA	rRNA
chr14:17515079-17515275	pericentromere	(TTCCA)n	Simple_repeat	Simple_repeat
chr14:17532566-17532722	pericentromere	(TTCCA)n	Simple_repeat	Simple_repeat
chr14:17778229-17778385	pericentromere	(TTCCA)n	Simple_repeat	Simple_repeat
chr14:17908740-17908896	centromere	ALR/Alpha	Satellite	centr
chr14:17993561-17993717	centromere	ALR/Alpha	Satellite	centr
chr14:18046963-18047119	centromere	ALR/Alpha	Satellite	centr
chr14:19622883-19623063	centromere	ALR/Alpha	Satellite	centr
chr14:20105758-20105914	centromere	ALR/Alpha	Satellite	centr
chr14:23920246-23920408	centromere	ALR/Alpha	Satellite	centr
chr14:31794046-31794202	centromere	ALR/Alpha	Satellite	centr
chr14:37770802-37770958	centromere	ALR/Alpha	Satellite	centr
chr14:39924027-39924281	centromere	ALR/Alpha	Satellite	centr
chr14:42282755-42282911	centromere	ALR/Alpha	Satellite	centr
chr14:43128614-43128770	centromere	ALR/Alpha	Satellite	centr
chr14:44643896-44644052	centromere	ALR/Alpha	Satellite	centr
chr14:45886800-45886956	centromere	ALR/Alpha	Satellite	centr
chr14:54851217-54851415	centromere	ALR/Alpha	Satellite	centr
chr14:56644000-56644156	centromere	ALR/Alpha	Satellite	centr
chr14:61055720-61055911	centromere	ALR/Alpha	Satellite	centr
chr14:62285000-62285156	centromere	ALR/Alpha	Satellite	centr
chr14:70424548-70425094	centromere	ALR/Alpha	Satellite	centr
chr14:87962452-87962608	centromere	ALR/Alpha	Satellite	centr
chr14:90177482-90177638	centromere	ALR/Alpha	Satellite	centr
chr14:90207974-90208130	centromere	ALR/Alpha	Satellite	centr
chr14:91434365-91434521	centromere	ALR/Alpha	Satellite	centr
chr14:96930697-96930853	centromere	ALR/Alpha	Satellite	centr
chr14_GL000225v1_random:110366-110522	centromere	ALR/Alpha	Satellite	centr
chr14_GL000225v1_random:125045-125297	centromere	ALR/Alpha	Satellite	centr
chr14_GL000225v1_random:125734-125891	centromere	ALR/Alpha	Satellite	centr
chr14_GL000225v1_random:131662-131828	centromere	ALR/Alpha	Satellite	centr
chr14_GL000225v1_random:13797-13953	centromere	ALR/Alpha	Satellite	centr
chr14_GL000225v1_random:25576-25759	centromere	ALR/Alpha	Satellite	centr
chr14_K1270726v1_random:35634-35790	centromere	ALR/Alpha	Satellite	centr
chr14_K1270844v1_alt:108334-108490	centromere	ALR/Alpha	Satellite	centr
chr15:17535776-17535932	centromere	ALR/Alpha	Satellite	centr
chr15:17601550-17601706	centromere	ALR/Alpha	Satellite	centr
chr15:17632285-17632441	centromere	ALR/Alpha	Satellite	centr
chr15:17862762-17862918	centromere	ALR/Alpha	Satellite	centr
chr15:17889376-17889532	centromere	ALR/Alpha	Satellite	centr
chr15:17961142-17961298	centromere	ALR/Alpha	Satellite	centr
chr15:18158509-18158665	centromere	ALR/Alpha	Satellite	centr
chr15:18333172-18333328	centromere	ALR/Alpha	Satellite	centr
chr15:18363237-18363490	centromere	ALR/Alpha	Satellite	centr
chr15:18628839-18628995	centromere	ALR/Alpha	Satellite	centr
chr15:18672470-18672626	centromere	ALR/Alpha	Satellite	centr
chr15:18878205-18878361	centromere	ALR/Alpha	Satellite	centr
chr15:18902333-18902561	centromere	ALR/Alpha	Satellite	centr
chr15:18970471-18970627	centromere	ALR/Alpha	Satellite	centr
chr15:19085932-19086122	centromere	ALR/Alpha	Satellite	centr
chr15:19124084-19124240	centromere	ALR/Alpha	Satellite	centr
chr15:19303899-19304055	centromere	ALR/Alpha	Satellite	centr
chr15:19406053-19406218	centromere	ALR/Alpha	Satellite	centr
chr15:19473254-19473410	centromere	ALR/Alpha	Satellite	centr
chr15:19510072-19510237	centromere	ALR/Alpha	Satellite	centr
chr15:19619604-19619760	centromere	ALR/Alpha	Satellite	centr
chr15:19678529-19678685	centromere	ALR/Alpha	Satellite	centr
chr15:29213197-29213354	gene	L1P1	LINE	L1

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chr15:38851966-38852122	gene	L1PA2	LINE	L1
chr15:39257512-39257668	intergenic	(GATA)n	Simple_repeat	Simple_repeat
chr15:51034782-51034946	gene	(TTCTC)n	Simple_repeat	Simple_repeat
chr15:55065703-55065864	intergenic	SSU-rRNA_Hsa	rRNA	rRNA
chr15:59781290-59781458	centromere	ALR/Alpha	Satellite	centr
chr15:60950658-60950814	centromere	ALR/Alpha	Satellite	centr
chr15:65161193-65161349	centromere	ALR/Alpha	Satellite	centr
chr15:79712837-79713069	centromere	ALR/Alpha	Satellite	centr
chr15:79746685-79746841	centromere	ALR/Alpha	Satellite	centr
chr15:81655689-81655845	centromere	ALR/Alpha	Satellite	centr
chr15:81732556-81732712	centromere	ALR/Alpha	Satellite	centr
chr15:84133417-84133573	centromere	ALR/Alpha	Satellite	centr
chr15:86967306-86967462	centromere	ALR/Alpha	Satellite	centr
chr15:87511404-87511657	centromere	ALR/Alpha	Satellite	centr
chr15:93677261-93677417	centromere	ALR/Alpha	Satellite	centr
chr15_KI270727v1_random:442195-442362	centromere	ALR/Alpha	Satellite	centr
chr16:12887462-12887620	centromere	ALR/Alpha	Satellite	centr
chr16:13374452-13374608	centromere	ALR/Alpha	Satellite	centr
chr16:33092428-33092584	centromere	ALR/Alpha	Satellite	centr
chr16:34588455-34588611	centromere	ALR/Alpha	Satellite	centr
chr16:34592630-34592933	centromere	ALR/Alpha	Satellite	centr
chr16:34594881-34595959	centromere	ALR/Alpha	Satellite	centr
chr16:36354791-36354992	centromere	ALR/Alpha	Satellite	centr
chr16:36358849-36359120	centromere	ALR/Alpha	Satellite	centr
chr16:36372584-36372740	centromere	ALR/Alpha	Satellite	centr
chr16:36381021-36381240	centromere	ALR/Alpha	Satellite	centr
chr16:36387027-36387218	centromere	ALR/Alpha	Satellite	centr
chr16:36390564-36390720	centromere	ALR/Alpha	Satellite	centr
chr16:36431358-36431532	centromere	ALR/Alpha	Satellite	centr
chr16:36433539-36433762	centromere	ALR/Alpha	Satellite	centr
chr16:36435220-36435459	centromere	ALR/Alpha	Satellite	centr
chr16:36443792-36443957	centromere	ALR/Alpha	Satellite	centr
chr16:36453722-36453901	centromere	ALR/Alpha	Satellite	centr
chr16:36473216-36473377	centromere	ALR/Alpha	Satellite	centr
chr16:36473738-36473894	centromere	ALR/Alpha	Satellite	centr
chr16:36475489-36475650	centromere	ALR/Alpha	Satellite	centr
chr16:36489374-36489672	centromere	ALR/Alpha	Satellite	centr
chr16:36490264-36490420	centromere	ALR/Alpha	Satellite	centr
chr16:36498828-36498984	centromere	ALR/Alpha	Satellite	centr
chr16:36500505-36500699	centromere	ALR/Alpha	Satellite	centr
chr16:36507354-36507510	centromere	ALR/Alpha	Satellite	centr
chr16:36509011-36509167	centromere	ALR/Alpha	Satellite	centr
chr16:36528171-36528502	centromere	ALR/Alpha	Satellite	centr
chr16:36528965-36529198	centromere	ALR/Alpha	Satellite	centr
chr16:36536686-36536842	centromere	ALR/Alpha	Satellite	centr
chr16:36537393-36537549	centromere	ALR/Alpha	Satellite	centr
chr16:36548420-36548700	centromere	ALR/Alpha	Satellite	centr
chr16:36553801-36554120	centromere	ALR/Alpha	Satellite	centr
chr16:36558928-36559089	centromere	ALR/Alpha	Satellite	centr
chr16:36617340-36617811	centromere	ALR/Alpha	Satellite	centr
chr16:36624025-36624226	centromere	ALR/Alpha	Satellite	centr
chr16:36634716-36634947	centromere	ALR/Alpha	Satellite	centr
chr16:36653229-36653407	centromere	ALR/Alpha	Satellite	centr
chr16:36653987-36654143	centromere	ALR/Alpha	Satellite	centr
chr16:36655769-36655925	centromere	ALR/Alpha	Satellite	centr
chr16:36659648-36659804	centromere	ALR/Alpha	Satellite	centr
chr16:36664135-36664329	centromere	ALR/Alpha	Satellite	centr
chr16:36665991-36666229	intergenic	(GGAAT)n	Simple_repeat	Simple_repeat
chr16:36672754-36672928	intergenic	norepeat	nofamily	noclass
chr16:36682091-36682291	centromere	ALR/Alpha	Satellite	centr
chr16:36684327-36684523	Unplaced_chr	LSU-rRNA_Hsa	rRNA	rRNA
chr16:36696275-36696431	Unplaced_chr	LSU-rRNA_Hsa	rRNA	rRNA
chr16:36712675-36712844	Unplaced_chr	(TCCAT)n	Simple_repeat	Simple_repeat
chr16:36740891-36741047	Unplaced_chr	norepeat	nofamily	noclass
chr16:36745096-36745312	Unplaced_chr	ALR/Alpha	Satellite	centr
chr16:36757894-36758117	Unplaced_chr	ALR/Alpha	Satellite	centr
chr16:36758386-36758542	Unplaced_chr	ALR/Alpha	Satellite	centr
chr16:36770633-36770805	Unplaced_chr	ALR/Alpha	Satellite	centr
chr16:36801309-36801479	Unplaced_chr	ALR/Alpha	Satellite	centr
chr16:36821379-36821606	intergenic	L1PA3	LINE	L1
chr16:36834480-36834696	gene	LSU-rRNA_Hsa	rRNA	rRNA
chr16:36846994-36847301	centromere	ALR/Alpha	Satellite	centr
chr16:36860756-36860912	Unplaced_chr	ALR/Alpha	Satellite	centr
chr16:36863476-36863721	intergenic	L1PA3	LINE	L1
chr16:36870900-36871100	gene	L1PA2	LINE	L1
chr16:36880370-36880526	intergenic	Tigger6a	DNA	TcMar-Tigger
chr16:36881049-36881245	gene	norepeat	nofamily	noclass
chr16:36889429-36889796	gene	L1PA4	LINE	L1
chr16:36891192-36891348	gene	L1HS	LINE	L1
chr16:36892637-36892793	centromere	ALR/Alpha	Satellite	centr
chr16:36899275-36899434	intergenic	L1PA2	LINE	L1
chr16:36911389-36911559	gene	Tigger11a	DNA	TcMar-Tigger
chr16:36912960-36913184	gene	L1PA4	LINE	L1
chr16:36925781-36925979	intergenic	L1PA2	LINE	L1
chr16:36936221-36936377	intergenic	L1PA3	LINE	L1
chr16:36972460-36972762	intergenic	L1PA3	LINE	L1
chr16:37009705-37009874	intergenic	L1PA2	LINE	L1
chr16:37027311-37027507	intergenic	L1PA3	LINE	L1
chr16:37030031-37030202	gene	L1PA3	LINE	L1
chr16:37048351-37048507	intergenic	L1PA2	LINE	L1
chr16:37056471-37056711	centromere	ALR/Alpha	Satellite	centr
chr16:37057209-37057400	gene	L1P2	LINE	L1
chr16:37058071-37058227	intergenic	L1PA4	LINE	L1
chr16:37058889-37059079	gene	L1PA2	LINE	L1
chr16:37070153-37070309	intergenic	L1PA2	LINE	L1
chr16:37103338-37103537	intergenic	L1PA4	LINE	L1
chr16:37105893-37106049	intergenic	L1PA2	LINE	L1
chr16:37106587-37106785	intergenic	L1HS	LINE	L1
chr16:37108352-37108508	gene	L1PA4	LINE	L1

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chr16:37108563-37108724				
chr16:37119357-37119667	intergenic	L1PA2	LINE	L1
chr16:37132365-37132562	centromere	L1PA3	LINE	L1
chr16:37135025-37135183	centromere	ALR/Alpha	Satellite	centr
chr16:37137106-37137379	centromere	ALR/Alpha	Satellite	centr
chr16:37139133-37139289	centromere	ALR/Alpha	Satellite	centr
chr16:37144380-37144542	centromere	ALR/Alpha	Satellite	centr
chr16:37148587-37148815	centromere	ALR/Alpha	Satellite	centr
chr16:37155673-37155898	centromere	ALR/Alpha	Satellite	centr
chr16:37192509-37192747	centromere	ALR/Alpha	Satellite	centr
chr16:37220124-37220280	centromere	ALR/Alpha	Satellite	centr
chr16:37222460-37222724	centromere	ALR/Alpha	Satellite	centr
chr16:37226894-37227063	centromere	ALR/Alpha	Satellite	centr
chr16:37251935-37252091	centromere	ALR/Alpha	Satellite	centr
chr16:37272237-37272393	centromere	ALR/Alpha	Satellite	centr
chr16:37279931-37280141	centromere	ALR/Alpha	Satellite	centr
chr16:37293276-37293432	centromere	ALR/Alpha	Satellite	centr
chr16:37300657-37300813	centromere	ALR/Alpha	Satellite	centr
chr16:37345505-37345666	centromere	ALR/Alpha	Satellite	centr
chr16:37371652-37371826	centromere	ALR/Alpha	Satellite	centr
chr16:37378171-37378521	centromere	ALR/Alpha	Satellite	centr
chr16:37380067-37380223	centromere	ALR/Alpha	Satellite	centr
chr16:37383095-37383281	centromere	ALR/Alpha	Satellite	centr
chr16:37387475-37387703	centromere	ALR/Alpha	Satellite	centr
chr16:37391619-37391786	centromere	ALR/Alpha	Satellite	centr
chr16:37395792-37395968	centromere	ALR/Alpha	Satellite	centr
chr16:37403095-37403353	centromere	ALR/Alpha	Satellite	centr
chr16:37404955-37405111	centromere	ALR/Alpha	Satellite	centr
chr16:37418419-37418686	centromere	ALR/Alpha	Satellite	centr
chr16:37437373-37437577	centromere	ALR/Alpha	Satellite	centr
chr16:37437947-37438204	centromere	ALR/Alpha	Satellite	centr
chr16:37450975-37451131	centromere	ALR/Alpha	Satellite	centr
chr16:37464647-37464803	centromere	ALR/Alpha	Satellite	centr
chr16:37470076-37470232	centromere	ALR/Alpha	Satellite	centr
chr16:37474190-37474399	centromere	ALR/Alpha	Satellite	centr
chr16:37492860-37493056	centromere	ALR/Alpha	Satellite	centr
chr16:37502092-37502248	centromere	ALR/Alpha	Satellite	centr
chr16:37512758-37512914	centromere	ALR/Alpha	Satellite	centr
chr16:37525996-37526152	centromere	ALR/Alpha	Satellite	centr
chr16:37531883-37532084	centromere	ALR/Alpha	Satellite	centr
chr16:37535908-37536123	centromere	ALR/Alpha	Satellite	centr
chr16:37537149-37537447	centromere	ALR/Alpha	Satellite	centr
chr16:37553476-37553711	centromere	ALR/Alpha	Satellite	centr
chr16:37581357-37581639	centromere	ALR/Alpha	Satellite	centr
chr16:37581880-37582036	centromere	ALR/Alpha	Satellite	centr
chr16:37596090-37596311	centromere	ALR/Alpha	Satellite	centr
chr16:37597173-37597389	centromere	ALR/Alpha	Satellite	centr
chr16:37598971-37599187	centromere	ALR/Alpha	Satellite	centr
chr16:37603363-37603618	centromere	ALR/Alpha	Satellite	centr
chr16:37607225-37607406	centromere	ALR/Alpha	Satellite	centr
chr16:37629655-37629857	centromere	ALR/Alpha	Satellite	centr
chr16:37630836-37630992	centromere	ALR/Alpha	Satellite	centr
chr16:37632493-37632751	centromere	ALR/Alpha	Satellite	centr
chr16:37636548-37636704	centromere	ALR/Alpha	Satellite	centr
chr16:37679167-37679684	centromere	ALR/Alpha	Satellite	centr
chr16:37723412-37723639	centromere	ALR/Alpha	Satellite	centr
chr16:37731756-37731963	centromere	ALR/Alpha	Satellite	centr
chr16:37778383-37778605	centromere	ALR/Alpha	Satellite	centr
chr16:37790746-37790930	centromere	ALR/Alpha	Satellite	centr
chr16:37793817-37793998	centromere	ALR/Alpha	Satellite	centr
chr16:37798007-37798163	centromere	ALR/Alpha	Satellite	centr
chr16:37800556-37800752	centromere	ALR/Alpha	Satellite	centr
chr16:37809092-37809288	centromere	ALR/Alpha	Satellite	centr
chr16:37812548-37812709	centromere	SAR	Satellite	Satellite
chr16:37818143-37818311	centromere	ALR/Alpha	Satellite	centr
chr16:37823647-37823803	centromere	ALR/Alpha	Satellite	centr
chr16:37836230-37836390	centromere	ALR/Alpha	Satellite	centr
chr16:37846826-37846983	centromere	ALR/Alpha	Satellite	centr
chr16:37851177-37851353	centromere	ALR/Alpha	Satellite	centr
chr16:37866900-37867129	centromere	ALR/Alpha	Satellite	centr
chr16:37894038-37894214	gene	L1PA2	LINE	L1
chr16:37897390-37897546	gene	L1PA3	LINE	L1
chr16:37899885-37900096	intergenic	L1HS	LINE	L1
chr16:37947356-37947547	intergenic	L1PA5	LINE	L1
chr16:37956685-37956919	centromere	ALR/Alpha	Satellite	centr
chr16:37960249-37960406	intergenic	L2a	LINE	L2
chr16:37976643-37976799	intergenic	L1PA2	LINE	L1
chr16:37999682-37999838	gene	norepeat	nofamily	noclass
chr16:38004675-38004864	gene	L1PA3	LINE	L1
chr16:38021384-38021621	intergenic	L1HS	LINE	L1
chr16:38053271-38053455	intergenic	L1HS	LINE	L1
chr16:38075570-38075871	intergenic	L1P1	LINE	L1
chr16:38078616-38078772	intergenic	L1HS	LINE	L1
chr16:38109001-38109157	intergenic	L1PA3	LINE	L1
chr16:38112399-38112579	centromere	ALR/Alpha	Satellite	centr
chr16:38120004-38120160	intergenic	L1PA3	LINE	L1
chr16:38140093-38140312	intergenic	(CA)n	Simple_repeat	Simple_repeat
chr16:38142995-38143151	gene	L1PA3	LINE	L1
chr16:38145357-38145751	gene	L1PA5	LINE	L1
chr16:38151338-38151606	gene	L1HS	LINE	L1
chr16:38177196-38177364	gene	L1PA4	LINE	L1
chr16:38177919-38178154	intergenic	L1PA2	LINE	L1
chr16:38194330-38194588	centromere	ALR/Alpha	Satellite	centr
chr16:38201170-38201359	intergenic	L1PA2	LINE	L1
chr16:38202649-38202805	gene	(TTCTGA)n	Simple_repeat	Simple_repeat
chr16:38203415-38203637	gene	Tigger6b	DNA	TcMar-Tigger
chr16:38204190-38204346	Unplaced_chr	L1PA4	LINE	L1
chr16:38204998-38205154	Unplaced_chr	L1PA4	LINE	L1
chr16:38205424-38205605	intergenic	norepeat	nofamily	noclass

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chr16:38206109-38206366	intergenic	norepeat	nofamily	noclass
chr16:38209760-38210225	intergenic	norepeat	nofamily	noclass
chr16:38227738-38227923	intergenic	L1PA2	LINE	L1
chr16:38230485-38230641	intergenic	L1PA3	LINE	L1
chr16:38243315-38243503	pericentromere	(GATTC)n	Simple_repeat	Simple_repeat
chr16:46388601-46389424	intergenic	L1PA3	LINE	L1
chr16:46389639-46391344	gene	L1PA2	LINE	L1
chr16:46398241-46399668	intergenic	L1PA2	LINE	L1
chr16:46399922-46401612	intergenic	L1PA4	LINE	L1
chr16:55792267-55792432	intergenic	L1PA5	LINE	L1
chr16:63391937-63392093	intergenic	L1PA3	LINE	L1
chr16:72585362-72585602	intergenic	L1PA4	LINE	L1
chr16:72632869-72633045	gene	L1HS	LINE	L1
chr16:74134140-74134296	intergenic	(CATTc)n	Satellite Simple_repeat	Satellite Simple_repeat
chr16:79530844-79531000	intergenic	(CATTc)n	Satellite Simple_repeat	Satellite Simple_repeat
chr16:80086621-80086777	pericentromere	(GATTC)n	Simple_repeat	Simple_repeat
chr16:86236076-86236238	intergenic	(CATTc)n	Satellite Simple_repeat	Satellite Simple_repeat
chr16:88299185-88299341	intergenic	(TCCAT)n	Simple_repeat	Simple_repeat
chr16:9317755-9317911	intergenic	(TCCAT)n	Simple_repeat	Simple_repeat
chr16:9730908-9731064	intergenic	(TCCAT)n	Simple_repeat	Simple_repeat
chr16_KI270853v1_alt:1313649-1313805	intergenic	(TCCAT)n	Simple_repeat	Simple_repeat
chr17:22825433-22825589	intergenic	(TCCAT)n	Simple_repeat	Simple_repeat
chr17:22831256-22831412	intergenic	(TCCAT)n	Simple_repeat	Simple_repeat
chr17:22856277-22856487	intergenic	(TCCAT)n	Simple_repeat	Simple_repeat
chr17:22927468-22927735	intergenic	(TCCAT)n	Simple_repeat	Simple_repeat
chr17:22993097-22993253	intergenic	(TCCAT)n	Simple_repeat	Simple_repeat
chr17:23035433-23035589	pericentromere	(GATTC)n	Simple_repeat	Simple_repeat
chr17:23089508-23089667	intergenic	(TCCAT)n	Simple_repeat	Simple_repeat
chr17:23175102-23175258	intergenic	(TCCAT)n	Simple_repeat	Simple_repeat
chr17:23284761-23284917	pericentromere	(GAATG)n	Satellite Simple_repeat	Satellite Simple_repeat
chr17:23309629-23309785	centromere	ALR/Alpha	Satellite	centr
chr17:23404001-23404157	centromere	ALR/Alpha	Satellite	centr
chr17:23596881-23597037	centromere	ALR/Alpha	Satellite	centr
chr17:23634644-23634800	centromere	ALR/Alpha	Satellite	centr
chr17:23871169-23871325	centromere	ALR/Alpha	Satellite	centr
chr17:24000574-24000832	pericentromere	norepeat	nofamily	noclass
chr17:24090543-24090721	centromere	ALR/Alpha	Satellite	centr
chr17:24180810-24180966	centromere	ALR/Alpha	Satellite	centr
chr17:24227494-24227650	centromere	ALR/Alpha	Satellite	centr
chr17:24310545-24310803	centromere	ALR/Alpha	Satellite	centr
chr17:24380319-24380487	centromere	ALR/Alpha	Satellite	centr
chr17:24419381-24419537	centromere	ALR/Alpha	Satellite	centr
chr17:24500342-24500498	centromere	ALR/Alpha	Satellite	centr
chr17:24518018-24518291	centromere	ALR/Alpha	Satellite	centr
chr17:24770802-24771006	centromere	ALR/Alpha	Satellite	centr
chr17:24822432-24822588	centromere	ALR/Alpha	Satellite	centr
chr17:24848811-24848980	pericentromere	norepeat	nofamily	noclass
chr17:24882702-24882858	centromere	ALR/Alpha	Satellite	centr
chr17:24902189-24902362	centromere	ALR/Alpha	Satellite	centr
chr17:25020730-25020918	centromere	ALR/Alpha	Satellite	centr
chr17:25033965-25034174	centromere	ALR/Alpha	Satellite	centr
chr17:25074354-25074579	centromere	ALR/Alpha	Satellite	centr
chr17:25174506-25174662	centromere	ALR/Alpha	Satellite	centr
chr17:25239505-25239661	centromere	ALR/Alpha	Satellite	centr
chr17:25330816-25331142	centromere	ALR/Alpha	Satellite	centr
chr17:25342956-25343112	centromere	ALR/Alpha	Satellite	centr
chr17:25389796-25389973	centromere	ALR/Alpha	Satellite	centr
chr17:25390467-25390702	pericentromere	norepeat	nofamily	noclass
chr17:25512349-25512548	centromere	ALR/Alpha	Satellite	centr
chr17:25722046-25722202	centromere	ALR/Alpha	Satellite	centr
chr17:25920109-25920277	centromere	ALR/Alpha	Satellite	centr
chr17:25945730-25945886	centromere	ALR/Alpha	Satellite	centr
chr17:25956715-25956871	centromere	ALR/Alpha	Satellite	centr
chr17:26161497-26161653	centromere	ALR/Alpha	Satellite	centr
chr17:26212958-26213144	centromere	ALR/Alpha	Satellite	centr
chr17:26307694-26307850	centromere	ALR/Alpha	Satellite	centr
chr17:26455462-26455630	centromere	ALR/Alpha	Satellite	centr
chr17:3139708-3139864	centromere	ALR/Alpha	Satellite	centr
chr17:42338037-42338213	pericentromere	norepeat	nofamily	noclass
chr17:42338297-42338553	centromere	ALR/Alpha	Satellite	centr
chr17:53500461-53500646	centromere	ALR/Alpha	Satellite	centr
chr17:55106721-55106877	centromere	ALR/Alpha	Satellite	centr
chr17:56384401-56384557	centromere	ALR/Alpha	Satellite	centr
chr17:68872049-68872209	centromere	ALR/Alpha	Satellite	centr
chr17_KI270729v1_random:24570-24758	centromere	ALR/Alpha	Satellite	centr
chr17_KI270729v1_random:27683-27941	centromere	ALR/Alpha	Satellite	centr
chr17_KI270729v1_random:3557-3727	centromere	ALR/Alpha	Satellite	centr
chr17_KI270729v1_random:5565-5770	centromere	ALR/Alpha	Satellite	centr
chr17_KI270729v1_random:895-1158	centromere	ALR/Alpha	Satellite	centr
chr18:108407-108625	gene	L1PA3	LINE	L1
chr18:15479946-15480218	pericentromere	norepeat	nofamily	noclass
chr18:15515766-15515922	centromere	ALR/Alpha	Satellite	centr
chr18:15525927-15526083	centromere	ALR/Alpha	Satellite	centr
chr18:15551786-15551942	centromere	ALR/Alpha	Satellite	centr
chr18:15558812-15559087	centromere	ALR/Alpha	Satellite	centr
chr18:15584019-15584175	centromere	ALR/Alpha	Satellite	centr
chr18:15599373-15599529	centromere	ALR/Alpha	Satellite	centr
chr18:15653222-15653378	centromere	ALR/Alpha	Satellite	centr
chr18:15731970-15732185	centromere	ALR/Alpha	Satellite	centr
chr18:15755402-15755558	centromere	ALR/Alpha	Satellite	centr
chr18:15880124-15880280	centromere	ALR/Alpha	Satellite	centr
chr18:15886287-15886443	pericentromere	norepeat	nofamily	noclass
chr18:15956993-15957149	centromere	ALR/Alpha	Satellite	centr
chr18:16086118-16086274	centromere	ALR/Alpha	Satellite	centr
chr18:16113963-16114169	centromere	ALR/Alpha	Satellite	centr
chr18:16115256-16115503	centromere	ALR/Alpha	Satellite	centr
chr18:16140640-16140834	centromere	ALR/Alpha	Satellite	centr
chr18:16175912-16176153	centromere	ALR/Alpha	Satellite	centr
chr18:16204295-16204451	centromere	ALR/Alpha	Satellite	centr

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chr18:16267535-16267691	centromere	ALR/Alpha	Satellite	centr
chr18:16268735-16268891	centromere	ALR/Alpha	Satellite	centr
chr18:16272064-16272332	centromere	ALR/Alpha	Satellite	centr
chr18:16343416-16343627	pericentromere	norepeat	nofamily	noclass
chr18:16403542-16403698	centromere	ALR/Alpha	Satellite	centr
chr18:16413438-16413594	centromere	ALR/Alpha	Satellite	centr
chr18:16456783-16456939	centromere	ALR/Alpha	Satellite	centr
chr18:16479849-16480021	centromere	ALR/Alpha	Satellite	centr
chr18:16509190-16509361	centromere	ALR/Alpha	Satellite	centr
chr18:16509618-16509838	centromere	ALR/Alpha	Satellite	centr
chr18:16520870-16521044	centromere	ALR/Alpha	Satellite	centr
chr18:16553245-16553401	centromere	ALR/Alpha	Satellite	centr
chr18:16574997-16575153	centromere	ALR/Alpha	Satellite	centr
chr18:16587414-16587570	centromere	ALR/Alpha	Satellite	centr
chr18:16641220-16641376	pericentromere	norepeat	nofamily	noclass
chr18:16653307-16653493	centromere	ALR/Alpha	Satellite	centr
chr18:16673086-16673242	centromere	ALR/Alpha	Satellite	centr
chr18:16698580-16698765	centromere	ALR/Alpha	Satellite	centr
chr18:16730729-16730921	centromere	ALR/Alpha	Satellite	centr
chr18:16752288-16752444	centromere	ALR/Alpha	Satellite	centr
chr18:16793319-16793475	centromere	ALR/Alpha	Satellite	centr
chr18:16818329-16818621	centromere	ALR/Alpha	Satellite	centr
chr18:16832352-16832508	centromere	ALR/Alpha	Satellite	centr
chr18:16841962-16842118	centromere	ALR/Alpha	Satellite	centr
chr18:16843823-16843979	centromere	ALR/Alpha	Satellite	centr
chr18:16846728-16846884	pericentromere	(GATTCCATTCA)n	Simple_repeat	Simple_repeat
chr18:16916568-16916848	centromere	ALR/Alpha	Satellite	centr
chr18:16960721-16960877	centromere	ALR/Alpha	Satellite	centr
chr18:17033135-17033389	centromere	ALR/Alpha	Satellite	centr
chr18:17061504-17061683	centromere	ALR/Alpha	Satellite	centr
chr18:17081800-17081956	centromere	ALR/Alpha	Satellite	centr
chr18:17193946-17194190	centromere	ALR/Alpha	Satellite	centr
chr18:17223976-17224132	centromere	ALR/Alpha	Satellite	centr
chr18:17268512-17268668	centromere	ALR/Alpha	Satellite	centr
chr18:17346285-17346441	centromere	ALR/Alpha	Satellite	centr
chr18:17367720-17367876	centromere	ALR/Alpha	Satellite	centr
chr18:17494734-17494890	pericentromere	(ATTCCATTCC)n	Simple_repeat	Simple_repeat
chr18:17509323-17509481	centromere	ALR/Alpha	Satellite	centr
chr18:17584097-17584253	centromere	ALR/Alpha	Satellite	centr
chr18:17662218-17662374	centromere	ALR/Alpha	Satellite	centr
chr18:17701343-17701499	centromere	ALR/Alpha	Satellite	centr
chr18:17755626-17755782	centromere	ALR/Alpha	Satellite	centr
chr18:17783940-17784224	centromere	ALR/Alpha	Satellite	centr
chr18:17861056-17861212	centromere	ALR/Alpha	Satellite	centr
chr18:17866650-17866806	centromere	ALR/Alpha	Satellite	centr
chr18:17926978-17927213	centromere	ALR/Alpha	Satellite	centr
chr18:18064990-18065146	centromere	ALR/Alpha	Satellite	centr
chr18:18093437-18093830	pericentromere	(GATTCCATT)n	Simple_repeat	Simple_repeat
chr18:18116682-18116846	centromere	ALR/Alpha	Satellite	centr
chr18:18170990-18171166	centromere	ALR/Alpha	Satellite	centr
chr18:18208423-18208615	centromere	ALR/Alpha	Satellite	centr
chr18:18238219-18238375	centromere	ALR/Alpha	Satellite	centr
chr18:18251091-18251247	centromere	ALR/Alpha	Satellite	centr
chr18:18258143-18258299	centromere	ALR/Alpha	Satellite	centr
chr18:18276042-18276226	centromere	ALR/Alpha	Satellite	centr
chr18:18296606-18296762	centromere	ALR/Alpha	Satellite	centr
chr18:18311457-18311613	centromere	ALR/Alpha	Satellite	centr
chr18:18392091-18392247	centromere	ALR/Alpha	Satellite	centr
chr18:18438505-18438661	pericentromere	(GATTCCATT)n	Simple_repeat	Simple_repeat
chr18:18446884-18447100	centromere	ALR/Alpha	Satellite	centr
chr18:18461330-18461486	centromere	ALR/Alpha	Satellite	centr
chr18:18510689-18510882	centromere	ALR/Alpha	Satellite	centr
chr18:18688785-18688941	centromere	ALR/Alpha	Satellite	centr
chr18:18785013-18785179	centromere	ALR/Alpha	Satellite	centr
chr18:18890519-18890677	centromere	ALR/Alpha	Satellite	centr
chr18:18972967-18973296	centromere	ALR/Alpha	Satellite	centr
chr18:19000430-19000586	centromere	ALR/Alpha	Satellite	centr
chr18:19037007-19037163	centromere	ALR/Alpha	Satellite	centr
chr18:19058570-19058762	centromere	ALR/Alpha	Satellite	centr
chr18:19311022-19311308	pericentromere	(ATTCCATTCC)n	Simple_repeat	Simple_repeat
chr18:19321433-19321684	centromere	ALR/Alpha	Satellite	centr
chr18:19338819-19339031	centromere	ALR/Alpha	Satellite	centr
chr18:19403427-19403583	centromere	ALR/Alpha	Satellite	centr
chr18:19636330-19636527	centromere	ALR/Alpha	Satellite	centr
chr18:19650209-19650365	centromere	ALR/Alpha	Satellite	centr
chr18:19729790-19729946	centromere	ALR/Alpha	Satellite	centr
chr18:19789940-19790172	centromere	ALR/Alpha	Satellite	centr
chr18:19945316-19945472	centromere	ALR/Alpha	Satellite	centr
chr18:19986443-19986599	centromere	ALR/Alpha	Satellite	centr
chr18:20103294-20103574	centromere	ALR/Alpha	Satellite	centr
chr18:20181403-20181559	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr18:20352893-20353049	centromere	ALR/Alpha	Satellite	centr
chr18:20376891-20377047	centromere	ALR/Alpha	Satellite	centr
chr18:20476655-20476846	centromere	ALR/Alpha	Satellite	centr
chr18:20495803-20495972	centromere	ALR/Alpha	Satellite	centr
chr18:20529900-20530056	centromere	ALR/Alpha	Satellite	centr
chr18:20538363-20538519	centromere	ALR/Alpha	Satellite	centr
chr18:24619407-24619565	centromere	ALR/Alpha	Satellite	centr
chr18:27281769-27281925	centromere	ALR/Alpha	Satellite	centr
chr18:33279846-33280002	centromere	ALR/Alpha	Satellite	centr
chr18:3738941-3739097	centromere	ALR/Alpha	Satellite	centr
chr18:41778913-41779069	gene	LHS	LINE	L1
chr18:51744417-51744573	pericentromere	norepeat	nofamily	noclass
chr18:67914706-67914862	centromere	ALR/Alpha	Satellite	centr
chr18:70686349-70686505	centromere	ALR/Alpha	Satellite	centr
chr18:7402700-7402856	centromere	ALR/Alpha	Satellite	centr
chr18:80262915-80263155	centromere	ALR/Alpha	Satellite	centr
chr18:9815331-9815627	centromere	ALR/Alpha	Satellite	centr
chr18_GL383570v1_alt:78480-78636	centromere	ALR/Alpha	Satellite	centr

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chr19:23894666-23894822	centromere	ALR/Alpha	Satellite	centr
chr19:24593471-24593627	centromere	ALR/Alpha	Satellite	centr
chr19:24600859-24601034	centromere	ALR/Alpha	Satellite	centr
chr19:24660553-24660709	centromere	ALR/Alpha	Satellite	centr
chr19:24764735-24764891	pericentromere	norepeat	nofamily	noclass
chr19:24787737-24787893	centromere	ALR/Alpha	Satellite	centr
chr19:24865303-24865459	centromere	ALR/Alpha	Satellite	centr
chr19:24929997-24930192	centromere	ALR/Alpha	Satellite	centr
chr19:24954431-24954699	centromere	ALR/Alpha	Satellite	centr
chr19:24959295-24959451	centromere	ALR/Alpha	Satellite	centr
chr19:24996337-24996493	centromere	ALR/Alpha	Satellite	centr
chr19:24997452-24997674	centromere	ALR/Alpha	Satellite	centr
chr19:25032289-25032445	centromere	ALR/Alpha	Satellite	centr
chr19:25034615-25034838	centromere	ALR/Alpha	Satellite	centr
chr19:25036035-25036191	centromere	ALR/Alpha	Satellite	centr
chr19:25038357-25038532	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr19:25044089-25044245	centromere	ALR/Alpha	Satellite	centr
chr19:25052000-25052211	centromere	ALR/Alpha	Satellite	centr
chr19:25077779-25077935	centromere	ALR/Alpha	Satellite	centr
chr19:25085880-25086076	centromere	ALR/Alpha	Satellite	centr
chr19:25111200-25111356	centromere	ALR/Alpha	Satellite	centr
chr19:25164759-25164939	centromere	ALR/Alpha	Satellite	centr
chr19:25171316-25171600	centromere	ALR/Alpha	Satellite	centr
chr19:25174017-25174173	centromere	ALR/Alpha	Satellite	centr
chr19:25212539-25212734	centromere	ALR/Alpha	Satellite	centr
chr19:25226016-25226174	centromere	ALR/Alpha	Satellite	centr
chr19:25232124-25232280	pericentromere	(ATCAAATGGA)n	Simple_repeat	Simple_repeat
chr19:25232787-25232947	centromere	ALR/Alpha	Satellite	centr
chr19:25233004-25233182	centromere	ALR/Alpha	Satellite	centr
chr19:25239873-25240029	centromere	ALR/Alpha	Satellite	centr
chr19:25271148-25271387	centromere	ALR/Alpha	Satellite	centr
chr19:25271835-25272024	centromere	ALR/Alpha	Satellite	centr
chr19:25286590-25286746	centromere	ALR/Alpha	Satellite	centr
chr19:25366084-25366240	centromere	ALR/Alpha	Satellite	centr
chr19:25412007-25412169	centromere	ALR/Alpha	Satellite	centr
chr19:25432531-25432687	centromere	ALR/Alpha	Satellite	centr
chr19:25436437-25436625	centromere	ALR/Alpha	Satellite	centr
chr19:25441432-25441659	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr19:25449954-25450110	centromere	ALR/Alpha	Satellite	centr
chr19:25525055-25525228	pericentromere	ALR/Alpha	Satellite	centr
chr19:25526633-25527100	pericentromere	ALR/Alpha	Satellite	centr
chr19:25550272-25550514	pericentromere	ALR/Alpha	Satellite	centr
chr19:25553580-25553750	pericentromere	ALR/Alpha	Satellite	centr
chr19:25570314-25570470	pericentromere	ALR/Alpha	Satellite	centr
chr19:25570946-25571189	gene	L1PA4	LINE	L1
chr19:25574074-25574283	gene	L1PA4	LINE	L1
chr19:25575106-25575262	gene	L1PA4	LINE	L1
chr19:25576489-25576658	intergenic	L1PA3	LINE	L1
chr19:25608758-25608935	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr19:25640196-25640353	intergenic	L1PA5	LINE	L1
chr19:25640415-25640571	gene	L1HS	LINE	L1
chr19:25648733-25649084	intergenic	L1PA3	LINE	L1
chr19:25684320-25684507	gene	L1PA3	LINE	L1
chr19:25687475-25687631	intergenic	L1PA3	LINE	L1
chr19:25694425-25694664	intergenic	L1PA3	LINE	L1
chr19:25703062-25703218	gene	L1PA5	LINE	L1
chr19:25711143-25711299	gene	L1PA3	LINE	L1
chr19:25716836-25717023	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr19:25726820-25726976	intergenic	L1MB5	LINE	L1
chr19:25728810-25728966	gene	L1PA3	LINE	L1
chr19:25759934-25760091	gene	L1PA3	LINE	L1
chr19:25769147-25769303	intergenic	HERVH-int	LTR	ERV1
chr19:25802841-25803031	intergenic	L1PA2	LINE	L1
chr19:25828204-25828378	gene	L1PA3	LINE	L1
chr19:25837969-25838125	intergenic	L1PA2	LINE	L1
chr19:25839154-25839310	gene	L1PA2	LINE	L1
chr19:25849208-25849389	gene	L1PA4	LINE	L1
chr19:25852870-25853051	gene	L1HS	LINE	L1
chr19:25885862-25886094	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr19:25892909-25893065	intergenic	L1PA4	LINE	L1
chr19:25902942-25903098	intergenic	L1PA5	LINE	L1
chr19:25909349-25909550	intergenic	(TTTA)n	Simple_repeat	Simple_repeat
chr19:25925671-25925928	intergenic	L1PA4	LINE	L1
chr19:25927521-25927677	intergenic	L1PA2	LINE	L1
chr19:25950258-25950431	gene	L1HS	LINE	L1
chr19:25957035-25957229	gene	L1PA3	LINE	L1
chr19:25959555-25959854	gene	AluSg	SINE	Alu
chr19:25961859-25962054	intergenic	L1PA5	LINE	L1
chr19:25980130-25980296	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr19:25998367-25998523	intergenic	L1PA2	LINE	L1
chr19:26049202-26049358	gene	L1PA4	LINE	L1
chr19:26070583-26070771	gene	L1PA4	LINE	L1
chr19:26073857-26074028	intergenic	(ATACAT)n	Simple_repeat	Simple_repeat
chr19:26082906-26083084	gene	L1PA4	LINE	L1
chr19:26089384-26089542	intergenic	L1HS	LINE	L1
chr19:26128522-26128755	intergenic	L1PA2	LINE	L1
chr19:26158750-26158906	intergenic	L1PA4	LINE	L1
chr19:26164918-26165074	intergenic	L1PA5	LINE	L1
chr19:26168382-26168590	gene	L1PA4	LINE	L1
chr19:26183865-26184190	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr19:26189323-26189479	gene	L1PA2	LINE	L1
chr19:26191528-26191701	gene	L1PA2	LINE	L1
chr19:26195658-26195856	gene	L1PA5	LINE	L1
chr19:26197674-26197875	gene	L1PA6	LINE	L1
chr19:26203915-26204081	gene	L1PA3	LINE	L1
chr19:26218362-26218518	gene	L1PA2	LINE	L1
chr19:26249388-26249544	intergenic	L1PA5	LINE	L1
chr19:26254668-26254824	intergenic	L1PA3	LINE	L1
chr19:26297823-26297979	intergenic	L1PA2	LINE	L1

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chr19:26321583-26321739	pericentromere	norepeat	nofamily	noclass
chr19:26329831-26330127	intergenic	L1PA3	LINE	L1
chr19:26381430-26381664	intergenic	L1PA3	LINE	L1
chr19:26412222-26412378	gene	L1PA6	LINE	L1
chr19:26437168-26437359	gene	BSR/Beta	Satellite	Satellite
chr19:26446896-26447085	Unplaced_chr	L1PA2	LINE	L1
chr19:26458054-26458246	Unplaced_chr	(GAATG)n	Satellite Simple_repeat	Satellite Simple_repeat
chr19:26461155-26461311	subtelomere	(TAACCC)n	Simple_repeat	Simple_repeat
chr19:26473479-26473636	intergenic	norepeat	nofamily	noclass
chr19:26473983-26474177	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr19:26477622-26477857	gene	L1PA2	LINE	L1
chr19:26502434-26502594	gene	L1PA3	LINE	L1
chr19:26528820-26529039	intergenic	L1PA4	LINE	L1
chr19:26531753-26531946	gene	L1HS	LINE	L1
chr19:26536994-26537266	intergenic	L1PA3	LINE	L1
chr19:26557490-26557646	intergenic	L1HS	LINE	L1
chr19:26563279-26563559	intergenic	L1HS	LINE	L1
chr19:26569608-26569920	pericentromere	norepeat	nofamily	noclass
chr19:26571493-26571649	gene	L1PA3	LINE	L1
chr19:26584218-26584374	intergenic	L1P1	LINE	L1
chr19:26589787-26590100	intergenic	L1PA2	LINE	L1
chr19:26601131-26601309	gene	L1PA4	LINE	L1
chr19:26619783-26619944	intergenic	L1PA3	LINE	L1
chr19:26640177-26640364	pericentromere	L1PA3	LINE	L1
chr19:26658402-26658656	centromere	ALR/Alpha	Satellite	centr
chr19:26676422-26676578	centromere	ALR/Alpha	Satellite	centr
chr19:26692100-26692256	pericentromere	norepeat	nofamily	noclass
chr19:26702989-26703219	centromere	ALR/Alpha	Satellite	centr
chr19:26706082-26706264	centromere	ALR/Alpha	Satellite	centr
chr19:26712200-26712359	centromere	ALR/Alpha	Satellite	centr
chr19:26715136-26715336	centromere	ALR/Alpha	Satellite	centr
chr19:26724315-26724471	centromere	ALR/Alpha	Satellite	centr
chr19:26745677-26745843	centromere	ALR/Alpha	Satellite	centr
chr19:26747708-26747864	centromere	ALR/Alpha	Satellite	centr
chr19:26756946-26757138	centromere	ALR/Alpha	Satellite	centr
chr19:26759173-26759356	centromere	ALR/Alpha	Satellite	centr
chr19:26760928-26761084	centromere	ALR/Alpha	Satellite	centr
chr19:26802602-26803070	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr19:26805172-26805328	centromere	ALR/Alpha	Satellite	centr
chr19:26817087-26817243	centromere	ALR/Alpha	Satellite	centr
chr19:26821953-26822115	centromere	ALR/Alpha	Satellite	centr
chr19:26829168-26829418	centromere	ALR/Alpha	Satellite	centr
chr19:26840664-26840820	centromere	ALR/Alpha	Satellite	centr
chr19:26843471-26843627	centromere	ALR/Alpha	Satellite	centr
chr19:26853719-26853941	centromere	ALR/Alpha	Satellite	centr
chr19:26868870-26869117	centromere	ALR/Alpha	Satellite	centr
chr19:26872478-26872643	centromere	ALR/Alpha	Satellite	centr
chr19:26881022-26881178	centromere	ALR/Alpha	Satellite	centr
chr19:26895988-26896186	pericentromere	norepeat	nofamily	noclass
chr19:26898650-26898950	centromere	ALR/Alpha	Satellite	centr
chr19:26906802-26906958	centromere	ALR/Alpha	Satellite	centr
chr19:26907782-26907948	centromere	ALR/Alpha	Satellite	centr
chr19:26917105-26917291	centromere	ALR/Alpha	Satellite	centr
chr19:26924299-26924582	centromere	ALR/Alpha	Satellite	centr
chr19:26926575-26926731	centromere	ALR/Alpha	Satellite	centr
chr19:26936805-26937017	centromere	ALR/Alpha	Satellite	centr
chr19:26937559-26937715	centromere	ALR/Alpha	Satellite	centr
chr19:26946924-26947188	centromere	ALR/Alpha	Satellite	centr
chr19:26951134-26951310	centromere	ALR/Alpha	Satellite	centr
chr19:26952897-26953089	pericentromere	norepeat	nofamily	noclass
chr19:26958364-26958520	centromere	ALR/Alpha	Satellite	centr
chr19:26969461-26969636	centromere	ALR/Alpha	Satellite	centr
chr19:27000400-27000592	centromere	ALR/Alpha	Satellite	centr
chr19:27004263-27004453	centromere	ALR/Alpha	Satellite	centr
chr19:27014277-27014459	centromere	ALR/Alpha	Satellite	centr
chr19:27047738-27047940	centromere	ALR/Alpha	Satellite	centr
chr19:27049906-27050074	centromere	ALR/Alpha	Satellite	centr
chr19:27055588-27055744	centromere	ALR/Alpha	Satellite	centr
chr19:27056969-27057125	centromere	ALR/Alpha	Satellite	centr
chr19:27059150-27059337	centromere	ALR/Alpha	Satellite	centr
chr19:27065240-27065591	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr19:27073560-27073716	centromere	ALR/Alpha	Satellite	centr
chr19:27075094-27075250	centromere	ALR/Alpha	Satellite	centr
chr19:27092622-27092778	centromere	ALR/Alpha	Satellite	centr
chr19:27095969-27096128	centromere	ALR/Alpha	Satellite	centr
chr19:27106879-27107048	centromere	ALR/Alpha	Satellite	centr
chr19:27112034-27112192	centromere	ALR/Alpha	Satellite	centr
chr19:27119263-27119419	centromere	ALR/Alpha	Satellite	centr
chr19:27135487-27135643	centromere	ALR/Alpha	Satellite	centr
chr19:27140482-27140677	centromere	ALR/Alpha	Satellite	centr
chr19:27142612-27142800	centromere	ALR/Alpha	Satellite	centr
chr19:27144800-27144956	pericentromere	norepeat	nofamily	noclass
chr19:27146619-27147056	centromere	ALR/Alpha	Satellite	centr
chr19:27148595-27148836	centromere	ALR/Alpha	Satellite	centr
chr19:27152776-27153157	centromere	ALR/Alpha	Satellite	centr
chr19:27163058-27163240	centromere	ALR/Alpha	Satellite	centr
chr19:27168370-27168560	centromere	ALR/Alpha	Satellite	centr
chr19:27174090-27174322	centromere	ALR/Alpha	Satellite	centr
chr19:27176400-27176556	centromere	ALR/Alpha	Satellite	centr
chr19:27187624-27187792	centromere	ALR/Alpha	Satellite	centr
chr19:4793656-4793815	centromere	ALR/Alpha	Satellite	centr
chr19_GL949752v1_alt:873938-874094	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr2:105054698-105055502	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr2:10805446-10805788	centromere	ALR/Alpha	Satellite	centr
chr2:109199588-109199836	centromere	ALR/Alpha	Satellite	centr
chr2:10999989-11000145	centromere	ALR/Alpha	Satellite	centr
chr2:110018803-110018959	centromere	ALR/Alpha	Satellite	centr
chr2:110074546-110074779	centromere	ALR/Alpha	Satellite	centr
chr2:111588989-111589145	centromere	ALR/Alpha	Satellite	centr

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chr2:114058827-114058983	centromere	ALR/Alpha	Satellite	centr
chr2:115487369-115487534	centromere	ALR/Alpha	Satellite	centr
chr2:116051819-116052012	centromere	ALR/Alpha	Satellite	centr
chr2:117077383-117077539	centromere	ALR/Alpha	Satellite	centr
chr2:124140938-124141094	gene	norepeat	nofamily	noclass
chr2:129414245-129414401	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr2:132255449-132255656	centromere	ALR/Alpha	Satellite	centr
chr2:136818109-136818282	centromere	ALR/Alpha	Satellite	centr
chr2:137072734-137072890	centromere	ALR/Alpha	Satellite	centr
chr2:138540727-138540883	centromere	ALR/Alpha	Satellite	centr
chr2:139309303-139309473	centromere	ALR/Alpha	Satellite	centr
chr2:139310060-139310270	centromere	ALR/Alpha	Satellite	centr
chr2:141044095-141044294	centromere	ALR/Alpha	Satellite	centr
chr2:144203970-144204150	centromere	ALR/Alpha	Satellite	centr
chr2:146793277-146793469	centromere	ALR/Alpha	Satellite	centr
chr2:149547312-149547468	centromere	ALR/Alpha	Satellite	centr
chr2:155765271-155765435	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr2:156771574-156771730	centromere	ALR/Alpha	Satellite	centr
chr2:158226723-158226879	centromere	ALR/Alpha	Satellite	centr
chr2:160119955-160120111	centromere	ALR/Alpha	Satellite	centr
chr2:160527337-160527493	centromere	ALR/Alpha	Satellite	centr
chr2:161536591-161536747	centromere	ALR/Alpha	Satellite	centr
chr2:173354563-173354833	centromere	ALR/Alpha	Satellite	centr
chr2:176799195-176799351	centromere	ALR/Alpha	Satellite	centr
chr2:179201430-179201651	centromere	ALR/Alpha	Satellite	centr
chr2:180830775-180830931	centromere	ALR/Alpha	Satellite	centr
chr2:183854294-183854450	centromere	ALR/Alpha	Satellite	centr
chr2:186371409-186371565	pericentromere	norepeat	nofamily	noclass
chr2:19210908-19211064	centromere	ALR/Alpha	Satellite	centr
chr2:192361171-192361327	centromere	ALR/Alpha	Satellite	centr
chr2:193914118-193914274	centromere	ALR/Alpha	Satellite	centr
chr2:195526749-195526905	centromere	ALR/Alpha	Satellite	centr
chr2:203284607-203284763	centromere	ALR/Alpha	Satellite	centr
chr2:208696453-208696609	centromere	ALR/Alpha	Satellite	centr
chr2:208805525-208805719	centromere	ALR/Alpha	Satellite	centr
chr2:209332406-209332562	centromere	ALR/Alpha	Satellite	centr
chr2:211892399-211892581	centromere	ALR/Alpha	Satellite	centr
chr2:223257264-223257420	centromere	ALR/Alpha	Satellite	centr
chr2:226574859-226575015	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr2:230339567-230339792	centromere	ALR/Alpha	Satellite	centr
chr2:23226511-23226667	centromere	ALR/Alpha	Satellite	centr
chr2:236386800-236386956	centromere	ALR/Alpha	Satellite	centr
chr2:29203350-29203507	centromere	ALR/Alpha	Satellite	centr
chr2:30909351-30909555	centromere	ALR/Alpha	Satellite	centr
chr2:32916246-32916432	centromere	ALR/Alpha	Satellite	centr
chr2:35234659-35234824	centromere	ALR/Alpha	Satellite	centr
chr2:43660820-43660976	centromere	ALR/Alpha	Satellite	centr
chr2:43661710-43661893	centromere	ALR/Alpha	Satellite	centr
chr2:43662762-43662918	centromere	ALR/Alpha	Satellite	centr
chr2:52714706-52714890	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr2:56555672-56555828	centromere	ALR/Alpha	Satellite	centr
chr2:58383212-58383381	centromere	ALR/Alpha	Satellite	centr
chr2:62836664-62836915	centromere	ALR/Alpha	Satellite	centr
chr2:66208036-66208192	centromere	ALR/Alpha	Satellite	centr
chr2:67176773-67176929	centromere	ALR/Alpha	Satellite	centr
chr2:76299786-76299942	centromere	ALR/Alpha	Satellite	centr
chr2:77595536-77595749	centromere	ALR/Alpha	Satellite	centr
chr2:84108402-84108558	centromere	ALR/Alpha	Satellite	centr
chr2:87272457-87272613	centromere	ALR/Alpha	Satellite	centr
chr2:88731831-88731998	centromere	ALR/Alpha	Satellite	centr
chr2:89833158-89833433	pericentromere	norepeat	nofamily	noclass
chr2:89836368-89836531	centromere	ALR/Alpha	Satellite	centr
chr2:90380732-90380888	centromere	ALR/Alpha	Satellite	centr
chr2:90383661-90383994	centromere	ALR/Alpha	Satellite	centr
chr2:92329188-92329344	centromere	ALR/Alpha	Satellite	centr
chr2:92374706-92374862	centromere	ALR/Alpha	Satellite	centr
chr2:92542041-92542197	centromere	ALR/Alpha	Satellite	centr
chr2:92602652-92602809	centromere	ALR/Alpha	Satellite	centr
chr2:92637455-92637611	centromere	ALR/Alpha	Satellite	centr
chr2:92678896-92679052	centromere	ALR/Alpha	Satellite	centr
chr2:93091158-93091362	centromere	ALR/Alpha	Satellite	centr
chr2:93098230-93098438	pericentromere	norepeat	nofamily	noclass
chr2:93114786-93115018	centromere	ALR/Alpha	Satellite	centr
chr2:93155784-93156064	centromere	ALR/Alpha	Satellite	centr
chr2:93356400-93356556	centromere	ALR/Alpha	Satellite	centr
chr2:93357876-93358032	centromere	ALR/Alpha	Satellite	centr
chr2:93402556-93402739	centromere	ALR/Alpha	Satellite	centr
chr2:93432402-93432673	centromere	ALR/Alpha	Satellite	centr
chr2:93749895-93750051	centromere	ALR/Alpha	Satellite	centr
chr2:93852125-93852281	centromere	ALR/Alpha	Satellite	centr
chr2:93952135-93952291	centromere	ALR/Alpha	Satellite	centr
chr2:94079101-94079294	centromere	ALR/Alpha	Satellite	centr
chr2:98265649-98266010	pericentromere	norepeat	nofamily	noclass
chr2:98990262-98990418	centromere	ALR/Alpha	Satellite	centr
chr2:99227786-99227942	centromere	ALR/Alpha	Satellite	centr
chr2_K1270715v1_random:153959-154187	centromere	ALR/Alpha	Satellite	centr
chr2_K1270716v1_random:135098-135257	centromere	ALR/Alpha	Satellite	centr
chr2_K1270716v1_random:67160-67316	centromere	ALR/Alpha	Satellite	centr
chr2_K1270716v1_random:72262-72418	centromere	ALR/Alpha	Satellite	centr
chr2_K1270716v1_random:86280-86448	centromere	ALR/Alpha	Satellite	centr
chr2_K1270716v1_random:92449-92605	centromere	ALR/Alpha	Satellite	centr
chr20:10969067-10969223	centromere	ALR/Alpha	Satellite	centr
chr20:13521415-13521571	centromere	ALR/Alpha	Satellite	centr
chr20:16994076-16994232	pericentromere	norepeat	nofamily	noclass
chr20:25713835-25714086	centromere	ALR/Alpha	Satellite	centr
chr20:25729735-25729959	centromere	ALR/Alpha	Satellite	centr
chr20:26477826-26477982	centromere	ALR/Alpha	Satellite	centr
chr20:26624085-26624289	centromere	ALR/Alpha	Satellite	centr
chr20:26652239-26652430	centromere	ALR/Alpha	Satellite	centr

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chr20:26677616-26677772	centromere	ALR/Alpha	Satellite	centr
chr20:26684650-26685010	centromere	ALR/Alpha	Satellite	centr
chr20:26688306-26688591	centromere	ALR/Alpha	Satellite	centr
chr20:26724541-26724746	centromere	ALR/Alpha	Satellite	centr
chr20:26751473-26751629	centromere	ALR/Alpha	Satellite	centr
chr20:26772008-26772205	pericentromere	(AATCAA)n	Simple_repeat	Simple_repeat
chr20:26791059-26791215	centromere	ALR/Alpha	Satellite	centr
chr20:26850418-26850634	centromere	ALR/Alpha	Satellite	centr
chr20:26858726-26858882	centromere	ALR/Alpha	Satellite	centr
chr20:26873358-26873514	centromere	ALR/Alpha	Satellite	centr
chr20:26875295-26875451	centromere	ALR/Alpha	Satellite	centr
chr20:26880671-26880859	centromere	ALR/Alpha	Satellite	centr
chr20:26936411-26936567	centromere	ALR/Alpha	Satellite	centr
chr20:26940065-26940221	centromere	ALR/Alpha	Satellite	centr
chr20:26992994-26993150	centromere	ALR/Alpha	Satellite	centr
chr20:26994963-26995128	centromere	ALR/Alpha	Satellite	centr
chr20:26996283-26996439	gene	norepeat	nofamily	noclass
chr20:27007079-27007235	pericentromere	norepeat	nofamily	noclass
chr20:27033355-27033511	centromere	ALR/Alpha	Satellite	centr
chr20:27043109-27043265	centromere	ALR/Alpha	Satellite	centr
chr20:27047020-27047176	centromere	ALR/Alpha	Satellite	centr
chr20:27047679-27047887	centromere	ALR/Alpha	Satellite	centr
chr20:27087777-27087933	centromere	ALR/Alpha	Satellite	centr
chr20:27090797-27091040	centromere	ALR/Alpha	Satellite	centr
chr20:27091924-27092092	intergenic	(TGGAA)n	Simple_repeat	Simple_repeat
chr20:27094843-27095005	intergenic	(TGGAA)n	Simple_repeat	Simple_repeat
chr20:27108541-27108711	pericentromere	norepeat	nofamily	noclass
chr20:27116478-27116634	intergenic	(TCCAT)n	Simple_repeat	Simple_repeat
chr20:27120759-27120951	intergenic	(TCCAT)n	Simple_repeat	Simple_repeat
chr20:27127994-27128329	intergenic	(TCCAT)n	Simple_repeat	Simple_repeat
chr20:27136945-27137101	intergenic	(CATT)n	Satellite Simple_repeat	Satellite Simple_repeat
chr20:27177108-27177348	centromere	ALR/Alpha	Satellite	centr
chr20:27183371-27183527	centromere	ALR/Alpha	Satellite	centr
chr20:27190915-27191071	centromere	ALR/Alpha	Satellite	centr
chr20:27195795-27195970	pericentromere	norepeat	nofamily	noclass
chr20:27206650-27207040	centromere	ALR/Alpha	Satellite	centr
chr20:27213708-27213924	centromere	ALR/Alpha	Satellite	centr
chr20:27217330-27217664	intergenic	L1PA2	LINE	L1
chr20:27217917-27218133	gene	L1PA3	LINE	L1
chr20:27223857-27224013	gene	L1PA3	LINE	L1
chr20:27324708-27324864	intergenic	THEID	LTR	ERV1-MaLR
chr20:27331594-27331795	gene	MIRb	SINE	MIR
chr20:27349913-27350069	gene	L1PA3	LINE	L1
chr20:27354764-27354920	intergenic	L1PA3	LINE	L1
chr20:27355019-27355257	intergenic	L1PA3	LINE	L1
chr20:27361896-27362052	pericentromere	norepeat	nofamily	noclass
chr20:27370321-27370477	gene	L1PA2	LINE	L1
chr20:27403121-27403299	gene	L1PA3	LINE	L1
chr20:27433017-27433173	gene	norepeat	nofamily	noclass
chr20:27453422-27453633	gene	norepeat	nofamily	noclass
chr20:27474991-27475147	intergenic	L1PA4	LINE	L1
chr20:27486531-27486805	intergenic	L1PA3	LINE	L1
chr20:27492251-27492443	intergenic	L1PA3	LINE	L1
chr20:27545736-27545906	gene	L1PA5	LINE	L1
chr20:27547389-27547545	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr20:27564780-27564936	intergenic	L1PA3	LINE	L1
chr20:27579114-27579270	gene	L1PA4	LINE	L1
chr20:27598411-27598586	intergenic	L1HS	LINE	L1
chr20:27600718-27600951	gene	L1PA3	LINE	L1
chr20:27643060-27643245	intergenic	L1PA5	LINE	L1
chr20:27650361-27650567	gene	L1PA3	LINE	L1
chr20:27654006-27654199	intergenic	L1PA8	LINE	L1
chr20:27677917-27678221	gene	L1PA3	LINE	L1
chr20:27679173-27679437	gene	(TGGT)n	Simple_repeat	Simple_repeat
chr20:27684437-27684696	pericentromere	norepeat	nofamily	noclass
chr20:27708720-27708876	gene	MIR3	SINE	MIR
chr20:27711211-27711427	intergenic	L1PA4	LINE	L1
chr20:27716408-27716586	gene	L1HS	LINE	L1
chr20:27720140-27720296	gene	L1MA3	LINE	L1
chr20:27723603-27723763	intergenic	L1HS	LINE	L1
chr20:27748289-27748445	gene	L1PA5	LINE	L1
chr20:27751203-27751508	gene	L1PA6	LINE	L1
chr20:27798916-27799157	intergenic	SSU-rRNA_Hsa	rRNA	rRNA
chr20:27800940-27801096	gene	norepeat	nofamily	noclass
chr20:27838324-27838480	gene	L1PA3	LINE	L1
chr20:27845106-27845262	gene	norepeat	nofamily	noclass
chr20:27848177-27848449	intergenic	L1PA4	LINE	L1
chr20:27886364-27886520	intergenic	L1PA3	LINE	L1
chr20:27904329-27904490	gene	L1PA5	LINE	L1
chr20:27931994-27932150	intergenic	L1PA3	LINE	L1
chr20:27969879-27970035	intergenic	(AT)n	Simple_repeat	Simple_repeat
chr20:27975469-27975625	intergenic	L1PA3	LINE	L1
chr20:27995920-27996117	pericentromere	ALR/Alpha	Satellite	centr
chr20:28021064-28021229	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr20:28028846-28029040	pericentromere	ALR/Alpha	Satellite	centr
chr20:28049228-28049384	centromere	ALR/Alpha	Satellite	centr
chr20:28100804-28100960	centromere	ALR/Alpha	Satellite	centr
chr20:28147903-28148059	centromere	ALR/Alpha	Satellite	centr
chr20:28152165-28152395	centromere	ALR/Alpha	Satellite	centr
chr20:28186920-28187168	centromere	ALR/Alpha	Satellite	centr
chr20:28195087-28195345	centromere	ALR/Alpha	Satellite	centr
chr20:28211175-28211354	centromere	ALR/Alpha	Satellite	centr
chr20:28211544-28211873	centromere	ALR/Alpha	Satellite	centr
chr20:28234338-28234494	centromere	ALR/Alpha	Satellite	centr
chr20:28258180-28258377	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr20:28357994-28358304	centromere	ALR/Alpha	Satellite	centr
chr20:28380329-28380485	centromere	ALR/Alpha	Satellite	centr
chr20:28382481-28382641	centromere	ALR/Alpha	Satellite	centr
chr20:28403027-28403286	centromere	ALR/Alpha	Satellite	centr

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chr20:28408903-28409059	centromere	ALR/Alpha	Satellite	centr
chr20:28412276-28412502	centromere	ALR/Alpha	Satellite	centr
chr20:28415199-28415370	centromere	ALR/Alpha	Satellite	centr
chr20:28422290-28422461	centromere	ALR/Alpha	Satellite	centr
chr20:28457677-28457833	centromere	ALR/Alpha	Satellite	centr
chr20:28470017-28470177	centromere	ALR/Alpha	Satellite	centr
chr20:31052668-31052908	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr20:31057118-31057278	centromere	ALR/Alpha	Satellite	centr
chr20:31065866-31066032	centromere	ALR/Alpha	Satellite	centr
chr20:31164920-31165182	centromere	ALR/Alpha	Satellite	centr
chr20:31241614-31241888	centromere	ALR/Alpha	Satellite	centr
chr20:40347900-40348056	centromere	ALR/Alpha	Satellite	centr
chr20:41683001-41683157	centromere	ALR/Alpha	Satellite	centr
chr20:43396258-43396581	centromere	ALR/Alpha	Satellite	centr
chr20:5381033-5381203	centromere	ALR/Alpha	Satellite	centr
chr20:55814674-55814830	centromere	ALR/Alpha	Satellite	centr
chr20:55863508-55863916	centromere	ALR/Alpha	Satellite	centr
chr20:9296586-9296742	pericentromere	ALR/Alpha	Satellite	centr
chr21:10685275-10685431	pericentromere	norepeat	nofamily	noclass
chr21:10692721-10693086	centromere	ALR/Alpha	Satellite	centr
chr21:10716672-10716828	centromere	ALR/Alpha	Satellite	centr
chr21:11185827-11185983	centromere	ALR/Alpha	Satellite	centr
chr21:11276181-11276337	centromere	ALR/Alpha	Satellite	centr
chr21:11277785-11277941	centromere	ALR/Alpha	Satellite	centr
chr21:11283276-11283438	centromere	ALR/Alpha	Satellite	centr
chr21:11296964-11297120	centromere	ALR/Alpha	Satellite	centr
chr21:11352020-11352176	centromere	ALR/Alpha	Satellite	centr
chr21:11353420-11353576	centromere	ALR/Alpha	Satellite	centr
chr21:11380976-11381132	centromere	ALR/Alpha	Satellite	centr
chr21:11431988-11432144	pericentromere	norepeat	nofamily	noclass
chr21:11444925-11445081	centromere	ALR/Alpha	Satellite	centr
chr21:11452739-11452895	centromere	ALR/Alpha	Satellite	centr
chr21:11452970-11453185	centromere	ALR/Alpha	Satellite	centr
chr21:11476543-11476802	centromere	ALR/Alpha	Satellite	centr
chr21:11498853-11499009	centromere	ALR/Alpha	Satellite	centr
chr21:11531412-11531584	centromere	ALR/Alpha	Satellite	centr
chr21:11567685-11567942	centromere	ALR/Alpha	Satellite	centr
chr21:11568433-11568589	centromere	ALR/Alpha	Satellite	centr
chr21:11610326-11610505	centromere	ALR/Alpha	Satellite	centr
chr21:11622063-11622321	centromere	ALR/Alpha	Satellite	centr
chr21:11641205-11641397	pericentromere	norepeat	nofamily	noclass
chr21:11681484-11681650	centromere	ALR/Alpha	Satellite	centr
chr21:11758322-11758478	centromere	ALR/Alpha	Satellite	centr
chr21:11788203-11788359	centromere	ALR/Alpha	Satellite	centr
chr21:11812864-11813020	centromere	ALR/Alpha	Satellite	centr
chr21:11872106-11872334	centromere	ALR/Alpha	Satellite	centr
chr21:11914105-11914261	centromere	ALR/Alpha	Satellite	centr
chr21:11925874-11926031	centromere	ALR/Alpha	Satellite	centr
chr21:11944947-11945106	centromere	ALR/Alpha	Satellite	centr
chr21:11960876-11961055	centromere	ALR/Alpha	Satellite	centr
chr21:11982651-11982807	centromere	ALR/Alpha	Satellite	centr
chr21:12017034-12017190	pericentromere	norepeat	nofamily	noclass
chr21:12029316-12029518	centromere	ALR/Alpha	Satellite	centr
chr21:12057488-12057644	centromere	ALR/Alpha	Satellite	centr
chr21:12066883-12067102	centromere	ALR/Alpha	Satellite	centr
chr21:12068250-12068406	centromere	ALR/Alpha	Satellite	centr
chr21:12108006-12108313	centromere	ALR/Alpha	Satellite	centr
chr21:12123270-12123485	centromere	ALR/Alpha	Satellite	centr
chr21:12129794-12129962	centromere	ALR/Alpha	Satellite	centr
chr21:12144382-12144538	centromere	ALR/Alpha	Satellite	centr
chr21:12180068-12180224	centromere	ALR/Alpha	Satellite	centr
chr21:12442773-12442969	centromere	ALR/Alpha	Satellite	centr
chr21:12492156-12492312	pericentromere	(ATTCCATTCG)n	Simple_repeat	Simple_repeat
chr21:12725689-12725848	centromere	ALR/Alpha	Satellite	centr
chr21:12778235-12778420	centromere	ALR/Alpha	Satellite	centr
chr21:12792980-12793148	centromere	ALR/Alpha	Satellite	centr
chr21:12811130-12811297	centromere	ALR/Alpha	Satellite	centr
chr21:12856580-12856736	centromere	ALR/Alpha	Satellite	centr
chr21:26897758-26897952	centromere	ALR/Alpha	Satellite	centr
chr21:33926095-33926251	centromere	ALR/Alpha	Satellite	centr
chr21:42629546-42629784	centromere	ALR/Alpha	Satellite	centr
chr21:46495117-46495273	centromere	ALR/Alpha	Satellite	centr
chr21:8217546-8217719	centromere	ALR/Alpha	Satellite	centr
chr21:8444819-8445005	pericentromere	norepeat	nofamily	noclass
chr22:11252151-11252310	centromere	ALR/Alpha	Satellite	centr
chr22:13125071-13125227	centromere	ALR/Alpha	Satellite	centr
chr22:13137672-13137860	centromere	ALR/Alpha	Satellite	centr
chr22:13144480-13144679	centromere	ALR/Alpha	Satellite	centr
chr22:13354262-13354418	centromere	ALR/Alpha	Satellite	centr
chr22:13362351-13362507	centromere	ALR/Alpha	Satellite	centr
chr22:13381363-13381597	centromere	ALR/Alpha	Satellite	centr
chr22:13409087-13409243	centromere	ALR/Alpha	Satellite	centr
chr22:13416286-13416442	centromere	ALR/Alpha	Satellite	centr
chr22:13424105-13424282	centromere	ALR/Alpha	Satellite	centr
chr22:13436331-13436524	pericentromere	norepeat	nofamily	noclass
chr22:13502460-13502670	centromere	ALR/Alpha	Satellite	centr
chr22:13559070-13559226	centromere	ALR/Alpha	Satellite	centr
chr22:13561122-13561278	centromere	ALR/Alpha	Satellite	centr
chr22:13577291-13577506	centromere	ALR/Alpha	Satellite	centr
chr22:13639925-13640081	centromere	ALR/Alpha	Satellite	centr
chr22:13651832-13651988	centromere	ALR/Alpha	Satellite	centr
chr22:13658595-13658767	centromere	ALR/Alpha	Satellite	centr
chr22:13727682-13727838	centromere	ALR/Alpha	Satellite	centr
chr22:13760610-13760831	centromere	ALR/Alpha	Satellite	centr
chr22:13764526-13764690	centromere	ALR/Alpha	Satellite	centr
chr22:13779679-13779878	pericentromere	norepeat	nofamily	noclass
chr22:13822275-13822442	centromere	ALR/Alpha	Satellite	centr
chr22:13846943-13847099	centromere	ALR/Alpha	Satellite	centr
chr22:13857924-13858125	centromere	ALR/Alpha	Satellite	centr

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chr22:13860994-13861150	centromere	ALR/Alpha	Satellite	centr
chr22:13867361-13867566	centromere	ALR/Alpha	Satellite	centr
chr22:13932423-13932579	centromere	ALR/Alpha	Satellite	centr
chr22:13974363-13974519	centromere	ALR/Alpha	Satellite	centr
chr22:14022069-14022281	centromere	ALR/Alpha	Satellite	centr
chr22:14040126-14040331	centromere	ALR/Alpha	Satellite	centr
chr22:14158291-14158523	centromere	ALR/Alpha	Satellite	centr
chr22:14159063-14159224	pericentromere	(ATTCCATTCC)n	Simple_repeat	Simple_repeat
chr22:14167829-14167985	centromere	ALR/Alpha	Satellite	centr
chr22:14210930-14211086	centromere	ALR/Alpha	Satellite	centr
chr22:14231477-14231744	centromere	ALR/Alpha	Satellite	centr
chr22:14248223-14248379	centromere	ALR/Alpha	Satellite	centr
chr22:14278255-14278411	centromere	ALR/Alpha	Satellite	centr
chr22:14310696-14310852	centromere	ALR/Alpha	Satellite	centr
chr22:14315063-14315245	centromere	ALR/Alpha	Satellite	centr
chr22:14346511-14346667	centromere	ALR/Alpha	Satellite	centr
chr22:14372504-14372660	centromere	ALR/Alpha	Satellite	centr
chr22:14384397-14384553	centromere	ALR/Alpha	Satellite	centr
chr22:14496069-14496225	pericentromere	norepeat	nofamily	noclass
chr22:14521219-14521375	centromere	ALR/Alpha	Satellite	centr
chr22:14701738-14701894	centromere	ALR/Alpha	Satellite	centr
chr22:14790628-14790784	centromere	ALR/Alpha	Satellite	centr
chr22:14936752-14936908	centromere	ALR/Alpha	Satellite	centr
chr22:14970727-14970883	centromere	ALR/Alpha	Satellite	centr
chr22:16347139-16347403	centromere	ALR/Alpha	Satellite	centr
chr22:41468751-41468976	centromere	ALR/Alpha	Satellite	centr
chr22_K1270733v1_random:133887-134089	centromere	ALR/Alpha	Satellite	centr
chr22_K1270733v1_random:178960-179176	centromere	ALR/Alpha	Satellite	centr
chr22_K1270737v1_random:38540-38705	centromere	ALR/Alpha	Satellite	centr
chr22_K1270737v1_random:79907-80069	pericentromere	ALR/Alpha	Satellite	centr
chr3:106978530-106978686	pericentromere	norepeat	nofamily	noclass
chr3:107694039-107694238	centromere	ALR/Alpha	Satellite	centr
chr3:109202655-109202833	centromere	ALR/Alpha	Satellite	centr
chr3:122357614-122357770	centromere	ALR/Alpha	Satellite	centr
chr3:126334278-126334445	centromere	ALR/Alpha	Satellite	centr
chr3:12841542-12841845	centromere	ALR/Alpha	Satellite	centr
chr3:129399376-129399642	centromere	ALR/Alpha	Satellite	centr
chr3:130239996-130240176	centromere	ALR/Alpha	Satellite	centr
chr3:131409791-131409947	centromere	ALR/Alpha	Satellite	centr
chr3:132948181-132948337	centromere	ALR/Alpha	Satellite	centr
chr3:133000268-133000424	centromere	ALR/Alpha	Satellite	centr
chr3:137353758-137353914	pericentromere	(ATTCCATTCC)n	Simple_repeat	Simple_repeat
chr3:137455555-137455711	centromere	ALR/Alpha	Satellite	centr
chr3:137457006-137457269	centromere	ALR/Alpha	Satellite	centr
chr3:137824338-137824494	centromere	ALR/Alpha	Satellite	centr
chr3:152249140-152249296	centromere	ALR/Alpha	Satellite	centr
chr3:157193973-157194129	centromere	ALR/Alpha	Satellite	centr
chr3:159095904-159096145	centromere	ALR/Alpha	Satellite	centr
chr3:1671485-1671641	centromere	ALR/Alpha	Satellite	centr
chr3:173420383-173420539	centromere	ALR/Alpha	Satellite	centr
chr3:178865003-178865159	centromere	ALR/Alpha	Satellite	centr
chr3:18001381-18001606	centromere	ALR/Alpha	Satellite	centr
chr3:18518314-18518470	pericentromere	(TGATTCCATTCC)n	Simple_repeat	Simple_repeat
chr3:187893271-187893427	centromere	ALR/Alpha	Satellite	centr
chr3:18935283-18935439	centromere	ALR/Alpha	Satellite	centr
chr3:19186266-19186422	centromere	ALR/Alpha	Satellite	centr
chr3:196898706-196898973	centromere	ALR/Alpha	Satellite	centr
chr3:197132541-197132781	centromere	ALR/Alpha	Satellite	centr
chr3:22312587-22312743	centromere	ALR/Alpha	Satellite	centr
chr3:22804109-22804265	centromere	ALR/Alpha	Satellite	centr
chr3:26477970-26478126	centromere	ALR/Alpha	Satellite	centr
chr3:26919355-26919523	centromere	ALR/Alpha	Satellite	centr
chr3:35821847-35822090	centromere	ALR/Alpha	Satellite	centr
chr3:35902614-35902770	pericentromere	(ATTCCATTCC)n	Simple_repeat	Simple_repeat
chr3:36437048-36437204	centromere	ALR/Alpha	Satellite	centr
chr3:39586167-39586342	centromere	ALR/Alpha	Satellite	centr
chr3:42106187-42106429	centromere	ALR/Alpha	Satellite	centr
chr3:4255041-4255241	centromere	ALR/Alpha	Satellite	centr
chr3:55393048-55393204	centromere	ALR/Alpha	Satellite	centr
chr3:58847762-58847918	centromere	ALR/Alpha	Satellite	centr
chr3:6144838-6144994	centromere	ALR/Alpha	Satellite	centr
chr3:63213737-63214054	centromere	ALR/Alpha	Satellite	centr
chr3:74194478-74194634	centromere	ALR/Alpha	Satellite	centr
chr3:75275684-75275840	centromere	ALR/Alpha	Satellite	centr
chr3:83804694-83804850	pericentromere	norepeat	nofamily	noclass
chr3:85916693-85916849	centromere	ALR/Alpha	Satellite	centr
chr3:86020541-86020697	centromere	ALR/Alpha	Satellite	centr
chr3:87341243-87341399	centromere	ALR/Alpha	Satellite	centr
chr3:91149437-91149593	centromere	ALR/Alpha	Satellite	centr
chr3:91188493-91188674	centromere	ALR/Alpha	Satellite	centr
chr3:91592984-91593153	centromere	ALR/Alpha	Satellite	centr
chr3:91594083-91594380	centromere	ALR/Alpha	Satellite	centr
chr3:91644178-91644343	centromere	ALR/Alpha	Satellite	centr
chr3:91650415-91650571	centromere	ALR/Alpha	Satellite	centr
chr3:91663075-91663231	centromere	ALR/Alpha	Satellite	centr
chr3:91681484-91681640	pericentromere	norepeat	nofamily	noclass
chr3:91733273-91733486	centromere	ALR/Alpha	Satellite	centr
chr3:91880515-91880691	centromere	ALR/Alpha	Satellite	centr
chr3:91881580-91881736	centromere	ALR/Alpha	Satellite	centr
chr3:91910453-91910609	centromere	ALR/Alpha	Satellite	centr
chr3:91942460-91942616	centromere	ALR/Alpha	Satellite	centr
chr3:91986432-91986702	centromere	ALR/Alpha	Satellite	centr
chr3:91988062-91988272	centromere	ALR/Alpha	Satellite	centr
chr3:92011461-92011677	centromere	ALR/Alpha	Satellite	centr
chr3:92017272-92017428	centromere	ALR/Alpha	Satellite	centr
chr3:92034571-92034788	centromere	ALR/Alpha	Satellite	centr
chr3:92050215-92050406	pericentromere	norepeat	nofamily	noclass
chr3:92063897-92064056	centromere	ALR/Alpha	Satellite	centr
chr3:92094464-92094633	centromere	ALR/Alpha	Satellite	centr

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chr3:92141394-92141550	centromere	ALR/Alpha	Satellite	centr
chr3:92243381-92243537	centromere	ALR/Alpha	Satellite	centr
chr3:92245082-92245289	centromere	ALR/Alpha	Satellite	centr
chr3:92262141-92262297	centromere	ALR/Alpha	Satellite	centr
chr3:92283660-92283822	centromere	ALR/Alpha	Satellite	centr
chr3:92321440-92321596	centromere	ALR/Alpha	Satellite	centr
chr3:92323980-92324136	centromere	ALR/Alpha	Satellite	centr
chr3:92465478-92465634	centromere	ALR/Alpha	Satellite	centr
chr3:92536865-92537052	pericentromere	(GAATGGAATC)n	Simple_repeat	Simple_repeat
chr3:92602288-92602444	centromere	ALR/Alpha	Satellite	centr
chr3:92609797-92609960	centromere	ALR/Alpha	Satellite	centr
chr3:92617825-92618046	centromere	ALR/Alpha	Satellite	centr
chr3:92640480-92640636	centromere	ALR/Alpha	Satellite	centr
chr3:92693333-92693576	centromere	ALR/Alpha	Satellite	centr
chr3:92739134-92739290	centromere	ALR/Alpha	Satellite	centr
chr3:92748536-92748692	centromere	ALR/Alpha	Satellite	centr
chr3:92869360-92869516	centromere	ALR/Alpha	Satellite	centr
chr3:92939537-92939693	centromere	ALR/Alpha	Satellite	centr
chr3:92975202-92975358	centromere	ALR/Alpha	Satellite	centr
chr3:93016747-93016903	pericentromere	(ATCGAATGCA)n	Simple_repeat	Simple_repeat
chr3:93028756-93028912	centromere	ALR/Alpha	Satellite	centr
chr3:93114761-93114917	centromere	ALR/Alpha	Satellite	centr
chr3:93138317-93138486	centromere	ALR/Alpha	Satellite	centr
chr3:93246502-93246658	centromere	ALR/Alpha	Satellite	centr
chr3:93251069-93251225	centromere	ALR/Alpha	Satellite	centr
chr3:93283018-93283174	centromere	ALR/Alpha	Satellite	centr
chr3:93317886-93318042	centromere	ALR/Alpha	Satellite	centr
chr3:93332710-93332866	centromere	ALR/Alpha	Satellite	centr
chr3:93376874-93377030	centromere	ALR/Alpha	Satellite	centr
chr3:93377738-93377915	centromere	ALR/Alpha	Satellite	centr
chr3:93410980-93411136	pericentromere	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr3:93419165-93419321	centromere	ALR/Alpha	Satellite	centr
chr3:93432189-93432345	centromere	ALR/Alpha	Satellite	centr
chr3:93470328-93470852	centromere	ALR/Alpha	Satellite	centr
chr3:93514682-93514850	centromere	ALR/Alpha	Satellite	centr
chr3:93592762-93592991	centromere	ALR/Alpha	Satellite	centr
chr3:93614355-93614511	centromere	ALR/Alpha	Satellite	centr
chr3:93617673-93617829	centromere	ALR/Alpha	Satellite	centr
chr3:93629312-93629525	centromere	ALR/Alpha	Satellite	centr
chr3:93631566-93631722	centromere	ALR/Alpha	Satellite	centr
chr3_GL000221v1_random:135372-135528	centromere	ALR/Alpha	Satellite	centr
chr3_K1270782v1_alt:146215-146371	pericentromere	ALR/Alpha	Satellite	centr
chr4:100453678-100453834	pericentromere	(ATCGAATGCA)n	Simple_repeat	Simple_repeat
chr4:101866732-101866888	centromere	ALR/Alpha	Satellite	centr
chr4:103828546-103828702	centromere	ALR/Alpha	Satellite	centr
chr4:106490999-106491234	centromere	ALR/Alpha	Satellite	centr
chr4:10776908-10777075	centromere	ALR/Alpha	Satellite	centr
chr4:108650316-108650535	centromere	ALR/Alpha	Satellite	centr
chr4:11077485-11077781	centromere	ALR/Alpha	Satellite	centr
chr4:111248542-111248698	centromere	ALR/Alpha	Satellite	centr
chr4:111458754-111458910	centromere	ALR/Alpha	Satellite	centr
chr4:111899285-111899441	centromere	ALR/Alpha	Satellite	centr
chr4:118163323-118163479	centromere	ALR/Alpha	Satellite	centr
chr4:121694320-121694476	pericentromere	norepeat	nofamily	noclass
chr4:122570062-122570275	centromere	ALR/Alpha	Satellite	centr
chr4:127021555-127021715	centromere	ALR/Alpha	Satellite	centr
chr4:12752179-12752335	centromere	ALR/Alpha	Satellite	centr
chr4:128897310-128897527	centromere	ALR/Alpha	Satellite	centr
chr4:129028237-129028534	centromere	ALR/Alpha	Satellite	centr
chr4:134590403-134590988	centromere	ALR/Alpha	Satellite	centr
chr4:137595270-137595426	centromere	ALR/Alpha	Satellite	centr
chr4:138548990-138549146	centromere	ALR/Alpha	Satellite	centr
chr4:141882055-141882211	centromere	ALR/Alpha	Satellite	centr
chr4:1428921-1429088	centromere	ALR/Alpha	Satellite	centr
chr4:1435313-1435515	pericentromere	norepeat	nofamily	noclass
chr4:1441753-1442012	centromere	ALR/Alpha	Satellite	centr
chr4:145378791-145378947	centromere	ALR/Alpha	Satellite	centr
chr4:145460443-145460599	centromere	ALR/Alpha	Satellite	centr
chr4:146893516-146893689	centromere	ALR/Alpha	Satellite	centr
chr4:148321211-148321367	centromere	ALR/Alpha	Satellite	centr
chr4:148322074-148322230	centromere	ALR/Alpha	Satellite	centr
chr4:149593005-149593161	centromere	ALR/Alpha	Satellite	centr
chr4:151551555-151551711	centromere	ALR/Alpha	Satellite	centr
chr4:152749664-152749820	centromere	ALR/Alpha	Satellite	centr
chr4:163636503-163636659	centromere	ALR/Alpha	Satellite	centr
chr4:164653740-164653902	centromere	ALR/Alpha	Satellite	centr
chr4:167262706-167262862	centromere	ALR/Alpha	Satellite	centr
chr4:170436370-170436535	centromere	ALR/Alpha	Satellite	centr
chr4:175024162-175024318	centromere	ALR/Alpha	Satellite	centr
chr4:183151254-183151410	centromere	ALR/Alpha	Satellite	centr
chr4:190178338-190178502	centromere	ALR/Alpha	Satellite	centr
chr4:19336229-19336385	centromere	ALR/Alpha	Satellite	centr
chr4:19949654-19949810	centromere	ALR/Alpha	Satellite	centr
chr4:22887774-22887951	centromere	ALR/Alpha	Satellite	centr
chr4:31685452-31685650	centromere	ALR/Alpha	Satellite	centr
chr4:34654887-34655105	pericentromere	norepeat	nofamily	noclass
chr4:42698172-42698328	centromere	ALR/Alpha	Satellite	centr
chr4:46055646-46055802	centromere	ALR/Alpha	Satellite	centr
chr4:49092697-49092914	centromere	ALR/Alpha	Satellite	centr
chr4:49108325-49108596	centromere	ALR/Alpha	Satellite	centr
chr4:49110678-49110918	centromere	ALR/Alpha	Satellite	centr
chr4:49118911-49119124	centromere	ALR/Alpha	Satellite	centr
chr4:49121067-49121254	centromere	ALR/Alpha	Satellite	centr
chr4:49129993-49130156	centromere	ALR/Alpha	Satellite	centr
chr4:49132340-49132511	centromere	ALR/Alpha	Satellite	centr
chr4:49134820-49134995	centromere	ALR/Alpha	Satellite	centr
chr4:49137140-49137379	pericentromere	(GAATGGAATC)n	Simple_repeat	Simple_repeat
chr4:49139643-49139890	centromere	ALR/Alpha	Satellite	centr
chr4:49141978-49142316	centromere	ALR/Alpha	Satellite	centr

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chr4:49147311-49147527	centromere	ALR/Alpha	Satellite	centr
chr4:49149638-49149901	centromere	ALR/Alpha	Satellite	centr
chr4:49153437-49153706	centromere	ALR/Alpha	Satellite	centr
chr4:49644549-49644724	centromere	ALR/Alpha	Satellite	centr
chr4:49720600-49720795	centromere	ALR/Alpha	Satellite	centr
chr4:49729047-49729235	centromere	ALR/Alpha	Satellite	centr
chr4:49729610-49729782	centromere	ALR/Alpha	Satellite	centr
chr4:49732177-497322410	centromere	ALR/Alpha	Satellite	centr
chr4:49746759-49746918	pericentromere	norepeat	nofamily	noclass
chr4:49752054-49752210	centromere	ALR/Alpha	Satellite	centr
chr4:49762820-49763047	centromere	ALR/Alpha	Satellite	centr
chr4:49766439-49766599	centromere	ALR/Alpha	Satellite	centr
chr4:49777860-49778016	centromere	ALR/Alpha	Satellite	centr
chr4:49784442-49784706	centromere	ALR/Alpha	Satellite	centr
chr4:49793234-49793390	centromere	ALR/Alpha	Satellite	centr
chr4:49804223-49804379	centromere	ALR/Alpha	Satellite	centr
chr4:49804559-49804872	centromere	ALR/Alpha	Satellite	centr
chr4:49810960-49811160	centromere	ALR/Alpha	Satellite	centr
chr4:49811511-49811705	centromere	ALR/Alpha	Satellite	centr
chr4:49817494-49817650	gene	norepeat	nofamily	noclass
chr4:49819550-49819706	centromere	ALR/Alpha	Satellite	centr
chr4:49820766-49821005	centromere	ALR/Alpha	Satellite	centr
chr4:49831241-49831449	centromere	ALR/Alpha	Satellite	centr
chr4:49832395-49832655	centromere	ALR/Alpha	Satellite	centr
chr4:49860742-49860913	centromere	ALR/Alpha	Satellite	centr
chr4:49863884-49864040	centromere	ALR/Alpha	Satellite	centr
chr4:49865235-49865428	centromere	ALR/Alpha	Satellite	centr
chr4:49865856-49866049	centromere	ALR/Alpha	Satellite	centr
chr4:49867140-49867325	centromere	ALR/Alpha	Satellite	centr
chr4:49870380-49870587	centromere	ALR/Alpha	Satellite	centr
chr4:49872944-49873100	gene	norepeat	nofamily	noclass
chr4:49898326-49898546	centromere	ALR/Alpha	Satellite	centr
chr4:49917460-49917708	centromere	ALR/Alpha	Satellite	centr
chr4:49930121-49930277	centromere	ALR/Alpha	Satellite	centr
chr4:49963061-49963217	centromere	ALR/Alpha	Satellite	centr
chr4:49972006-49972232	centromere	ALR/Alpha	Satellite	centr
chr4:49974264-49974441	centromere	ALR/Alpha	Satellite	centr
chr4:49975861-49976049	centromere	ALR/Alpha	Satellite	centr
chr4:49984099-49984279	centromere	ALR/Alpha	Satellite	centr
chr4:50014340-50014496	centromere	ALR/Alpha	Satellite	centr
chr4:50021630-50021786	centromere	ALR/Alpha	Satellite	centr
chr4:50025736-50025892	gene	norepeat	nofamily	noclass
chr4:50047382-50047586	centromere	ALR/Alpha	Satellite	centr
chr4:50076449-50076698	centromere	ALR/Alpha	Satellite	centr
chr4:50091111-50091267	centromere	ALR/Alpha	Satellite	centr
chr4:50110783-50110947	centromere	ALR/Alpha	Satellite	centr
chr4:50111687-50111853	centromere	ALR/Alpha	Satellite	centr
chr4:50116883-50117090	centromere	ALR/Alpha	Satellite	centr
chr4:50117729-50117885	centromere	ALR/Alpha	Satellite	centr
chr4:50124838-50125048	centromere	ALR/Alpha	Satellite	centr
chr4:50138897-50139076	centromere	ALR/Alpha	Satellite	centr
chr4:50163053-50163314	centromere	ALR/Alpha	Satellite	centr
chr4:50164753-50165010	gene	MER20	DNA	hAT-Charlie
chr4:50225692-50225896	pericentromere	ALR/Alpha	Satellite	centr
chr4:50227457-50227732	gene	norepeat	nofamily	noclass
chr4:50231050-50231206	centromere	ALR/Alpha	Satellite	centr
chr4:50231706-50231888	centromere	ALR/Alpha	Satellite	centr
chr4:50232272-50232578	centromere	ALR/Alpha	Satellite	centr
chr4:50242845-50243029	centromere	ALR/Alpha	Satellite	centr
chr4:50264480-50264636	centromere	ALR/Alpha	Satellite	centr
chr4:50290267-50290560	centromere	ALR/Alpha	Satellite	centr
chr4:50305195-50305374	centromere	ALR/Alpha	Satellite	centr
chr4:50315243-50315448	centromere	ALR/Alpha	Satellite	centr
chr4:50355981-50356173	centromere	ALR/Alpha	Satellite	centr
chr4:50360203-50360403	centromere	ALR/Alpha	Satellite	centr
chr4:50366139-50366295	gene	norepeat	nofamily	noclass
chr4:50367956-50368121	centromere	ALR/Alpha	Satellite	centr
chr4:50368332-50368508	centromere	ALR/Alpha	Satellite	centr
chr4:50370179-50370403	centromere	ALR/Alpha	Satellite	centr
chr4:50372693-50372874	centromere	ALR/Alpha	Satellite	centr
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chr4:50408160-50408316	centromere	ALR/Alpha	Satellite	centr
chr4:50409578-50409886	centromere	ALR/Alpha	Satellite	centr
chr4:50421381-50421540	centromere	ALR/Alpha	Satellite	centr
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chr4:50454624-50454783	centromere	ALR/Alpha	Satellite	centr
chr4:50456083-50456239	centromere	ALR/Alpha	Satellite	centr
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chr4:50526418-50526597	centromere	ALR/Alpha	Satellite	centr
chr4:50535359-50535574	centromere	ALR/Alpha	Satellite	centr
chr4:50538738-50538894	centromere	ALR/Alpha	Satellite	centr
chr4:50570762-50570978	centromere	ALR/Alpha	Satellite	centr
chr4:50573943-50574209	centromere	ALR/Alpha	Satellite	centr
chr4:50581981-50582220	centromere	ALR/Alpha	Satellite	centr
chr4:50583132-50583288	gene	norepeat	nofamily	noclass
chr4:50586773-50586929	centromere	ALR/Alpha	Satellite	centr
chr4:50597373-50597706	centromere	ALR/Alpha	Satellite	centr
chr4:50608703-50608938	centromere	ALR/Alpha	Satellite	centr
chr4:50625672-50625828	centromere	ALR/Alpha	Satellite	centr
chr4:50628818-50628985	centromere	ALR/Alpha	Satellite	centr
chr4:50629256-50629478	centromere	ALR/Alpha	Satellite	centr
chr4:50637676-50637846	centromere	ALR/Alpha	Satellite	centr
chr4:50648617-50648776	centromere	ALR/Alpha	Satellite	centr
chr4:50655871-50656027	centromere	ALR/Alpha	Satellite	centr
chr4:50656943-50657099	centromere	ALR/Alpha	Satellite	centr
chr4:50675038-50675315	gene	norepeat	nofamily	noclass
chr4:50676942-50677186	centromere	ALR/Alpha	Satellite	centr

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chr4:50678863-50679024	centromere	ALR/Alpha	Satellite	centr
chr4:50693657-50693846	centromere	ALR/Alpha	Satellite	centr
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chr4:50714651-50714807	centromere	ALR/Alpha	Satellite	centr
chr4:50716739-50716895	centromere	ALR/Alpha	Satellite	centr
chr4:50735401-50735561	centromere	ALR/Alpha	Satellite	centr
chr4:50741621-50741785	centromere	ALR/Alpha	Satellite	centr
chr4:50748741-50748909	centromere	ALR/Alpha	Satellite	centr
chr4:50755637-50755793	centromere	ALR/Alpha	Satellite	centr
chr4:50762357-50762569	gene	norepeat	nofamily	noclass
chr4:50763938-50764094	centromere	ALR/Alpha	Satellite	centr
chr4:50781357-50781513	centromere	ALR/Alpha	Satellite	centr
chr4:50789004-50789199	centromere	ALR/Alpha	Satellite	centr
chr4:50793922-50794111	centromere	ALR/Alpha	Satellite	centr
chr4:50804462-50804621	centromere	ALR/Alpha	Satellite	centr
chr4:50881515-50881926	centromere	ALR/Alpha	Satellite	centr
chr4:50882360-50882516	centromere	ALR/Alpha	Satellite	centr
chr4:50942988-50943146	centromere	ALR/Alpha	Satellite	centr
chr4:50954677-50954833	centromere	ALR/Alpha	Satellite	centr
chr4:50957030-50957227	centromere	ALR/Alpha	Satellite	centr
chr4:50959882-50960038	gene	norepeat	nofamily	noclass
chr4:50980440-50980876	centromere	ALR/Alpha	Satellite	centr
chr4:50983858-50984014	centromere	ALR/Alpha	Satellite	centr
chr4:50985968-50986137	centromere	ALR/Alpha	Satellite	centr
chr4:50987773-50987961	centromere	ALR/Alpha	Satellite	centr
chr4:50989852-50990024	centromere	ALR/Alpha	Satellite	centr
chr4:51002874-51003030	centromere	ALR/Alpha	Satellite	centr
chr4:51015501-51015718	centromere	ALR/Alpha	Satellite	centr
chr4:51051687-51051843	centromere	ALR/Alpha	Satellite	centr
chr4:51053013-51053172	centromere	ALR/Alpha	Satellite	centr
chr4:51054917-51055100	centromere	ALR/Alpha	Satellite	centr
chr4:51063390-51063564	gene	norepeat	nofamily	noclass
chr4:51069628-51069821	centromere	ALR/Alpha	Satellite	centr
chr4:51074280-51074436	centromere	ALR/Alpha	Satellite	centr
chr4:51113691-51113873	centromere	ALR/Alpha	Satellite	centr
chr4:51122603-51122878	centromere	ALR/Alpha	Satellite	centr
chr4:51129680-51129839	centromere	ALR/Alpha	Satellite	centr
chr4:51139584-51139760	centromere	ALR/Alpha	Satellite	centr
chr4:51148114-51148273	centromere	ALR/Alpha	Satellite	centr
chr4:51185529-51185700	centromere	ALR/Alpha	Satellite	centr
chr4:51187231-51187430	centromere	ALR/Alpha	Satellite	centr
chr4:51214322-51214495	centromere	ALR/Alpha	Satellite	centr
chr4:51256586-51256900	gene	norepeat	nofamily	noclass
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chr4:51281707-51281863	centromere	ALR/Alpha	Satellite	centr
chr4:51299268-51299520	centromere	ALR/Alpha	Satellite	centr
chr4:51310880-51311060	centromere	ALR/Alpha	Satellite	centr
chr4:51338962-51339133	centromere	ALR/Alpha	Satellite	centr
chr4:51343067-51343240	centromere	ALR/Alpha	Satellite	centr
chr4:51346243-51346399	centromere	ALR/Alpha	Satellite	centr
chr4:51351144-51351314	centromere	ALR/Alpha	Satellite	centr
chr4:51378968-51379129	centromere	ALR/Alpha	Satellite	centr
chr4:51393564-51393722	centromere	ALR/Alpha	Satellite	centr
chr4:51399246-51399502	gene	norepeat	nofamily	noclass
chr4:51425715-51425892	centromere	ALR/Alpha	Satellite	centr
chr4:51436463-51436634	centromere	ALR/Alpha	Satellite	centr
chr4:51437972-51438141	centromere	ALR/Alpha	Satellite	centr
chr4:51451597-51451754	centromere	ALR/Alpha	Satellite	centr
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chr4:51485444-51485682	centromere	ALR/Alpha	Satellite	centr
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chr4:51542594-51542750	centromere	ALR/Alpha	Satellite	centr
chr4:51546455-51546613	centromere	ALR/Alpha	Satellite	centr
chr4:51549568-51549747	pericentromere	ALR/Alpha	Satellite	centr
chr4:51550009-51550165	gene	norepeat	nofamily	noclass
chr4:51561733-51561956	centromere	ALR/Alpha	Satellite	centr
chr4:51566048-51566204	centromere	ALR/Alpha	Satellite	centr
chr4:51574123-51574355	centromere	ALR/Alpha	Satellite	centr
chr4:51577818-51578059	centromere	ALR/Alpha	Satellite	centr
chr4:51581067-51581347	centromere	ALR/Alpha	Satellite	centr
chr4:51583647-51583835	centromere	ALR/Alpha	Satellite	centr
chr4:51584890-51585203	centromere	ALR/Alpha	Satellite	centr
chr4:51595200-51595413	centromere	ALR/Alpha	Satellite	centr
chr4:51616318-51616606	centromere	ALR/Alpha	Satellite	centr
chr4:51623369-51623562	centromere	ALR/Alpha	Satellite	centr
chr4:51626371-51626527	gene	LIPA2	LINE	L1
chr4:51629435-51629596	centromere	ALR/Alpha	Satellite	centr
chr4:51647615-51647878	centromere	ALR/Alpha	Satellite	centr
chr4:51659343-51659499	centromere	ALR/Alpha	Satellite	centr
chr4:51660507-51660663	centromere	ALR/Alpha	Satellite	centr
chr4:51669528-51669684	centromere	ALR/Alpha	Satellite	centr
chr4:51672181-51672399	centromere	ALR/Alpha	Satellite	centr
chr4:51674761-51674917	centromere	ALR/Alpha	Satellite	centr
chr4:51678781-51678937	centromere	ALR/Alpha	Satellite	centr
chr4:51691023-51691179	centromere	ALR/Alpha	Satellite	centr
chr4:51700905-51701066	centromere	ALR/Alpha	Satellite	centr
chr4:51707008-51707347	intergenic	LIPA3	LINE	L1
chr4:51712454-51712610	centromere	ALR/Alpha	Satellite	centr
chr4:51722905-51723143	centromere	ALR/Alpha	Satellite	centr
chr4:51743659-51743897	centromere	ALR/Alpha	Satellite	centr
chr4:51800885-51801053	centromere	ALR/Alpha	Satellite	centr
chr4:51807514-51807672	centromere	ALR/Alpha	Satellite	centr
chr4:51809724-51809892	centromere	ALR/Alpha	Satellite	centr
chr4:51811259-51811425	centromere	ALR/Alpha	Satellite	centr
chr4:51814312-51814468	centromere	ALR/Alpha	Satellite	centr
chr4:52895980-52896136	centromere	ALR/Alpha	Satellite	centr
chr4:53182539-53182695	centromere	ALR/Alpha	Satellite	centr
chr4:53203043-53203199	gene	LIPA2	LINE	L1

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chr4:58388775-58388931	centromere	ALR/Alpha	Satellite	centr
chr4:59432353-59432659	centromere	ALR/Alpha	Satellite	centr
chr4:61944468-61944624	centromere	ALR/Alpha	Satellite	centr
chr4:72166973-72167129	centromere	ALR/Alpha	Satellite	centr
chr4:72291598-72291754	centromere	ALR/Alpha	Satellite	centr
chr4:72596142-72596298	centromere	ALR/Alpha	Satellite	centr
chr4:73554420-73554576	centromere	ALR/Alpha	Satellite	centr
chr4:75316098-75316254	centromere	ALR/Alpha	Satellite	centr
chr4:80691305-80691461	centromere	ALR/Alpha	Satellite	centr
chr4:82573838-82573996	centromere	ALR/Alpha	Satellite	centr
chr4:88924895-88925103	intergenic	L1P1	LINE	L1
chr4:92954974-92955130	centromere	ALR/Alpha	Satellite	centr
chr4:94294764-94294920	centromere	ALR/Alpha	Satellite	centr
chr4:95918324-95918482	centromere	ALR/Alpha	Satellite	centr
chr4:96410739-96410895	centromere	ALR/Alpha	Satellite	centr
chr4:96871305-96871664	centromere	ALR/Alpha	Satellite	centr
chr4:99349324-99349480	centromere	ALR/Alpha	Satellite	centr
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chr4_K1270790v1_alt:60586-60760	centromere	ALR/Alpha	Satellite	centr
chr5:10046-11230	centromere	ALR/Alpha	Satellite	centr
chr5:101921329-101921485	centromere	ALR/Alpha	Satellite	centr
chr5:110990266-110990477	intergenic	L1PA6	LINE	L1
chr5:119668043-119668199	centromere	ALR/Alpha	Satellite	centr
chr5:120668020-120668176	centromere	ALR/Alpha	Satellite	centr
chr5:122240900-122241056	centromere	ALR/Alpha	Satellite	centr
chr5:126904086-126904315	centromere	ALR/Alpha	Satellite	centr
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chr5:14808915-14809071	centromere	ALR/Alpha	Satellite	centr
chr5:148318769-148318925	centromere	ALR/Alpha	Satellite	centr
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chr5:152429155-152429311	gene	L1PA3	LINE	L1
chr5:153383720-153383876	centromere	ALR/Alpha	Satellite	centr
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chr5:160812023-160812179	centromere	ALR/Alpha	Satellite	centr
chr5:166969850-166970006	centromere	ALR/Alpha	Satellite	centr
chr5:170934703-170934873	centromere	ALR/Alpha	Satellite	centr
chr5:174471607-174471778	centromere	ALR/Alpha	Satellite	centr
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chr5:39552761-39552917	centromere	ALR/Alpha	Satellite	centr
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chr5:46915289-46915445	centromere	ALR/Alpha	Satellite	centr
chr5:47051968-47052124	centromere	ALR/Alpha	Satellite	centr
chr5:47319154-47319333	gene	L1PA2	LINE	L1
chr5:47320322-47320478	centromere	ALR/Alpha	Satellite	centr
chr5:47330530-47330687	centromere	ALR/Alpha	Satellite	centr
chr5:47333260-47333438	centromere	ALR/Alpha	Satellite	centr
chr5:47343280-47343440	centromere	ALR/Alpha	Satellite	centr
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chr5:47383772-47383928	centromere	ALR/Alpha	Satellite	centr
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chr5:47393814-47393991	centromere	ALR/Alpha	Satellite	centr
chr5:47397945-47398101	centromere	ALR/Alpha	Satellite	centr
chr5:47411096-47411278	gene	L1PA2	LINE	L1
chr5:47430966-47431188	centromere	ALR/Alpha	Satellite	centr
chr5:47459874-47460054	centromere	ALR/Alpha	Satellite	centr
chr5:47485641-47485797	centromere	ALR/Alpha	Satellite	centr
chr5:47495597-47495753	centromere	ALR/Alpha	Satellite	centr
chr5:47496198-47496435	centromere	ALR/Alpha	Satellite	centr
chr5:47497480-47497639	centromere	ALR/Alpha	Satellite	centr
chr5:47511136-47511299	centromere	ALR/Alpha	Satellite	centr
chr5:47528597-47528773	centromere	ALR/Alpha	Satellite	centr
chr5:47530564-47530848	centromere	ALR/Alpha	Satellite	centr
chr5:47531459-47531615	centromere	ALR/Alpha	Satellite	centr
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chr5:47567584-47567740	gene	L1PA3	LINE	L1
chr5:47569167-47569323	centromere	ALR/Alpha	Satellite	centr
chr5:47571737-47572006	centromere	ALR/Alpha	Satellite	centr
chr5:47604159-47604315	centromere	ALR/Alpha	Satellite	centr
chr5:47604856-47605042	centromere	ALR/Alpha	Satellite	centr
chr5:47626497-47626684	centromere	ALR/Alpha	Satellite	centr
chr5:47648524-47648718	centromere	ALR/Alpha	Satellite	centr
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chr5:47700601-47700757	centromere	ALR/Alpha	Satellite	centr
chr5:47703571-47703737	centromere	ALR/Alpha	Satellite	centr
chr5:47717212-47717489	gene	L1PA5	LINE	L1
chr5:47723108-47723294	centromere	ALR/Alpha	Satellite	centr
chr5:47798245-47798401	centromere	ALR/Alpha	Satellite	centr
chr5:47812611-47812813	centromere	ALR/Alpha	Satellite	centr
chr5:47813811-47814040	centromere	ALR/Alpha	Satellite	centr
chr5:47824669-47824825	centromere	ALR/Alpha	Satellite	centr
chr5:47825657-47825864	centromere	ALR/Alpha	Satellite	centr
chr5:47830343-47830499	centromere	ALR/Alpha	Satellite	centr
chr5:47832948-47833106	centromere	ALR/Alpha	Satellite	centr
chr5:47836932-47837088	centromere	ALR/Alpha	Satellite	centr
chr5:47887871-47888028	centromere	ALR/Alpha	Satellite	centr
chr5:47894279-47894435	gene	L1PA4	LINE	L1

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chr5:47894596-47894766	centromere	ALR/Alpha	Satellite	centr
chr5:47913146-47913373	centromere	ALR/Alpha	Satellite	centr
chr5:47916563-47916719	centromere	ALR/Alpha	Satellite	centr
chr5:47926241-47926425	centromere	ALR/Alpha	Satellite	centr
chr5:47944479-47944641	centromere	ALR/Alpha	Satellite	centr
chr5:47974580-47974765	centromere	ALR/Alpha	Satellite	centr
chr5:47997139-47997295	centromere	ALR/Alpha	Satellite	centr
chr5:48006344-48006537	centromere	ALR/Alpha	Satellite	centr
chr5:48009287-48009473	centromere	ALR/Alpha	Satellite	centr
chr5:48015035-48015219	centromere	ALR/Alpha	Satellite	centr
chr5:48093060-48093216	centromere	ALR/Alpha	Satellite	centr
chr5:48117573-48117731	centromere	ALR/Alpha	Satellite	centr
chr5:48136234-48136442	centromere	ALR/Alpha	Satellite	centr
chr5:48140671-48140849	centromere	ALR/Alpha	Satellite	centr
chr5:48173441-48173626	centromere	ALR/Alpha	Satellite	centr
chr5:48180395-48180551	centromere	ALR/Alpha	Satellite	centr
chr5:48200691-48200863	centromere	ALR/Alpha	Satellite	centr
chr5:48211158-48211314	centromere	ALR/Alpha	Satellite	centr
chr5:48220189-48220418	centromere	ALR/Alpha	Satellite	centr
chr5:48238450-48238633	centromere	ALR/Alpha	Satellite	centr
chr5:48241529-48241710	gene	L1PA2	LINE	L1
chr5:48249377-48249622	centromere	ALR/Alpha	Satellite	centr
chr5:48252384-48252604	centromere	ALR/Alpha	Satellite	centr
chr5:48254590-48254746	centromere	ALR/Alpha	Satellite	centr
chr5:48292222-48292378	centromere	ALR/Alpha	Satellite	centr
chr5:48306664-48306820	centromere	ALR/Alpha	Satellite	centr
chr5:48312632-48312794	centromere	ALR/Alpha	Satellite	centr
chr5:48316802-48316958	centromere	ALR/Alpha	Satellite	centr
chr5:48317865-48318021	centromere	ALR/Alpha	Satellite	centr
chr5:48321048-48321204	centromere	ALR/Alpha	Satellite	centr
chr5:48322048-48322209	centromere	ALR/Alpha	Satellite	centr
chr5:48333790-48334026	intergenic	L1PA3	LINE	L1
chr5:48334738-48334957	centromere	ALR/Alpha	Satellite	centr
chr5:48341749-48341905	centromere	ALR/Alpha	Satellite	centr
chr5:48348505-48348682	centromere	ALR/Alpha	Satellite	centr
chr5:48362372-48362528	centromere	ALR/Alpha	Satellite	centr
chr5:48368246-48368402	centromere	ALR/Alpha	Satellite	centr
chr5:48378568-48378730	centromere	ALR/Alpha	Satellite	centr
chr5:48418721-48418931	centromere	ALR/Alpha	Satellite	centr
chr5:48448661-48448817	centromere	ALR/Alpha	Satellite	centr
chr5:48449618-48449836	centromere	ALR/Alpha	Satellite	centr
chr5:48528994-48529150	centromere	ALR/Alpha	Satellite	centr
chr5:48545133-48545289	intergenic	L1PA3	LINE	L1
chr5:48593038-48593194	centromere	ALR/Alpha	Satellite	centr
chr5:48604332-48604543	centromere	ALR/Alpha	Satellite	centr
chr5:48625456-48625751	centromere	ALR/Alpha	Satellite	centr
chr5:48678279-48678555	centromere	ALR/Alpha	Satellite	centr
chr5:48687629-48687785	centromere	ALR/Alpha	Satellite	centr
chr5:48689992-48690154	centromere	ALR/Alpha	Satellite	centr
chr5:48701785-48702034	centromere	ALR/Alpha	Satellite	centr
chr5:48717501-48717657	centromere	ALR/Alpha	Satellite	centr
chr5:48722045-48722217	centromere	ALR/Alpha	Satellite	centr
chr5:48724983-48725147	centromere	ALR/Alpha	Satellite	centr
chr5:48732212-48732368	gene	L1MEd	LINE	L1
chr5:48765978-48766153	centromere	ALR/Alpha	Satellite	centr
chr5:48768811-48768967	centromere	ALR/Alpha	Satellite	centr
chr5:48808818-48808984	centromere	ALR/Alpha	Satellite	centr
chr5:48829160-48829316	centromere	ALR/Alpha	Satellite	centr
chr5:48840248-48840423	centromere	ALR/Alpha	Satellite	centr
chr5:48847621-48847787	centromere	ALR/Alpha	Satellite	centr
chr5:48858580-48858866	centromere	ALR/Alpha	Satellite	centr
chr5:48874410-48874686	centromere	ALR/Alpha	Satellite	centr
chr5:48878194-48878350	centromere	ALR/Alpha	Satellite	centr
chr5:48880994-48881152	centromere	ALR/Alpha	Satellite	centr
chr5:48886146-48886324	gene	norepeat	no family	noclass
chr5:48890284-48890464	centromere	ALR/Alpha	Satellite	centr
chr5:48895115-48895271	centromere	ALR/Alpha	Satellite	centr
chr5:48899722-48899905	centromere	ALR/Alpha	Satellite	centr
chr5:48925431-48925601	centromere	ALR/Alpha	Satellite	centr
chr5:48929354-48929542	centromere	ALR/Alpha	Satellite	centr
chr5:48935592-48935807	centromere	ALR/Alpha	Satellite	centr
chr5:48957898-48958134	centromere	ALR/Alpha	Satellite	centr
chr5:48970100-48970382	centromere	ALR/Alpha	Satellite	centr
chr5:48985321-48985481	centromere	ALR/Alpha	Satellite	centr
chr5:48992719-48992932	centromere	ALR/Alpha	Satellite	centr
chr5:49002724-49002882	gene	L1PA2	LINE	L1
chr5:49005158-49005314	centromere	ALR/Alpha	Satellite	centr
chr5:49034189-49034524	centromere	ALR/Alpha	Satellite	centr
chr5:49040616-49040772	centromere	ALR/Alpha	Satellite	centr
chr5:49043566-49043729	centromere	ALR/Alpha	Satellite	centr
chr5:49044899-49045055	centromere	ALR/Alpha	Satellite	centr
chr5:49086312-49086585	centromere	ALR/Alpha	Satellite	centr
chr5:49088905-49089061	centromere	ALR/Alpha	Satellite	centr
chr5:49096482-49096638	centromere	ALR/Alpha	Satellite	centr
chr5:49110829-49110995	centromere	ALR/Alpha	Satellite	centr
chr5:49124741-49124897	centromere	ALR/Alpha	Satellite	centr
chr5:49141467-49141623	centromere	ALR/Alpha	Satellite	centr
chr5:49149558-49149714	intergenic	L1HS	LINE	L1
chr5:49205629-49205821	centromere	ALR/Alpha	Satellite	centr
chr5:49217426-49217615	centromere	ALR/Alpha	Satellite	centr
chr5:49222501-49222732	centromere	ALR/Alpha	Satellite	centr
chr5:49226746-49226923	centromere	ALR/Alpha	Satellite	centr
chr5:49229824-49230009	centromere	ALR/Alpha	Satellite	centr
chr5:49234754-49234910	centromere	ALR/Alpha	Satellite	centr
chr5:49241127-49241338	centromere	ALR/Alpha	Satellite	centr
chr5:49243952-49244118	centromere	ALR/Alpha	Satellite	centr
chr5:49244557-49244777	centromere	ALR/Alpha	Satellite	centr
chr5:49263018-49263232	centromere	ALR/Alpha	Satellite	centr
chr5:49337314-49337513	intergenic	L1PA5	LINE	L1

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chr5:49362312-49362508	centromere	ALR/Alpha	Satellite	centr
chr5:49366282-49366452	centromere	ALR/Alpha	Satellite	centr
chr5:49394738-49394928	centromere	ALR/Alpha	Satellite	centr
chr5:49403065-49403223	centromere	ALR/Alpha	Satellite	centr
chr5:49403834-49403990	centromere	ALR/Alpha	Satellite	centr
chr5:49412832-49413044	centromere	ALR/Alpha	Satellite	centr
chr5:49425015-49425281	centromere	ALR/Alpha	Satellite	centr
chr5:49438250-49438443	centromere	ALR/Alpha	Satellite	centr
chr5:49445424-49445580	centromere	ALR/Alpha	Satellite	centr
chr5:49448177-49448436	centromere	ALR/Alpha	Satellite	centr
chr5:49459379-49459784	gene	L1PA3	LINE	L1
chr5:49467548-49467704	centromere	ALR/Alpha	Satellite	centr
chr5:49479580-49479736	centromere	ALR/Alpha	Satellite	centr
chr5:49485173-49485405	centromere	ALR/Alpha	Satellite	centr
chr5:49491038-49491226	centromere	ALR/Alpha	Satellite	centr
chr5:49496408-49496572	centromere	ALR/Alpha	Satellite	centr
chr5:49499202-49499363	centromere	ALR/Alpha	Satellite	centr
chr5:49507443-49507599	centromere	ALR/Alpha	Satellite	centr
chr5:49520838-49520994	centromere	ALR/Alpha	Satellite	centr
chr5:49528086-49528242	centromere	ALR/Alpha	Satellite	centr
chr5:49533179-49533335	centromere	ALR/Alpha	Satellite	centr
chr5:49543100-49543264	gene	L1PA3	LINE	L1
chr5:49545446-49545646	centromere	ALR/Alpha	Satellite	centr
chr5:49546180-49546404	centromere	ALR/Alpha	Satellite	centr
chr5:49546473-49546639	centromere	ALR/Alpha	Satellite	centr
chr5:49547300-49547486	centromere	ALR/Alpha	Satellite	centr
chr5:49562795-49562951	centromere	ALR/Alpha	Satellite	centr
chr5:49563544-49563730	centromere	ALR/Alpha	Satellite	centr
chr5:49569564-49569757	centromere	ALR/Alpha	Satellite	centr
chr5:49573888-49574100	centromere	ALR/Alpha	Satellite	centr
chr5:49576875-49577124	centromere	ALR/Alpha	Satellite	centr
chr5:49601441-49601845	centromere	ALR/Alpha	Satellite	centr
chr5:49602343-49602594	gene	norepeat	nofamily	noclass
chr5:49658374-49658813	centromere	ALR/Alpha	Satellite	centr
chr5:49659748-49659991	centromere	ALR/Alpha	Satellite	centr
chr5:49660956-49661214	centromere	ALR/Alpha	Satellite	centr
chr5:49666714-49666870	centromere	ALR/Alpha	Satellite	centr
chr5:49727139-49727323	centromere	ALR/Alpha	Satellite	centr
chr5:49793935-49794091	centromere	ALR/Alpha	Satellite	centr
chr5:49803454-49803718	centromere	ALR/Alpha	Satellite	centr
chr5:49876975-49877138	centromere	ALR/Alpha	Satellite	centr
chr5:50024917-50025073	centromere	ALR/Alpha	Satellite	centr
chr5:57352341-57352560	centromere	ALR/Alpha	Satellite	centr
chr5:59970856-59971023	gene	L1PA4	LINE	L1
chr5:64480731-64480987	centromere	ALR/Alpha	Satellite	centr
chr5:70326597-70326753	centromere	ALR/Alpha	Satellite	centr
chr5:7127379-7127535	centromere	ALR/Alpha	Satellite	centr
chr5:73633433-73633589	centromere	ALR/Alpha	Satellite	centr
chr5:79098154-79098397	centromere	ALR/Alpha	Satellite	centr
chr5:82505798-82505954	centromere	ALR/Alpha	Satellite	centr
chr5:82870174-82870433	centromere	ALR/Alpha	Satellite	centr
chr5:83317813-83318111	centromere	ALR/Alpha	Satellite	centr
chr5:8713048-8713204	centromere	ALR/Alpha	Satellite	centr
chr5:90686886-90687079	centromere	ALR/Alpha	Satellite	centr
chr5:95927506-95927708	gene	(TCCCCG)n	Simple_repeat	Simple_repeat
chr5:97183336-97183539	centromere	ALR/Alpha	Satellite	centr
chr5:98191590-98191746	centromere	ALR/Alpha	Satellite	centr
chr5:99830684-99830840	centromere	ALR/Alpha	Satellite	centr
chr6:100030541-100030697	centromere	ALR/Alpha	Satellite	centr
chr6:101155493-101155649	centromere	ALR/Alpha	Satellite	centr
chr6:104093311-104093467	intergenic	L1PA6	LINE	L1
chr6:105248069-105248286	gene	L1PA3	LINE	L1
chr6:110180219-110180464	gene	MIRb	SINE	MIR
chr6:112916841-112917019	gene	L1PA3	LINE	L1
chr6:114918669-114918825	gene	MamRTE1	LINE	RTE-BovB
chr6:115579140-115579296	gene	L1P1	LINE	L1
chr6:117724456-117724612	gene	L1HS	LINE	L1
chr6:120205691-120205861	gene	L1PA5	LINE	L1
chr6:120316290-120316446	intergenic	L1PA3	LINE	L1
chr6:123475519-123475675	intergenic	L1PA3	LINE	L1
chr6:125319733-125319889	intergenic	L1PA3	LINE	L1
chr6:147720977-147721133	intergenic	L1PA4	LINE	L1
chr6:153397880-153398036	intergenic	norepeat	nofamily	noclass
chr6:157668220-157668376	intergenic	L1PA2	LINE	L1
chr6:15806487-15806643	intergenic	AluSq2	SINE	Alu
chr6:160100628-160100798	gene	L1PA3	LINE	L1
chr6:160409390-160409546	intergenic	L1PA3	LINE	L1
chr6:166032848-166033084	intergenic	L1PA3	LINE	L1
chr6:167333187-167333354	intergenic	L1PA3	LINE	L1
chr6:30082238-30082394	gene	norepeat	nofamily	noclass
chr6:30249163-30249327	intergenic	L1PA2	LINE	L1
chr6:3307049-3307211	intergenic	L1PA4	LINE	L1
chr6:49389946-49390167	intergenic	L1HS	LINE	L1
chr6:49929729-49929887	intergenic	L1PA3	LINE	L1
chr6:54507231-54507392	intergenic	L1P1	LINE	L1
chr6:58452231-58452389	intergenic	L1PA3	LINE	L1
chr6:58452762-58452918	gene	L1PA3	LINE	L1
chr6:58554197-58554362	intergenic	L1HS	LINE	L1
chr6:58557600-58557776	gene	L1PA3	LINE	L1
chr6:58562263-58562419	intergenic	L1PA3	LINE	L1
chr6:58566305-58566559	gene	norepeat	nofamily	noclass
chr6:58569855-58570247	centromere	ALR/Alpha	Satellite	centr
chr6:58573910-58574107	gene	L1PA3	LINE	L1
chr6:58574253-58574409	gene	L1MEd	LINE	L1
chr6:58574508-58574665	gene	L1HS	LINE	L1
chr6:58579233-58579458	intergenic	L1M4a2	LINE	L1
chr6:58583691-58583905	gene	L1PA2	LINE	L1
chr6:58587002-58587158	Unplaced_chr	L1PA5	LINE	L1
chr6:58587415-58587571	Unplaced_chr	L1HS	LINE	L1

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chr6:58588281-58588443	Unplaced_chr	L1PA4	LINE	L1
chr6:58589145-58589364	Unplaced_chr	L1PA2	LINE	L1
chr6:58590981-58591253	Unplaced_chr	L1PA3	LINE	L1
chr6:58591664-58591862	Unplaced_chr	L1P1	LINE	L1
chr6:58593444-58593600	intergenic	L1PA3	LINE	L1
chr6:58593817-58594081	intergenic	L1PA2	LINE	L1
chr6:58595793-58595999	gene	L1PA3	LINE	L1
chr6:58602416-58602673	gene	L1PA2	LINE	L1
chr6:58603555-58603747	intergenic	L1P1	LINE	L1
chr6:58606142-58606657	intergenic	L1PA7	LINE	L1
chr6:58608111-58608393	intergenic	L1PA4	LINE	L1
chr6:58609235-58609391	pericentromere	norepeat	nofamily	noclass
chr6:58610533-58610689	centromere	ALR/Alpha	Satellite	centr
chr6:58611766-58611950	subtelomere	(CTAACC)n	Simple_repeat	Simple_repeat
chr6:58612290-58612578	centromere	ALR/Alpha	Satellite	centr
chr6:58615450-58615734	centromere	ALR/Alpha	Satellite	centr
chr6:58616241-58616641	centromere	ALR/Alpha	Satellite	centr
chr6:58621551-58621730	centromere	ALR/Alpha	Satellite	centr
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chr6:58627165-58627390	centromere	ALR/Alpha	Satellite	centr
chr6:58628184-58628372	centromere	ALR/Alpha	Satellite	centr
chr6:58629204-58629360	centromere	ALR/Alpha	Satellite	centr
chr6:58630995-58631248	gene	L1PA2	LINE	L1
chr6:58634009-58634184	centromere	ALR/Alpha	Satellite	centr
chr6:58634794-58635072	centromere	ALR/Alpha	Satellite	centr
chr6:58636143-58636472	centromere	ALR/Alpha	Satellite	centr
chr6:58637768-58637973	centromere	ALR/Alpha	Satellite	centr
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chr6:58642934-58643108	centromere	ALR/Alpha	Satellite	centr
chr6:58643169-58643383	intergenic	L1PA2	LINE	L1
chr6:58644774-58645035	centromere	ALR/Alpha	Satellite	centr
chr6:58645877-58646122	centromere	ALR/Alpha	Satellite	centr
chr6:58647908-58648135	centromere	ALR/Alpha	Satellite	centr
chr6:58650340-58650509	centromere	ALR/Alpha	Satellite	centr
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chr6:58651952-58652145	centromere	ALR/Alpha	Satellite	centr
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chr6:58656989-58657159	centromere	ALR/Alpha	Satellite	centr
chr6:58657717-58657913	centromere	ALR/Alpha	Satellite	centr
chr6:58658195-58658390	centromere	ALR/Alpha	Satellite	centr
chr6:58658769-58658989	gene	norepeat	nofamily	noclass
chr6:58663116-58663345	centromere	ALR/Alpha	Satellite	centr
chr6:58664820-58664997	centromere	ALR/Alpha	Satellite	centr
chr6:58666043-58666221	centromere	ALR/Alpha	Satellite	centr
chr6:58670600-58670811	centromere	ALR/Alpha	Satellite	centr
chr6:58672758-58672992	centromere	ALR/Alpha	Satellite	centr
chr6:58674709-58674919	centromere	ALR/Alpha	Satellite	centr
chr6:58676923-58677132	centromere	ALR/Alpha	Satellite	centr
chr6:58678593-58678887	centromere	ALR/Alpha	Satellite	centr
chr6:58679640-58679796	centromere	ALR/Alpha	Satellite	centr
chr6:58680086-58680257	centromere	ALR/Alpha	Satellite	centr
chr6:58680821-58680977	gene	norepeat	nofamily	noclass
chr6:58681467-58681761	centromere	ALR/Alpha	Satellite	centr
chr6:58682705-58682878	centromere	ALR/Alpha	Satellite	centr
chr6:58684878-58685124	centromere	ALR/Alpha	Satellite	centr
chr6:58685676-58685891	centromere	ALR/Alpha	Satellite	centr
chr6:58691851-58692007	centromere	ALR/Alpha	Satellite	centr
chr6:58692110-58692353	centromere	ALR/Alpha	Satellite	centr
chr6:58693735-58693909	centromere	ALR/Alpha	Satellite	centr
chr6:58695836-58696021	centromere	ALR/Alpha	Satellite	centr
chr6:58697964-58698220	centromere	ALR/Alpha	Satellite	centr
chr6:58700397-58700553	centromere	ALR/Alpha	Satellite	centr
chr6:58701093-58701249	intergenic	HERVE-int	LTR	ERV1
chr6:58701309-58701541	centromere	ALR/Alpha	Satellite	centr
chr6:58702920-58703076	centromere	ALR/Alpha	Satellite	centr
chr6:58704156-58704312	centromere	ALR/Alpha	Satellite	centr
chr6:58705264-58705516	centromere	ALR/Alpha	Satellite	centr
chr6:58708375-58708595	centromere	ALR/Alpha	Satellite	centr
chr6:58710116-58710362	centromere	ALR/Alpha	Satellite	centr
chr6:58711664-58711820	centromere	ALR/Alpha	Satellite	centr
chr6:58714489-58714645	centromere	ALR/Alpha	Satellite	centr
chr6:58715154-58715310	centromere	ALR/Alpha	Satellite	centr
chr6:58716618-58716874	centromere	ALR/Alpha	Satellite	centr
chr6:58718531-58718687	intergenic	L1PA4	LINE	L1
chr6:58719489-58719645	centromere	ALR/Alpha	Satellite	centr
chr6:58719891-58720098	centromere	ALR/Alpha	Satellite	centr
chr6:58720443-58720659	centromere	ALR/Alpha	Satellite	centr
chr6:58723340-58723537	centromere	ALR/Alpha	Satellite	centr
chr6:58728774-58728930	centromere	ALR/Alpha	Satellite	centr
chr6:58731624-58731827	centromere	ALR/Alpha	Satellite	centr
chr6:58734542-58734698	centromere	ALR/Alpha	Satellite	centr
chr6:58736116-58736440	centromere	ALR/Alpha	Satellite	centr
chr6:58738949-58739245	centromere	ALR/Alpha	Satellite	centr
chr6:58740757-58740915	centromere	ALR/Alpha	Satellite	centr
chr6:58741455-58741612	centromere	ALR/Alpha	Satellite	centr
chr6:58741871-58742032	centromere	ALR/Alpha	Satellite	centr
chr6:58744143-58744378	centromere	ALR/Alpha	Satellite	centr
chr6:58744921-58745156	centromere	ALR/Alpha	Satellite	centr
chr6:58746877-58747375	centromere	ALR/Alpha	Satellite	centr
chr6:58749337-58749642	centromere	ALR/Alpha	Satellite	centr
chr6:58754174-58754534	centromere	ALR/Alpha	Satellite	centr
chr6:58755089-58755316	centromere	ALR/Alpha	Satellite	centr
chr6:58755740-58755907	centromere	ALR/Alpha	Satellite	centr
chr6:58758613-58758848	centromere	ALR/Alpha	Satellite	centr

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chr6:58759636-58759792	centromere	ALR/Alpha	Satellite	centr
chr6:58760409-58760664	intergenic	L1PA2	LINE	L1
chr6:58763285-58763529	centromere	ALR/Alpha	Satellite	centr
chr6:58765896-58766142	centromere	ALR/Alpha	Satellite	centr
chr6:58767998-58768274	centromere	ALR/Alpha	Satellite	centr
chr6:58768562-58768728	centromere	ALR/Alpha	Satellite	centr
chr6:58769674-58769831	centromere	ALR/Alpha	Satellite	centr
chr6:58770291-58770534	centromere	ALR/Alpha	Satellite	centr
chr6:58771259-58771487	centromere	ALR/Alpha	Satellite	centr
chr6:58771996-58772448	centromere	ALR/Alpha	Satellite	centr
chr6:58772701-58772885	centromere	ALR/Alpha	Satellite	centr
chr6:58773843-58774430	centromere	ALR/Alpha	Satellite	centr
chr6:58775883-58776286	gene	L1PA2	LINE	L1
chr6:58776764-58776920	centromere	ALR/Alpha	Satellite	centr
chr6:58778845-58779001	centromere	ALR/Alpha	Satellite	centr
chr6:58781606-58781984	centromere	ALR/Alpha	Satellite	centr
chr6:58786009-58786251	centromere	ALR/Alpha	Satellite	centr
chr6:58787214-58787370	centromere	ALR/Alpha	Satellite	centr
chr6:58789163-58789610	centromere	ALR/Alpha	Satellite	centr
chr6:58791253-58791434	centromere	ALR/Alpha	Satellite	centr
chr6:58792653-58792809	centromere	ALR/Alpha	Satellite	centr
chr6:58795600-58795950	centromere	ALR/Alpha	Satellite	centr
chr6:58796445-58796607	centromere	ALR/Alpha	Satellite	centr
chr6:58797088-58797381	gene	L1PA3	LINE	L1
chr6:58798257-58798451	centromere	ALR/Alpha	Satellite	centr
chr6:58801345-58801583	centromere	ALR/Alpha	Satellite	centr
chr6:58802919-58803075	centromere	ALR/Alpha	Satellite	centr
chr6:58804491-58804662	centromere	ALR/Alpha	Satellite	centr
chr6:58806772-58806942	centromere	ALR/Alpha	Satellite	centr
chr6:58811833-58812153	centromere	ALR/Alpha	Satellite	centr
chr6:58813817-58813973	centromere	ALR/Alpha	Satellite	centr
chr6:58814645-58814981	centromere	ALR/Alpha	Satellite	centr
chr6:58816863-58817030	centromere	ALR/Alpha	Satellite	centr
chr6:58818220-58818436	gene	L1PA4	LINE	L1
chr6:58819156-58819312	centromere	ALR/Alpha	Satellite	centr
chr6:58819673-58819879	centromere	ALR/Alpha	Satellite	centr
chr6:58820249-58820426	centromere	ALR/Alpha	Satellite	centr
chr6:58822747-58822937	centromere	ALR/Alpha	Satellite	centr
chr6:58823719-58824156	centromere	ALR/Alpha	Satellite	centr
chr6:58833214-58833514	centromere	ALR/Alpha	Satellite	centr
chr6:58833829-58834004	centromere	ALR/Alpha	Satellite	centr
chr6:58836878-58837038	centromere	ALR/Alpha	Satellite	centr
chr6:58838158-58838383	centromere	ALR/Alpha	Satellite	centr
chr6:58841021-58841471	centromere	ALR/Alpha	Satellite	centr
chr6:58842282-58842438	gene	L1PA5	LINE	L1
chr6:58842647-58842817	centromere	ALR/Alpha	Satellite	centr
chr6:58842985-58843169	centromere	ALR/Alpha	Satellite	centr
chr6:58845153-58845536	centromere	ALR/Alpha	Satellite	centr
chr6:58845731-58845928	centromere	ALR/Alpha	Satellite	centr
chr6:58848581-58848803	centromere	ALR/Alpha	Satellite	centr
chr6:58849245-58849430	centromere	ALR/Alpha	Satellite	centr
chr6:58854019-58854175	centromere	ALR/Alpha	Satellite	centr
chr6:58854510-58854708	centromere	ALR/Alpha	Satellite	centr
chr6:58856296-58856792	centromere	ALR/Alpha	Satellite	centr
chr6:58857069-58857232	centromere	ALR/Alpha	Satellite	centr
chr6:58857467-58857639	centromere	ALR/Alpha	Satellite	centr
chr6:58858463-58858760	centromere	ALR/Alpha	Satellite	centr
chr6:58859494-58859816	centromere	ALR/Alpha	Satellite	centr
chr6:58860971-58861138	centromere	ALR/Alpha	Satellite	centr
chr6:58861615-58861791	centromere	ALR/Alpha	Satellite	centr
chr6:58861923-58862113	centromere	ALR/Alpha	Satellite	centr
chr6:58863843-58864086	centromere	ALR/Alpha	Satellite	centr
chr6:58865535-58865705	centromere	ALR/Alpha	Satellite	centr
chr6:58868089-58868297	centromere	ALR/Alpha	Satellite	centr
chr6:58868437-58868744	centromere	ALR/Alpha	Satellite	centr
chr6:58869015-58869258	centromere	ALR/Alpha	Satellite	centr
chr6:58870500-58870732	centromere	ALR/Alpha	Satellite	centr
chr6:58871327-58871483	centromere	ALR/Alpha	Satellite	centr
chr6:58871631-58871800	centromere	ALR/Alpha	Satellite	centr
chr6:58876632-58876807	centromere	ALR/Alpha	Satellite	centr
chr6:58876923-58877610	centromere	ALR/Alpha	Satellite	centr
chr6:58878117-58878364	centromere	ALR/Alpha	Satellite	centr
chr6:58879190-58879485	centromere	ALR/Alpha	Satellite	centr
chr6:58879597-58879753	centromere	ALR/Alpha	Satellite	centr
chr6:58882999-58883498	centromere	ALR/Alpha	Satellite	centr
chr6:58886627-58886864	centromere	ALR/Alpha	Satellite	centr
chr6:58887084-58887432	centromere	ALR/Alpha	Satellite	centr
chr6:58889784-58889968	centromere	ALR/Alpha	Satellite	centr
chr6:58890492-58890894	centromere	ALR/Alpha	Satellite	centr
chr6:58893225-58893386	centromere	ALR/Alpha	Satellite	centr
chr6:58893477-58893865	centromere	ALR/Alpha	Satellite	centr
chr6:58895208-58895755	intergenic	(ATCGAATGGA)n	Simple_repeat	Simple_repeat
chr6:58897174-58897351	intergenic	ALR/Alpha	Satellite	centr
chr6:58901056-58901248	intergenic	ALR/Alpha	Satellite	centr
chr6:58901650-58901806	intergenic	ALR/Alpha	Satellite	centr
chr6:58902652-58902856	intergenic	ALR/Alpha	Satellite	centr
chr6:58908612-58908780	intergenic	ALR/Alpha	Satellite	centr
chr6:58909269-58909508	intergenic	ALR/Alpha	Satellite	centr
chr6:58910282-58911171	centromere	ALR/Alpha	Satellite	centr
chr6:58911237-58911394	centromere	ALR/Alpha	Satellite	centr
chr6:58911826-58912244	centromere	ALR/Alpha	Satellite	centr
chr6:58913278-58913462	centromere	ALR/Alpha	Satellite	centr
chr6:58914352-58914508	centromere	ALR/Alpha	Satellite	centr
chr6:58914571-58914825	centromere	ALR/Alpha	Satellite	centr
chr6:58917803-58917991	centromere	ALR/Alpha	Satellite	centr
chr6:58918132-58918384	centromere	ALR/Alpha	Satellite	centr
chr6:58920021-58920177	centromere	ALR/Alpha	Satellite	centr
chr6:58920997-58921198	centromere	ALR/Alpha	Satellite	centr
chr6:58925396-58925552	centromere	ALR/Alpha	Satellite	centr

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chr6:58926639-58927178	centromere	ALR/Alpha	Satellite	centr
chr6:58931952-58932154	centromere	ALR/Alpha	Satellite	centr
chr6:58941951-58942472	centromere	ALR/Alpha	Satellite	centr
chr6:58948990-58949222	centromere	ALR/Alpha	Satellite	centr
chr6:58951276-58951569	intergenic	L1PA2	LINE	L1
chr6:58952922-58953273	intergenic	(AC)n	Simple_repeat	Simple_repeat
chr6:58959536-58959815	intergenic	L1PA4	LINE	L1
chr6:58960133-58960289	gene	L1HS	LINE	L1
chr6:58961592-58961748	gene	L1PA3	LINE	L1
chr6:58967466-58967622	gene	L1PA3	LINE	L1
chr6:58968273-58968568	gene	(TG)n	Simple_repeat	Simple_repeat
chr6:58969332-58969592	centromere	ALR/Alpha	Satellite	centr
chr6:58969796-58969954	centromere	ALR/Alpha	Satellite	centr
chr6:58973284-58973451	intergenic	L1PA5	LINE	L1
chr6:58974599-58974910	gene	L1PA3	LINE	L1
chr6:58975535-58975761	intergenic	L1PA2	LINE	L1
chr6:58978886-58979081	gene	L1PA4	LINE	L1
chr6:58979458-58979653	gene	L1HS	LINE	L1
chr6:58979811-58979989	gene	norepeat	nofamily	noclass
chr6:58981533-58981790	intergenic	L1PA3	LINE	L1
chr6:58981868-58982178	gene	L1PA4	LINE	L1
chr6:58985067-58985229	gene	L1M3	LINE	L1
chr6:58986014-58986295	centromere	ALR/Alpha	Satellite	centr
chr6:58987683-58987958	gene	(TG)n	Simple_repeat	Simple_repeat
chr6:58989163-58989372	intergenic	L1P1	LINE	L1
chr6:58990890-58991047	gene	MamTip2	DNA	hAT-Tip100
chr6:58993026-58993331	gene	L1HS	LINE	L1
chr6:58995020-58995275	intergenic	L1PA2	LINE	L1
chr6:58996161-58996317	intergenic	L1PA2	LINE	L1
chr6:58998772-58998992	intergenic	L1HS	LINE	L1
chr6:58999215-58999497	intergenic	L1PA2	LINE	L1
chr6:59011363-59011747	gene	L1HS	LINE	L1
chr6:59012612-59012844	intergenic	L1PA4	LINE	L1
chr6:59013232-59013416	centromere	ALR/Alpha	Satellite	centr
chr6:59013771-59014097	gene	L1PA3	LINE	L1
chr6:59014596-59014809	gene	L1PA5	LINE	L1
chr6:59017502-59017854	intergenic	L1PA4	LINE	L1
chr6:59018321-59018482	gene	L1PA5	LINE	L1
chr6:59019282-59019438	gene	L1PA3	LINE	L1
chr6:59022488-59022709	intergenic	L1HS	LINE	L1
chr6:59023271-59023479	gene	L1PA3	LINE	L1
chr6:59024430-59024647	gene	L2a	LINE	L2
chr6:59027812-59027984	gene	norepeat	nofamily	noclass
chr6:59028477-59028753	gene	norepeat	nofamily	noclass
chr6:59029752-59029926	centromere	ALR/Alpha	Satellite	centr
chr6:59030459-59030714	gene	norepeat	nofamily	noclass
chr6:59030770-59030926	gene	L1PA2	LINE	L1
chr6:59035717-59035944	gene	norepeat	nofamily	noclass
chr6:59036956-59037259	gene	L1HS	LINE	L1
chr6:59039259-59039415	gene	norepeat	nofamily	noclass
chr6:59039693-59039928	intergenic	L1PA5	LINE	L1
chr6:59045043-59045379	gene	L1PA4	LINE	L1
chr6:59045748-59046044	gene	L1HS	LINE	L1
chr6:59048861-59049020	intergenic	L1PA6	LINE	L1
chr6:59049307-59049502	centromere	ALR/Alpha	Satellite	centr
chr6:59050949-59051567	gene	L1P1	LINE	L1
chr6:59054094-59054462	centromere	ALR/Alpha	Satellite	centr
chr6:59055063-59055409	centromere	ALR/Alpha	Satellite	centr
chr6:59057747-59057914	centromere	ALR/Alpha	Satellite	centr
chr6:59058085-59058299	centromere	ALR/Alpha	Satellite	centr
chr6:59061643-59061852	centromere	ALR/Alpha	Satellite	centr
chr6:59063392-59063798	centromere	ALR/Alpha	Satellite	centr
chr6:59066059-59066245	centromere	ALR/Alpha	Satellite	centr
chr6:59067217-59067386	centromere	ALR/Alpha	Satellite	centr
chr6:59067468-59067625	centromere	ALR/Alpha	Satellite	centr
chr6:59069189-59069405	centromere	ALR/Alpha	Satellite	centr
chr6:59069501-59069785	centromere	ALR/Alpha	Satellite	centr
chr6:59072610-59073068	centromere	ALR/Alpha	Satellite	centr
chr6:59077589-59077745	centromere	ALR/Alpha	Satellite	centr
chr6:59079602-59079972	centromere	ALR/Alpha	Satellite	centr
chr6:59081274-59081430	centromere	ALR/Alpha	Satellite	centr
chr6:59082248-59082475	centromere	ALR/Alpha	Satellite	centr
chr6:59082917-59083114	centromere	ALR/Alpha	Satellite	centr
chr6:59083821-59084107	centromere	ALR/Alpha	Satellite	centr
chr6:59084614-59084814	centromere	ALR/Alpha	Satellite	centr
chr6:59087494-59087662	centromere	ALR/Alpha	Satellite	centr
chr6:59087870-59088026	centromere	ALR/Alpha	Satellite	centr
chr6:59089624-59089780	centromere	ALR/Alpha	Satellite	centr
chr6:59091624-59091836	centromere	ALR/Alpha	Satellite	centr
chr6:59092793-59093061	centromere	ALR/Alpha	Satellite	centr
chr6:59095808-59096153	centromere	ALR/Alpha	Satellite	centr
chr6:59096560-59096789	centromere	ALR/Alpha	Satellite	centr
chr6:59097998-59098158	centromere	ALR/Alpha	Satellite	centr
chr6:59101088-59101518	centromere	ALR/Alpha	Satellite	centr
chr6:59105711-59105891	centromere	ALR/Alpha	Satellite	centr
chr6:59110011-59110167	centromere	ALR/Alpha	Satellite	centr
chr6:59111711-59111917	centromere	ALR/Alpha	Satellite	centr
chr6:59112701-59112950	centromere	ALR/Alpha	Satellite	centr
chr6:59113513-59113669	centromere	ALR/Alpha	Satellite	centr
chr6:59113742-59113941	centromere	ALR/Alpha	Satellite	centr
chr6:59116080-59116297	centromere	ALR/Alpha	Satellite	centr
chr6:59116794-59116955	centromere	ALR/Alpha	Satellite	centr
chr6:59120490-59120646	centromere	ALR/Alpha	Satellite	centr
chr6:59120867-59121032	centromere	ALR/Alpha	Satellite	centr
chr6:59121136-59121331	centromere	ALR/Alpha	Satellite	centr
chr6:59121747-59121903	centromere	ALR/Alpha	Satellite	centr
chr6:59123099-59123341	centromere	ALR/Alpha	Satellite	centr
chr6:59124003-59124162	centromere	ALR/Alpha	Satellite	centr
chr6:59125119-59125387	centromere	ALR/Alpha	Satellite	centr

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chr6:59128510-59128694	centromere	ALR/Alpha	Satellite	centr
chr6:59130054-59130443	centromere	ALR/Alpha	Satellite	centr
chr6:59132796-59132958	centromere	ALR/Alpha	Satellite	centr
chr6:59134105-59134344	centromere	ALR/Alpha	Satellite	centr
chr6:59134931-59135330	centromere	ALR/Alpha	Satellite	centr
chr6:59137438-59137644	centromere	ALR/Alpha	Satellite	centr
chr6:59137975-59138311	centromere	ALR/Alpha	Satellite	centr
chr6:59138831-59139112	centromere	ALR/Alpha	Satellite	centr
chr6:59140108-59140264	centromere	ALR/Alpha	Satellite	centr
chr6:59141243-59141469	centromere	ALR/Alpha	Satellite	centr
chr6:59142412-59142707	centromere	ALR/Alpha	Satellite	centr
chr6:59143378-59143583	centromere	ALR/Alpha	Satellite	centr
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chr6:59159375-59159684	centromere	ALR/Alpha	Satellite	centr
chr6:59159911-59160124	centromere	ALR/Alpha	Satellite	centr
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chr6:59161702-59161926	centromere	ALR/Alpha	Satellite	centr
chr6:59163864-59164041	centromere	ALR/Alpha	Satellite	centr
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chr6:59167256-59167429	centromere	ALR/Alpha	Satellite	centr
chr6:59168032-59168202	centromere	ALR/Alpha	Satellite	centr
chr6:59168735-59168963	centromere	ALR/Alpha	Satellite	centr
chr6:59170315-59170726	centromere	ALR/Alpha	Satellite	centr
chr6:59171724-59171880	centromere	ALR/Alpha	Satellite	centr
chr6:59174860-59175062	centromere	ALR/Alpha	Satellite	centr
chr6:59180544-59180847	centromere	ALR/Alpha	Satellite	centr
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chr6:59188083-59188374	centromere	ALR/Alpha	Satellite	centr
chr6:59189057-59189346	centromere	ALR/Alpha	Satellite	centr
chr6:59190027-59190230	centromere	ALR/Alpha	Satellite	centr
chr6:59190750-59191069	centromere	ALR/Alpha	Satellite	centr
chr6:59192186-59192401	centromere	ALR/Alpha	Satellite	centr
chr6:59192552-59192750	centromere	ALR/Alpha	Satellite	centr
chr6:59193212-59193389	centromere	ALR/Alpha	Satellite	centr
chr6:59193637-59194028	centromere	ALR/Alpha	Satellite	centr
chr6:59194862-59195106	intergenic	L1PA3	LINE	L1
chr6:59199302-59199503	intergenic	L1PA4	LINE	L1
chr6:59199661-59199817	intergenic	L1PA2	LINE	L1
chr6:59200033-59200189	gene	L1PA3	LINE	L1
chr6:59201112-59201337	intergenic	L1PA4	LINE	L1
chr6:59202446-59202623	gene	L1PA3	LINE	L1
chr6:59203195-59203502	intergenic	L1PA4	LINE	L1
chr6:59205559-59205807	gene	L1PA5	LINE	L1
chr6:59211572-59211728	gene	L1HS	LINE	L1
chr6:59212672-59212885	gene	norepeat	nofamily	noclass
chr6:59215337-59215691	centromere	ALR/Alpha	Satellite	centr
chr6:59217482-59217677	gene	LSU-rRNA_Hsa	rRNA	rRNA
chr6:59218358-59218542	gene	L1HS	LINE	L1
chr6:59221107-59221419	intergenic	L1PA5	LINE	L1
chr6:59221602-59221791	gene	L1PA3	LINE	L1
chr6:59222762-59222946	gene	L1PA2	LINE	L1
chr6:59223776-59223941	gene	L1PA4	LINE	L1
chr6:59225675-59226059	gene	L1PA2	LINE	L1
chr6:59226295-59226562	gene	L1PA2	LINE	L1
chr6:59226977-59227152	gene	L1PA3	LINE	L1
chr6:59227583-59227804	centromere	ALR/Alpha	Satellite	centr
chr6:59230842-59231034	gene	L1PA2	LINE	L1
chr6:59231933-59232146	gene	L1PA2	LINE	L1
chr6:59232731-59232977	gene	L1PA2	LINE	L1
chr6:59233262-59233442	gene	L1PA3	LINE	L1
chr6:59234872-59235028	intergenic	L1PA4	LINE	L1
chr6:59237949-59238404	gene	L1P1	LINE	L1
chr6:59239019-59239329	intergenic	L1PA5	LINE	L1
chr6:59239742-59239998	gene	L1PA2	LINE	L1
chr6:59242835-59242991	intergenic	L1PA4	LINE	L1
chr6:59244884-59245354	intergenic	L1PA3	LINE	L1
chr6:59245946-59246267	centromere	ALR/Alpha	Satellite	centr
chr6:59246367-59246681	intergenic	L1PA2	LINE	L1
chr6:59247219-59247434	intergenic	L1PA2	LINE	L1
chr6:59248976-59249900	intergenic	L1PA3	LINE	L1
chr6:59250390-59250660	intergenic	L1PA2	LINE	L1
chr6:59250981-59251356	intergenic	L1PA2	LINE	L1
chr6:59253986-59254250	intergenic	L1PA3	LINE	L1
chr6:59254999-59255155	intergenic	(AC)n	Simple_repeat	Simple_repeat
chr6:59256096-59256461	intergenic	L1PA3	LINE	L1
chr6:59259755-59259911	intergenic	L1PA2	LINE	L1
chr6:59260418-59260574	gene	L1PA2	LINE	L1
chr6:59262304-59262629	centromere	ALR/Alpha	Satellite	centr
chr6:59264124-59264431	intergenic	L1PA3	LINE	L1
chr6:59265863-59266019	gene	L1PA3	LINE	L1
chr6:59275150-59275358	Unplaced_chr	L1PA4	LINE	L1
chr6:59276197-59276469	Unplaced_chr	L1PA3	LINE	L1
chr6:59276780-59276960	intergenic	L1PA4	LINE	L1
chr6:59277034-59277396	intergenic	L1PA4	LINE	L1
chr6:59281706-59281878	gene	L1HS	LINE	L1
chr6:59282734-59282890	intergenic	L1P1	LINE	L1
chr6:59284395-59284589	gene	L1PA3	LINE	L1
chr6:59286932-59287226	gene	L1HS	LINE	L1
chr6:59287868-59288210	centromere	ALR/Alpha	Satellite	centr
chr6:59289288-59289492	intergenic	L1PA2	LINE	L1

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chr6:59291161-59291318	gene	L1PA2	LINE	L1
chr6:59292610-59292827	gene	L1PA2	LINE	L1
chr6:59292913-59293171	gene	L1PA5	LINE	L1
chr6:59296107-59296497	intergenic	L1PA3	LINE	L1
chr6:59297669-59297992	intergenic	L1PA4	LINE	L1
chr6:59298546-59298838	intergenic	L1PA3	LINE	L1
chr6:59299945-59300101	intergenic	L1PA3	LINE	L1
chr6:59302983-59303206	intergenic	ERV1-E-int	LTR	ERV1
chr6:59303637-59303848	pericentromere	(TTCCA)n	Simple_repeat	Simple_repeat
chr6:59303993-59304490	centromere	ALR/Alpha	Satellite	centr
chr6:59304871-59305027	centromere	ALR/Alpha	Satellite	centr
chr6:59312218-59312410	centromere	ALR/Alpha	Satellite	centr
chr6:59313210-59313509	centromere	ALR/Alpha	Satellite	centr
chr6:59313850-59314006	centromere	ALR/Alpha	Satellite	centr
chr6:59314532-59314980	centromere	ALR/Alpha	Satellite	centr
chr6:59315737-59315953	centromere	ALR/Alpha	Satellite	centr
chr6:59318542-59318833	centromere	ALR/Alpha	Satellite	centr
chr6:59320369-59320525	centromere	ALR/Alpha	Satellite	centr
chr6:59321472-59321634	centromere	ALR/Alpha	Satellite	centr
chr6:59321819-59322071	centromere	ALR/Alpha	Satellite	centr
chr6:59322706-59322937	centromere	ALR/Alpha	Satellite	centr
chr6:59323041-59323197	centromere	ALR/Alpha	Satellite	centr
chr6:59324319-59324491	centromere	ALR/Alpha	Satellite	centr
chr6:59326368-59326630	centromere	ALR/Alpha	Satellite	centr
chr6:59327126-59327302	centromere	ALR/Alpha	Satellite	centr
chr6:59329069-59329225	centromere	ALR/Alpha	Satellite	centr
chr6:59331807-59331985	centromere	ALR/Alpha	Satellite	centr
chr6:59332193-59332349	centromere	ALR/Alpha	Satellite	centr
chr6:59335228-59335436	centromere	ALR/Alpha	Satellite	centr
chr6:59336307-59336646	centromere	ALR/Alpha	Satellite	centr
chr6:59337032-59337188	centromere	ALR/Alpha	Satellite	centr
chr6:59341159-59341390	centromere	ALR/Alpha	Satellite	centr
chr6:59342425-59342641	centromere	ALR/Alpha	Satellite	centr
chr6:59343754-59343931	centromere	ALR/Alpha	Satellite	centr
chr6:59344609-59344765	centromere	ALR/Alpha	Satellite	centr
chr6:59344975-59345190	centromere	ALR/Alpha	Satellite	centr
chr6:59345933-59346362	centromere	ALR/Alpha	Satellite	centr
chr6:59350143-59350345	centromere	ALR/Alpha	Satellite	centr
chr6:59355033-59355189	centromere	ALR/Alpha	Satellite	centr
chr6:59355356-59355512	centromere	ALR/Alpha	Satellite	centr
chr6:59356161-59356511	centromere	ALR/Alpha	Satellite	centr
chr6:59359210-59359424	centromere	ALR/Alpha	Satellite	centr
chr6:59360448-59360653	centromere	ALR/Alpha	Satellite	centr
chr6:59365771-59365927	centromere	ALR/Alpha	Satellite	centr
chr6:59368482-59368981	centromere	ALR/Alpha	Satellite	centr
chr6:59370374-59370708	centromere	ALR/Alpha	Satellite	centr
chr6:59371392-59371616	centromere	ALR/Alpha	Satellite	centr
chr6:59373429-59373592	centromere	ALR/Alpha	Satellite	centr
chr6:59375416-59375629	centromere	ALR/Alpha	Satellite	centr
chr6:59378952-59379235	centromere	ALR/Alpha	Satellite	centr
chr6:59380954-59381277	centromere	ALR/Alpha	Satellite	centr
chr6:59386701-59386874	centromere	ALR/Alpha	Satellite	centr
chr6:59388724-59388984	centromere	ALR/Alpha	Satellite	centr
chr6:59392516-59392930	centromere	ALR/Alpha	Satellite	centr
chr6:59393973-59394199	centromere	ALR/Alpha	Satellite	centr
chr6:59394493-59394774	centromere	ALR/Alpha	Satellite	centr
chr6:59396080-59396535	centromere	ALR/Alpha	Satellite	centr
chr6:59401406-59401597	centromere	ALR/Alpha	Satellite	centr
chr6:59405010-59405166	centromere	ALR/Alpha	Satellite	centr
chr6:59406650-59407021	centromere	ALR/Alpha	Satellite	centr
chr6:59408010-59408226	centromere	ALR/Alpha	Satellite	centr
chr6:59409716-59409882	centromere	ALR/Alpha	Satellite	centr
chr6:59412710-59412891	centromere	ALR/Alpha	Satellite	centr
chr6:59412949-59413129	centromere	ALR/Alpha	Satellite	centr
chr6:59414415-59414808	centromere	ALR/Alpha	Satellite	centr
chr6:59416658-59416814	centromere	ALR/Alpha	Satellite	centr
chr6:59422137-59422411	centromere	ALR/Alpha	Satellite	centr
chr6:59425021-59425247	centromere	ALR/Alpha	Satellite	centr
chr6:59429479-59429635	centromere	ALR/Alpha	Satellite	centr
chr6:59429766-59430180	centromere	ALR/Alpha	Satellite	centr
chr6:59431111-59431593	centromere	ALR/Alpha	Satellite	centr
chr6:59433787-59433944	centromere	ALR/Alpha	Satellite	centr
chr6:59434170-59434326	centromere	ALR/Alpha	Satellite	centr
chr6:59437647-59437805	centromere	ALR/Alpha	Satellite	centr
chr6:59437875-59438123	centromere	ALR/Alpha	Satellite	centr
chr6:59440703-59440971	centromere	ALR/Alpha	Satellite	centr
chr6:59441401-59441557	gene	L1PA3	LINE	L1
chr6:59441915-59442078	gene	L1PA2	LINE	L1
chr6:59442248-59442404	intergenic	L1PA3	LINE	L1
chr6:59445762-59445918	intergenic	(TGGAA)n	Simple_repeat	Simple_repeat
chr6:59446910-59447103	gene	AluX3	SINE	Alu
chr6:59447775-59448009	intergenic	L1PA3	LINE	L1
chr6:59448840-59448996	intergenic	L1PA4	LINE	L1
chr6:59451178-59451352	centromere	ALR/Alpha	Satellite	centr
chr6:59452212-59452533	gene	L1PA2	LINE	L1
chr6:59452617-59452793	gene	L1PA7	LINE	L1
chr6:59453459-59453636	gene	L1HS	LINE	L1
chr6:59455973-59456142	gene	L1PA3	LINE	L1
chr6:59458316-59458472	intergenic	L1PA5	LINE	L1
chr6:59465028-59465214	gene	L1PA2	LINE	L1
chr6:59467550-59467773	gene	L1PA3	LINE	L1
chr6:59468882-59469135	centromere	ALR/Alpha	Satellite	centr
chr6:59470515-59470714	gene	L1PA3	LINE	L1
chr6:59475613-59475769	gene	AluX	SINE	Alu
chr6:59475871-59476168	gene	L1PA4	LINE	L1
chr6:59480879-59481313	gene	L1HS	LINE	L1
chr6:59481894-59482075	gene	norepeat	nofamily	noclass
chr6:59484453-59484938	Unplaced_chr	(CATTCA)n	Satellite/Simple_repeat	Satellite/Simple_repeat
chr6:59485120-59485276	Unplaced_chr	(TTCCATTCCA)n	Simple_repeat	Simple_repeat

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chr6:59487339-59487556	Unplaced_chr	BSR/Beta	Satellite	Satellite
chr6:59493276-59493454	Unplaced_chr	BSR/Beta	Satellite	Satellite
chr6:59493633-59493789	centromere	ALR/Alpha	Satellite	centr
chr6:59496260-59496516	Unplaced_chr	LSU-rRNA_Hsa	rRNA	rRNA
chr6:59497481-59497637	Unplaced_chr	LSU-rRNA_Hsa	rRNA	rRNA
chr6:59499730-59499886	Unplaced_chr	ALR/Alpha	Satellite	centr
chr6:59500211-59500586	Unplaced_chr	ALR/Alpha	Satellite	centr
chr6:59501350-59501563	Unplaced_chr	ALR/Alpha	Satellite	centr
chr6:59501891-59502065	Unplaced_chr	ALR/Alpha	Satellite	centr
chr6:59503676-59503870	Unplaced_chr	ALR/Alpha	Satellite	centr
chr6:59504861-59505213	Unplaced_chr	ALR/Alpha	Satellite	centr
chr6:59506662-59506822	Unplaced_chr	(GGAATGGAAT)n	Simple_repeat	Simple_repeat
chr6:59509449-59509760	centromere	ALR/Alpha	Satellite	centr
chr6:59512317-59512473	Unplaced_chr	(GGAATGGAAT)n	Simple_repeat	Simple_repeat
chr6:59512858-59513294	intergenic	norepeat	nofamily	noclass
chr6:59515467-59515952	intergenic	L1HS	LINE	L1
chr6:59528404-59528563	gene	L1PA6	LINE	L1
chr6:59529479-59529635	gene	L1PA2	LINE	L1
chr6:59530237-59530745	gene	L1PB1	LINE	L1
chr6:59530921-59531077	intergenic	L1PA3	LINE	L1
chr6:59533679-59533935	centromere	ALR/Alpha	Satellite	centr
chr6:59534825-59534981	gene	norepeat	nofamily	noclass
chr6:59536403-59536623	intergenic	L1PA3	LINE	L1
chr6:59540641-59540877	gene	L1PA5	LINE	L1
chr6:59545377-59545611	intergenic	L1PA3	LINE	L1
chr6:59549805-59550030	intergenic	L1PA5	LINE	L1
chr6:59550094-59550683	intergenic	L1P1	LINE	L1
chr6:59552591-59553486	intergenic	L1P1	LINE	L1
chr6:59554133-59554545	intergenic	L1PA3	LINE	L1
chr6:59556186-59556496	pericentromere	L1PA2	LINE	L1
chr6:59557090-59557296	centromere	ALR/Alpha	Satellite	centr
chr6:59559187-59559452	centromere	ALR/Alpha	Satellite	centr
chr6:59560817-59561020	centromere	ALR/Alpha	Satellite	centr
chr6:59561334-59561490	centromere	ALR/Alpha	Satellite	centr
chr6:59563947-59564135	centromere	ALR/Alpha	Satellite	centr
chr6:59564307-59564501	centromere	ALR/Alpha	Satellite	centr
chr6:59565509-59565677	centromere	ALR/Alpha	Satellite	centr
chr6:59569708-59569864	centromere	ALR/Alpha	Satellite	centr
chr6:59570105-59570428	centromere	ALR/Alpha	Satellite	centr
chr6:59570739-59570908	centromere	ALR/Alpha	Satellite	centr
chr6:59572096-59572523	centromere	ALR/Alpha	Satellite	centr
chr6:59575788-59575946	centromere	ALR/Alpha	Satellite	centr
chr6:59577846-59578072	centromere	ALR/Alpha	Satellite	centr
chr6:59579492-59579650	centromere	ALR/Alpha	Satellite	centr
chr6:59580202-59580358	centromere	ALR/Alpha	Satellite	centr
chr6:59582474-59582630	centromere	ALR/Alpha	Satellite	centr
chr6:59584183-59584351	centromere	ALR/Alpha	Satellite	centr
chr6:59587087-59587335	centromere	ALR/Alpha	Satellite	centr
chr6:59591626-59591983	centromere	ALR/Alpha	Satellite	centr
chr6:59593702-59594021	centromere	ALR/Alpha	Satellite	centr
chr6:59594495-59594898	centromere	ALR/Alpha	Satellite	centr
chr6:59597738-59598025	centromere	ALR/Alpha	Satellite	centr
chr6:59598806-59599019	centromere	ALR/Alpha	Satellite	centr
chr6:59599956-59600177	centromere	ALR/Alpha	Satellite	centr
chr6:59601957-59602300	centromere	ALR/Alpha	Satellite	centr
chr6:59603086-59603251	centromere	ALR/Alpha	Satellite	centr
chr6:59603808-59603983	centromere	ALR/Alpha	Satellite	centr
chr6:59611342-59611498	centromere	ALR/Alpha	Satellite	centr
chr6:59611671-59611830	centromere	ALR/Alpha	Satellite	centr
chr6:59613468-59613715	centromere	ALR/Alpha	Satellite	centr
chr6:59616218-59616374	centromere	ALR/Alpha	Satellite	centr
chr6:59624363-59624576	centromere	ALR/Alpha	Satellite	centr
chr6:59625625-59625878	centromere	ALR/Alpha	Satellite	centr
chr6:59627152-59627614	centromere	ALR/Alpha	Satellite	centr
chr6:59628611-59629016	centromere	ALR/Alpha	Satellite	centr
chr6:59631141-59631448	centromere	ALR/Alpha	Satellite	centr
chr6:59633169-59633439	centromere	ALR/Alpha	Satellite	centr
chr6:59634312-59635222	centromere	ALR/Alpha	Satellite	centr
chr6:59635622-59635834	centromere	ALR/Alpha	Satellite	centr
chr6:59638781-59638964	centromere	ALR/Alpha	Satellite	centr
chr6:59641463-59641657	centromere	ALR/Alpha	Satellite	centr
chr6:59642801-59643138	centromere	ALR/Alpha	Satellite	centr
chr6:59646210-59646428	centromere	ALR/Alpha	Satellite	centr
chr6:59651902-59652074	centromere	ALR/Alpha	Satellite	centr
chr6:59656103-59656259	centromere	ALR/Alpha	Satellite	centr
chr6:59656738-59656894	centromere	ALR/Alpha	Satellite	centr
chr6:59657896-59658578	centromere	ALR/Alpha	Satellite	centr
chr6:59658646-59658952	centromere	ALR/Alpha	Satellite	centr
chr6:59659168-59659726	centromere	ALR/Alpha	Satellite	centr
chr6:59660125-59660339	centromere	ALR/Alpha	Satellite	centr
chr6:59661007-59661280	centromere	ALR/Alpha	Satellite	centr
chr6:59662097-59662392	centromere	ALR/Alpha	Satellite	centr
chr6:59662716-59662872	centromere	ALR/Alpha	Satellite	centr
chr6:59664819-59665055	centromere	ALR/Alpha	Satellite	centr
chr6:59665511-59665667	centromere	ALR/Alpha	Satellite	centr
chr6:59666731-59666910	centromere	ALR/Alpha	Satellite	centr
chr6:59667209-59667394	centromere	ALR/Alpha	Satellite	centr
chr6:59668247-59668504	centromere	ALR/Alpha	Satellite	centr
chr6:59670968-59671124	centromere	ALR/Alpha	Satellite	centr
chr6:59672677-59672833	centromere	ALR/Alpha	Satellite	centr
chr6:59677523-59677786	centromere	ALR/Alpha	Satellite	centr
chr6:59681452-59681608	centromere	ALR/Alpha	Satellite	centr
chr6:59683332-59683488	centromere	ALR/Alpha	Satellite	centr
chr6:59685284-59685440	centromere	ALR/Alpha	Satellite	centr
chr6:59686547-59686848	centromere	ALR/Alpha	Satellite	centr
chr6:59689720-59689997	centromere	ALR/Alpha	Satellite	centr
chr6:59691063-59691219	centromere	ALR/Alpha	Satellite	centr
chr6:59692774-59693136	centromere	ALR/Alpha	Satellite	centr
chr6:59693605-59693868	centromere	ALR/Alpha	Satellite	centr

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chr6:59696309-59696486	centromere	ALR/Alpha	Satellite	centr
chr6:59698678-59699066	centromere	ALR/Alpha	Satellite	centr
chr6:59703559-59703715	centromere	ALR/Alpha	Satellite	centr
chr6:59704850-59705050	centromere	ALR/Alpha	Satellite	centr
chr6:59705247-59705403	centromere	ALR/Alpha	Satellite	centr
chr6:59707594-59707847	centromere	ALR/Alpha	Satellite	centr
chr6:59709364-59709520	centromere	ALR/Alpha	Satellite	centr
chr6:59710035-59710214	centromere	ALR/Alpha	Satellite	centr
chr6:597113173-59713413	centromere	ALR/Alpha	Satellite	centr
chr6:59715753-59716214	centromere	ALR/Alpha	Satellite	centr
chr6:59718628-59718878	centromere	ALR/Alpha	Satellite	centr
chr6:59719279-59719582	centromere	ALR/Alpha	Satellite	centr
chr6:59722259-59722596	centromere	ALR/Alpha	Satellite	centr
chr6:59723131-59723472	centromere	ALR/Alpha	Satellite	centr
chr6:59723983-59724139	centromere	ALR/Alpha	Satellite	centr
chr6:59724208-59724578	centromere	ALR/Alpha	Satellite	centr
chr6:59725046-59725321	centromere	ALR/Alpha	Satellite	centr
chr6:59726079-59726337	centromere	ALR/Alpha	Satellite	centr
chr6:59728055-59728533	centromere	ALR/Alpha	Satellite	centr
chr6:59732173-59732360	centromere	ALR/Alpha	Satellite	centr
chr6:59733407-59733604	centromere	ALR/Alpha	Satellite	centr
chr6:59733807-59733963	centromere	ALR/Alpha	Satellite	centr
chr6:59735669-59735825	centromere	ALR/Alpha	Satellite	centr
chr6:59736431-59736831	centromere	ALR/Alpha	Satellite	centr
chr6:59737156-59737391	centromere	ALR/Alpha	Satellite	centr
chr6:59737521-59737907	centromere	ALR/Alpha	Satellite	centr
chr6:59738722-59738884	centromere	ALR/Alpha	Satellite	centr
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chr6:59744261-59744489	centromere	ALR/Alpha	Satellite	centr
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chr6:59756116-59756381	centromere	ALR/Alpha	Satellite	centr
chr6:59756657-59756845	centromere	ALR/Alpha	Satellite	centr
chr6:59757105-59757374	intergenic	L1PA3	LINE	L1
chr6:59757839-59758171	centromere	ALR/Alpha	Satellite	centr
chr6:59758966-59759122	centromere	ALR/Alpha	Satellite	centr
chr6:59760081-59760370	centromere	ALR/Alpha	Satellite	centr
chr6:59760957-59761261	centromere	ALR/Alpha	Satellite	centr
chr6:59761990-59762146	centromere	ALR/Alpha	Satellite	centr
chr6:59764414-59764650	centromere	ALR/Alpha	Satellite	centr
chr6:59766890-59767078	centromere	ALR/Alpha	Satellite	centr
chr6:59767329-59767613	centromere	ALR/Alpha	Satellite	centr
chr6:59768118-59768350	centromere	ALR/Alpha	Satellite	centr
chr6:59768987-59769519	centromere	ALR/Alpha	Satellite	centr
chr6:59776998-59777190	centromere	ALR/Alpha	Satellite	centr
chr6:59780974-59781214	centromere	ALR/Alpha	Satellite	centr
chr6:59781496-59781652	centromere	ALR/Alpha	Satellite	centr
chr6:59782717-59782873	centromere	ALR/Alpha	Satellite	centr
chr6:59783483-59783730	centromere	ALR/Alpha	Satellite	centr
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chr6:59787371-59787547	centromere	ALR/Alpha	Satellite	centr
chr6:59789855-59790215	centromere	ALR/Alpha	Satellite	centr
chr6:59790390-59790637	centromere	ALR/Alpha	Satellite	centr
chr6:59791566-59791781	centromere	ALR/Alpha	Satellite	centr
chr6:59793529-59793696	centromere	ALR/Alpha	Satellite	centr
chr6:59793768-59793970	centromere	ALR/Alpha	Satellite	centr
chr6:59794535-59794824	centromere	ALR/Alpha	Satellite	centr
chr6:59796573-59796880	centromere	ALR/Alpha	Satellite	centr
chr6:59796964-59797155	centromere	ALR/Alpha	Satellite	centr
chr6:59798335-59798610	centromere	ALR/Alpha	Satellite	centr
chr6:59798770-59798926	centromere	ALR/Alpha	Satellite	centr
chr6:59799936-59800155	centromere	ALR/Alpha	Satellite	centr
chr6:59800214-59800370	centromere	ALR/Alpha	Satellite	centr
chr6:59800825-59800981	centromere	ALR/Alpha	Satellite	centr
chr6:59803995-59804235	centromere	ALR/Alpha	Satellite	centr
chr6:59805004-59805174	centromere	ALR/Alpha	Satellite	centr
chr6:59805729-59806197	centromere	ALR/Alpha	Satellite	centr
chr6:59806739-59806935	centromere	ALR/Alpha	Satellite	centr
chr6:59808281-59808437	centromere	ALR/Alpha	Satellite	centr
chr6:59808779-59808979	centromere	ALR/Alpha	Satellite	centr
chr6:59810534-59810788	centromere	ALR/Alpha	Satellite	centr
chr6:59812008-59812164	centromere	ALR/Alpha	Satellite	centr
chr6:59814842-59815001	centromere	ALR/Alpha	Satellite	centr
chr6:59815054-59815252	centromere	ALR/Alpha	Satellite	centr
chr6:59817114-59817300	centromere	ALR/Alpha	Satellite	centr
chr6:59817788-59818226	centromere	ALR/Alpha	Satellite	centr
chr6:59819325-59819523	centromere	ALR/Alpha	Satellite	centr
chr6:59820950-59821210	centromere	ALR/Alpha	Satellite	centr
chr6:59821532-59821768	centromere	ALR/Alpha	Satellite	centr
chr6:59824498-59824733	centromere	ALR/Alpha	Satellite	centr
chr6:59825277-59825547	centromere	ALR/Alpha	Satellite	centr
chr6:59826131-59826287	centromere	ALR/Alpha	Satellite	centr
chr6:59828408-59828618	centromere	ALR/Alpha	Satellite	centr
chr6:59829147-59829303	centromere	ALR/Alpha	Satellite	centr
chr6:59829590-59829895	centromere	ALR/Alpha	Satellite	centr
chr6:6213994-6214150	centromere	ALR/Alpha	Satellite	centr
chr6:6261880-6262140	centromere	ALR/Alpha	Satellite	centr
chr6:66171324-66171480	centromere	ALR/Alpha	Satellite	centr
chr6:68288993-68289149	centromere	ALR/Alpha	Satellite	centr
chr6:70685011-70685167	centromere	ALR/Alpha	Satellite	centr
chr6:71366973-71367131	centromere	ALR/Alpha	Satellite	centr
chr6:72801697-72801989	centromere	ALR/Alpha	Satellite	centr
chr6:74156143-74156299	centromere	ALR/Alpha	Satellite	centr
chr6:74342116-74342279	centromere	ALR/Alpha	Satellite	centr
chr6:80496313-80496469	centromere	ALR/Alpha	Satellite	centr
chr6:82634379-82634535	centromere	ALR/Alpha	Satellite	centr

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chr6:86053219-86053375	centromere	ALR/Alpha	Satellite	centr
chr6:86279874-86280190	centromere	ALR/Alpha	Satellite	centr
chr6:93633321-93633535	centromere	ALR/Alpha	Satellite	centr
chr6:95694146-95694302	centromere	ALR/Alpha	Satellite	centr
chr6_GL000252v2_alt:1505131-1505287	centromere	ALR/Alpha	Satellite	centr
chr6_GL000252v2_alt:3861777-3861960	centromere	ALR/Alpha	Satellite	centr
chr6_GL000253v2_alt:442853-443009	centromere	ALR/Alpha	Satellite	centr
chr6_GL000256v2_alt:1383530-1383686	centromere	ALR/Alpha	Satellite	centr
chr6_GL000256v2_alt:425150-425306	centromere	ALR/Alpha	Satellite	centr
chr6_KI270801v1_alt:507303-507463	centromere	ALR/Alpha	Satellite	centr
chr7:100119315-100119579	centromere	ALR/Alpha	Satellite	centr
chr7:102709643-102709799	centromere	ALR/Alpha	Satellite	centr
chr7:102784145-102784301	centromere	ALR/Alpha	Satellite	centr
chr7:103227349-103227505	centromere	ALR/Alpha	Satellite	centr
chr7:105076753-105076909	centromere	ALR/Alpha	Satellite	centr
chr7:109013745-109013906	centromere	ALR/Alpha	Satellite	centr
chr7:111561383-111561539	centromere	ALR/Alpha	Satellite	centr
chr7:111968838-111968994	centromere	ALR/Alpha	Satellite	centr
chr7:113430480-113430729	centromere	ALR/Alpha	Satellite	centr
chr7:113536859-113537015	centromere	ALR/Alpha	Satellite	centr
chr7:113776415-113776571	centromere	ALR/Alpha	Satellite	centr
chr7:115261621-115261863	centromere	ALR/Alpha	Satellite	centr
chr7:117527780-117528036	centromere	ALR/Alpha	Satellite	centr
chr7:120236531-120236687	centromere	ALR/Alpha	Satellite	centr
chr7:120323537-120323693	centromere	ALR/Alpha	Satellite	centr
chr7:123080821-123080977	centromere	ALR/Alpha	Satellite	centr
chr7:125384996-125385152	centromere	ALR/Alpha	Satellite	centr
chr7:126618142-126618430	centromere	ALR/Alpha	Satellite	centr
chr7:126829331-126829487	centromere	ALR/Alpha	Satellite	centr
chr7:130702740-130702932	centromere	ALR/Alpha	Satellite	centr
chr7:13767802-13767958	centromere	ALR/Alpha	Satellite	centr
chr7:140765695-140765851	centromere	ALR/Alpha	Satellite	centr
chr7:140774886-140775042	centromere	ALR/Alpha	Satellite	centr
chr7:14315871-14316027	centromere	ALR/Alpha	Satellite	centr
chr7:143573164-143573320	centromere	ALR/Alpha	Satellite	centr
chr7:143756156-143756312	centromere	ALR/Alpha	Satellite	centr
chr7:144267748-144267904	centromere	ALR/Alpha	Satellite	centr
chr7:146604616-146604772	centromere	ALR/Alpha	Satellite	centr
chr7:146822990-146823156	centromere	ALR/Alpha	Satellite	centr
chr7:14709500-14709656	centromere	ALR/Alpha	Satellite	centr
chr7:154457543-154457699	centromere	ALR/Alpha	Satellite	centr
chr7:25925447-25925603	centromere	ALR/Alpha	Satellite	centr
chr7:40949199-40949355	centromere	ALR/Alpha	Satellite	centr
chr7:54310915-54311071	centromere	ALR/Alpha	Satellite	centr
chr7:58059988-58060159	centromere	ALR/Alpha	Satellite	centr
chr7:58196713-58196869	centromere	ALR/Alpha	Satellite	centr
chr7:58208251-58208407	centromere	ALR/Alpha	Satellite	centr
chr7:58228007-58228199	centromere	ALR/Alpha	Satellite	centr
chr7:58257939-58258095	centromere	ALR/Alpha	Satellite	centr
chr7:58267831-58268059	centromere	ALR/Alpha	Satellite	centr
chr7:58269485-58269659	centromere	ALR/Alpha	Satellite	centr
chr7:58281902-58282058	centromere	ALR/Alpha	Satellite	centr
chr7:58295882-58296038	centromere	ALR/Alpha	Satellite	centr
chr7:58316155-58316361	centromere	ALR/Alpha	Satellite	centr
chr7:58331558-58331734	centromere	ALR/Alpha	Satellite	centr
chr7:58349855-58350021	centromere	ALR/Alpha	Satellite	centr
chr7:58350320-58350477	centromere	ALR/Alpha	Satellite	centr
chr7:58361204-58361360	centromere	ALR/Alpha	Satellite	centr
chr7:58363597-58363822	centromere	ALR/Alpha	Satellite	centr
chr7:58376242-58376402	centromere	ALR/Alpha	Satellite	centr
chr7:58412890-58413046	centromere	ALR/Alpha	Satellite	centr
chr7:58427997-58428209	centromere	ALR/Alpha	Satellite	centr
chr7:58452962-58453118	centromere	ALR/Alpha	Satellite	centr
chr7:58454065-58454221	centromere	ALR/Alpha	Satellite	centr
chr7:58481384-58481540	centromere	ALR/Alpha	Satellite	centr
chr7:58520405-58520561	centromere	ALR/Alpha	Satellite	centr
chr7:58522541-58522701	centromere	ALR/Alpha	Satellite	centr
chr7:58529331-58529512	centromere	ALR/Alpha	Satellite	centr
chr7:58569578-58569762	centromere	ALR/Alpha	Satellite	centr
chr7:58614746-58614902	centromere	ALR/Alpha	Satellite	centr
chr7:58615680-58615863	centromere	ALR/Alpha	Satellite	centr
chr7:58615933-58616090	centromere	ALR/Alpha	Satellite	centr
chr7:58631490-58631646	centromere	ALR/Alpha	Satellite	centr
chr7:58633004-58633160	centromere	ALR/Alpha	Satellite	centr
chr7:58633281-58633647	centromere	ALR/Alpha	Satellite	centr
chr7:58638378-58638534	centromere	ALR/Alpha	Satellite	centr
chr7:58643603-58643842	centromere	ALR/Alpha	Satellite	centr
chr7:58657419-58657628	centromere	ALR/Alpha	Satellite	centr
chr7:58697886-58698042	centromere	ALR/Alpha	Satellite	centr
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chr7:58704977-58705145	centromere	ALR/Alpha	Satellite	centr
chr7:58705483-58705737	centromere	ALR/Alpha	Satellite	centr
chr7:58749458-58749614	centromere	ALR/Alpha	Satellite	centr
chr7:58771014-58771201	centromere	ALR/Alpha	Satellite	centr
chr7:58838349-58838505	centromere	ALR/Alpha	Satellite	centr
chr7:58854202-58854358	centromere	ALR/Alpha	Satellite	centr
chr7:58926595-58926751	centromere	ALR/Alpha	Satellite	centr
chr7:58928246-58928423	centromere	ALR/Alpha	Satellite	centr
chr7:58934472-58934772	centromere	ALR/Alpha	Satellite	centr
chr7:58936625-58936836	centromere	ALR/Alpha	Satellite	centr
chr7:58937163-58937345	centromere	ALR/Alpha	Satellite	centr
chr7:58938008-58938292	centromere	ALR/Alpha	Satellite	centr
chr7:58946231-58946387	centromere	ALR/Alpha	Satellite	centr
chr7:58957937-58958190	centromere	ALR/Alpha	Satellite	centr
chr7:58992804-58992968	centromere	ALR/Alpha	Satellite	centr
chr7:59005038-59005214	centromere	ALR/Alpha	Satellite	centr
chr7:59021377-59021533	centromere	ALR/Alpha	Satellite	centr
chr7:59023215-59023386	centromere	ALR/Alpha	Satellite	centr
chr7:59032453-59032844	centromere	ALR/Alpha	Satellite	centr
	intergenic	L1PA2	LINE	L1

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chr7:59042992-59043148	gene	L1HS	LINE	L1
chr7:59061751-59061907	gene	L1PA2	LINE	L1
chr7:59063313-59063469	gene	L1PA2	LINE	L1
chr7:59078847-59079003	centromere	ALR/Alpha	Satellite	centr
chr7:59158003-59158159	intergenic	L1PA6	LINE	L1
chr7:59167478-59167704	intergenic	L1PA4	LINE	L1
chr7:59260617-59260779	intergenic	L1PA4	LINE	L1
chr7:59275007-59275213	intergenic	L1PA4	LINE	L1
chr7:59293424-59293695	intergenic	L1PA3	LINE	L1
chr7:59321962-59322118	intergenic	L1PA3	LINE	L1
chr7:59329153-59329473	intergenic	L1PA2	LINE	L1
chr7:59371643-59372063	intergenic	L1PA3	LINE	L1
chr7:59393680-59393848	intergenic	L1PA3	LINE	L1
chr7:59433749-59433905	gene	L1HS	LINE	L1
chr7:59443726-59444035	centromere	ALR/Alpha	Satellite	centr
chr7:59466273-59466463	intergenic	L1PA3	LINE	L1
chr7:59483927-59484105	intergenic	L1PA3	LINE	L1
chr7:59490147-59490303	intergenic	L1PA4	LINE	L1
chr7:59490645-59490801	intergenic	L1P1	LINE	L1
chr7:59491164-59491326	gene	L1PA3	LINE	L1
chr7:59508574-59508730	intergenic	L1PA3	LINE	L1
chr7:59525964-59526250	gene	L1PA2	LINE	L1
chr7:59531121-59531277	intergenic	L1PA2	LINE	L1
chr7:59551140-59551296	gene	L1PA4	LINE	L1
chr7:59554594-59554921	centromere	ALR/Alpha	Satellite	centr
chr7:59576234-59576451	intergenic	L1PA3	LINE	L1
chr7:59586300-59586456	intergenic	L1PA3	LINE	L1
chr7:59607175-59607331	intergenic	L1PA4	LINE	L1
chr7:59624918-59625139	intergenic	L1HS	LINE	L1
chr7:59631760-59631916	intergenic	L1PA3	LINE	L1
chr7:59653526-59653682	intergenic	L1PA3	LINE	L1
chr7:59671721-59671947	intergenic	L1PA4	LINE	L1
chr7:59674444-59674600	intergenic	L1PA3	LINE	L1
chr7:59678327-59678555	intergenic	L1HS	LINE	L1
chr7:59680453-59680609	centromere	ALR/Alpha	Satellite	centr
chr7:59703906-59704109	gene	L1PA3	LINE	L1
chr7:59713209-59713372	intergenic	L1PA6	LINE	L1
chr7:59718376-59718548	intergenic	L1PA4	LINE	L1
chr7:59726553-59726728	intergenic	MIRb	SINE	MIR
chr7:59732673-59732829	intergenic	L1PA4	LINE	L1
chr7:59743499-59743655	intergenic	L1PA4	LINE	L1
chr7:59780549-59780705	gene	L1PA4	LINE	L1
chr7:59798680-59798836	intergenic	L1PA3	LINE	L1
chr7:59813915-59814071	gene	L1PA3	LINE	L1
chr7:59827959-59828189	intergenic	norepeat	nofamily	noclass
chr7:59836666-59836884	centromere	ALR/Alpha	Satellite	centr
chr7:59850382-59850589	centromere	ALR/Alpha	Satellite	centr
chr7:59871491-59871647	gene	L1P1	LINE	L1
chr7:59872412-59872570	gene	L1PA5	LINE	L1
chr7:59879396-59879573	gene	L1PA3	LINE	L1
chr7:59901825-59901981	subtelomere	(TTAGGG)n	Simple_repeat	Simple_repeat
chr7:59933887-59934043	Unplaced_chr	L1PA6	LINE	L1
chr7:59934586-59934749	intergenic	L1PA2	LINE	L1
chr7:59942114-59942270	intergenic	L1PA3	LINE	L1
chr7:59943507-59943734	pericentromere	(ATTCC)n	Simple_repeat	Simple_repeat
chr7:59974350-59974506	centromere	ALR/Alpha	Satellite	centr
chr7:59996387-59996677	intergenic	(ATTCC)n	Simple_repeat	Simple_repeat
chr7:60004098-60004260	intergenic	(GAATG)n	Satellite/Simple_repeat	Satellite/Simple_repeat
chr7:60006270-60006426	intergenic	L1PA2	LINE	L1
chr7:60046838-60047056	gene	L1HS	LINE	L1
chr7:60068793-60068949	pericentromere	(AATGGAATGG)n	Simple_repeat	Simple_repeat
chr7:60078558-60078795	pericentromere	(AATGGAATGG)n	Simple_repeat	Simple_repeat
chr7:60115169-60115337	pericentromere	(AATGGAATGG)n	Simple_repeat	Simple_repeat
chr7:60157696-60157920	pericentromere	(AATGGAATGG)n	Simple_repeat	Simple_repeat
chr7:60181860-60182018	pericentromere	(AATGGAATGG)n	Simple_repeat	Simple_repeat
chr7:60182490-60182704	centromere	ALR/Alpha	Satellite	centr
chr7:60257100-60257256	pericentromere	(AATGGAATGG)n	Simple_repeat	Simple_repeat
chr7:60369053-60369209	pericentromere	(AATGGAATGG)n	Simple_repeat	Simple_repeat
chr7:60396020-60396177	pericentromere	(AATGGAATGG)n	Simple_repeat	Simple_repeat
chr7:60396966-60397215	pericentromere	(AATGGAATGG)n	Simple_repeat	Simple_repeat
chr7:60420034-60420190	pericentromere	(AATGGAATGG)n	Simple_repeat	Simple_repeat
chr7:60426240-60426396	pericentromere	(AATGGAATGG)n	Simple_repeat	Simple_repeat
chr7:60467841-60468018	pericentromere	(AATGGAATGG)n	Simple_repeat	Simple_repeat
chr7:60468949-60469140	pericentromere	(AATGGAATGG)n	Simple_repeat	Simple_repeat
chr7:60470440-60470596	pericentromere	(AATGGAATGG)n	Simple_repeat	Simple_repeat
chr7:60499607-60499855	pericentromere	(AATGGAATGG)n	Simple_repeat	Simple_repeat
chr7:60506218-60506417	centromere	ALR/Alpha	Satellite	centr
chr7:60518143-60518309	pericentromere	(AATGGAATGG)n	Simple_repeat	Simple_repeat
chr7:60526717-60526873	subtelomere	(TTAGGG)n	Simple_repeat	Simple_repeat
chr7:60531510-60531666	centromere	ALR/Alpha	Satellite	centr
chr7:60567671-60567830	centromere	ALR/Alpha	Satellite	centr
chr7:60582826-60582982	centromere	ALR/Alpha	Satellite	centr
chr7:60598292-60598463	centromere	ALR/Alpha	Satellite	centr
chr7:60600754-60600989	centromere	ALR/Alpha	Satellite	centr
chr7:60619301-60619467	centromere	ALR/Alpha	Satellite	centr
chr7:60648734-60648932	centromere	ALR/Alpha	Satellite	centr
chr7:60660353-60660624	centromere	ALR/Alpha	Satellite	centr
chr7:60667111-60667331	centromere	ALR/Alpha	Satellite	centr
chr7:60668634-60668791	centromere	ALR/Alpha	Satellite	centr
chr7:60670130-60670359	centromere	ALR/Alpha	Satellite	centr
chr7:60675590-60675969	centromere	ALR/Alpha	Satellite	centr
chr7:60701109-60701272	centromere	ALR/Alpha	Satellite	centr
chr7:60741990-60742146	centromere	ALR/Alpha	Satellite	centr
chr7:60773928-60774096	centromere	ALR/Alpha	Satellite	centr
chr7:60788065-60788270	centromere	ALR/Alpha	Satellite	centr
chr7:60798044-60798219	centromere	ALR/Alpha	Satellite	centr
chr7:60800912-60801081	centromere	ALR/Alpha	Satellite	centr
chr7:60803014-60803181	centromere	ALR/Alpha	Satellite	centr
chr7:61071191-61071412	centromere	ALR/Alpha	Satellite	centr

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chr7:61155503-61155659	centromere	ALR/Alpha	Satellite	centr
chr7:61160301-61160529	centromere	ALR/Alpha	Satellite	centr
chr7:61173923-61174218	centromere	ALR/Alpha	Satellite	centr
chr7:61177487-61177643	centromere	ALR/Alpha	Satellite	centr
chr7:61178259-61178415	centromere	ALR/Alpha	Satellite	centr
chr7:61207535-61207691	centromere	ALR/Alpha	Satellite	centr
chr7:61380690-61380871	centromere	ALR/Alpha	Satellite	centr
chr7:61402570-61402745	centromere	ALR/Alpha	Satellite	centr
chr7:61416202-61416395	centromere	ALR/Alpha	Satellite	centr
chr7:61418270-61418522	centromere	ALR/Alpha	Satellite	centr
chr7:61421110-61421362	centromere	ALR/Alpha	Satellite	centr
chr7:61427340-61427550	centromere	ALR/Alpha	Satellite	centr
chr7:61433609-61433811	centromere	ALR/Alpha	Satellite	centr
chr7:61441032-61441212	centromere	ALR/Alpha	Satellite	centr
chr7:61457453-61457611	centromere	ALR/Alpha	Satellite	centr
chr7:61468393-61468550	centromere	ALR/Alpha	Satellite	centr
chr7:61477319-61477496	centromere	ALR/Alpha	Satellite	centr
chr7:61481463-61481720	centromere	ALR/Alpha	Satellite	centr
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chr7:63934115-63934271	centromere	ALR/Alpha	Satellite	centr
chr7:65420066-65420222	centromere	ALR/Alpha	Satellite	centr
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chr7:89277832-89277991	centromere	ALR/Alpha	Satellite	centr
chr7:91586905-91587061	centromere	ALR/Alpha	Satellite	centr
chr7:93744943-93745162	centromere	ALR/Alpha	Satellite	centr
chr7:93789780-93789960	centromere	ALR/Alpha	Satellite	centr
chr8:100856447-100856609	centromere	ALR/Alpha	Satellite	centr
chr8:105367342-105367753	centromere	ALR/Alpha	Satellite	centr
chr8:106113605-106113761	centromere	ALR/Alpha	Satellite	centr
chr8:106488587-106488850	centromere	ALR/Alpha	Satellite	centr
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chr8:111635810-111635966	centromere	ALR/Alpha	Satellite	centr
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chr8:129328452-129328608	centromere	ALR/Alpha	Satellite	centr
chr8:140292895-140293051	centromere	ALR/Alpha	Satellite	centr
chr8:17307237-17307393	centromere	ALR/Alpha	Satellite	centr
chr8:18597937-18598131	centromere	ALR/Alpha	Satellite	centr
chr8:20746835-20746991	centromere	ALR/Alpha	Satellite	centr
chr8:34037645-34037823	centromere	ALR/Alpha	Satellite	centr
chr8:44052686-44052844	centromere	ALR/Alpha	Satellite	centr
chr8:44062341-44062509	centromere	ALR/Alpha	Satellite	centr
chr8:44096719-44096875	centromere	ALR/Alpha	Satellite	centr
chr8:44110687-44110843	centromere	ALR/Alpha	Satellite	centr
chr8:44110921-44111077	centromere	ALR/Alpha	Satellite	centr
chr8:44124186-44124342	centromere	ALR/Alpha	Satellite	centr
chr8:44136740-44136896	centromere	ALR/Alpha	Satellite	centr
chr8:44190904-44191089	centromere	ALR/Alpha	Satellite	centr
chr8:44330989-44331145	centromere	ALR/Alpha	Satellite	centr
chr8:44333469-44333750	centromere	ALR/Alpha	Satellite	centr
chr8:44361621-44361817	intergenic	norepeat	nofamily	noclass
chr8:44411937-44412093	centromere	ALR/Alpha	Satellite	centr
chr8:44502436-44502592	centromere	ALR/Alpha	Satellite	centr
chr8:44503334-44503545	centromere	ALR/Alpha	Satellite	centr
chr8:44503813-44503969	centromere	ALR/Alpha	Satellite	centr
chr8:44510537-44510704	centromere	ALR/Alpha	Satellite	centr
chr8:44513605-44513796	pericentromere	norepeat	nofamily	noclass
chr8:44517883-44518108	pericentromere	norepeat	nofamily	noclass
chr8:44543550-44543721	pericentromere	norepeat	nofamily	noclass
chr8:44553665-44553839	pericentromere	norepeat	nofamily	noclass
chr8:44576648-44576804	pericentromere	norepeat	nofamily	noclass
chr8:44585349-44585505	centromere	ALR/Alpha	Satellite	centr
chr8:44586732-44586890	pericentromere	norepeat	nofamily	noclass
chr8:44633137-44633293	pericentromere	norepeat	nofamily	noclass
chr8:44646464-44646620	pericentromere	norepeat	nofamily	noclass
chr8:44657935-44658091	pericentromere	(ATGGA)n	Simple_repeat	Simple_repeat
chr8:44696735-44696891	pericentromere	(ATGGA)n	Simple_repeat	Simple_repeat
chr8:44772028-44772208	pericentromere	(ATGGA)n	Simple_repeat	Simple_repeat
chr8:44783323-44783532	pericentromere	(AATGG)n	Simple_repeat	Simple_repeat
chr8:44809623-44809783	pericentromere	(AATGG)n	Simple_repeat	Simple_repeat
chr8:44823986-44824158	pericentromere	norepeat	nofamily	noclass
chr8:44868432-44868738	centromere	ALR/Alpha	Satellite	centr
chr8:44893240-44893501	pericentromere	(ATCAAAATGGA)n	Simple_repeat	Simple_repeat
chr8:44933804-44933960	pericentromere	norepeat	nofamily	noclass
chr8:44956081-44956237	pericentromere	norepeat	nofamily	noclass
chr8:44979674-44979867	pericentromere	norepeat	nofamily	noclass
chr8:44993157-44993334	pericentromere	norepeat	nofamily	noclass
chr8:44995512-44995681	pericentromere	norepeat	nofamily	noclass
chr8:45003695-45003973	pericentromere	norepeat	nofamily	noclass
chr8:45012741-45012904	pericentromere	norepeat	nofamily	noclass
chr8:45052728-45052884	pericentromere	norepeat	nofamily	noclass
chr8:45053146-45053302	centromere	ALR/Alpha	Satellite	centr
chr8:45056142-45056298	pericentromere	norepeat	nofamily	noclass
chr8:45072137-45072340	pericentromere	norepeat	nofamily	noclass
chr8:45074812-45075000	pericentromere	(ATCGAATGGAATC)n	Simple_repeat	Simple_repeat
chr8:45078425-45078678	pericentromere	norepeat	nofamily	noclass

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chr8:45085575-45085797	pericentromere	norepeat	nofamily	noclass
chr8:45099792-45099990	pericentromere	norepeat	nofamily	noclass
chr8:45153412-45153568	pericentromere	norepeat	nofamily	noclass
chr8:45159698-45160050	pericentromere	norepeat	nofamily	noclass
chr8:45167335-45167491	pericentromere	norepeat	nofamily	noclass
chr8:45197705-45197861	pericentromere	norepeat	nofamily	noclass
chr8:45208761-45208917	centromere	ALR/Alpha	Satellite	centr
chr8:45218880-45219036	pericentromere	norepeat	nofamily	noclass
chr8:45292266-45292541	pericentromere	norepeat	nofamily	noclass
chr8:45327530-45327728	pericentromere	norepeat	nofamily	noclass
chr8:45330948-45331104	pericentromere	norepeat	nofamily	noclass
chr8:45349831-45350188	pericentromere	norepeat	nofamily	noclass
chr8:45361409-45361565	pericentromere	(GAATGGAATC)n	Simple_repeat	Simple_repeat
chr8:45378448-45378733	pericentromere	norepeat	nofamily	noclass
chr8:45395614-45395770	pericentromere	norepeat	nofamily	noclass
chr8:45397129-45397285	pericentromere	norepeat	nofamily	noclass
chr8:45415398-45415572	pericentromere	norepeat	nofamily	noclass
chr8:45483557-45483713	centromere	ALR/Alpha	Satellite	centr
chr8:45483895-45484051	pericentromere	norepeat	nofamily	noclass
chr8:45496339-45496499	pericentromere	norepeat	nofamily	noclass
chr8:45502261-45502493	pericentromere	norepeat	nofamily	noclass
chr8:45538148-45538344	gene	L1PA2	LINE	L1
chr8:45539436-45539592	intergenic	L1P1	LINE	L1
chr8:45601526-45601825	gene	norepeat	nofamily	noclass
chr8:45717486-45717762	gene	L1PA5	LINE	L1
chr8:45749022-45749178	gene	L1PA5	LINE	L1
chr8:45766773-45766929	intergenic	CR1-3_Croc	LINE	CR1
chr8:45780241-45780459	gene	L1PA2	LINE	L1
chr8:45805084-45805240	centromere	ALR/Alpha	Satellite	centr
chr8:45816153-45816321	intergenic	L1PA3	LINE	L1
chr8:45826311-45826528	intergenic	L1PA2	LINE	L1
chr8:45833660-45833816	gene	AluJr	SINE	Alu
chr8:46733406-46733562	gene	norepeat	nofamily	noclass
chr8:48338087-48338243	Unplaced_chr	norepeat	nofamily	noclass
chr8:48943834-48943990	Unplaced_chr	norepeat	nofamily	noclass
chr8:50486159-50486315	gene	L1PA3	LINE	L1
chr8:55639898-55640054	gene	L1PA3	LINE	L1
chr8:57158844-57159000	gene	MER51-int	LTR	ERV1
chr8:59542286-59542565	gene	L1PA3	LINE	L1
chr8:61482927-61483197	centromere	ALR/Alpha	Satellite	centr
chr8:66025807-66026004	gene	L1PA7	LINE	L1
chr8:66064184-66064340	gene	L1PA3	LINE	L1
chr8:69690042-69690366	gene	L1PA3	LINE	L1
chr8:76425451-76425615	gene	L1PA2	LINE	L1
chr8:78927587-78927743	intergenic	L1P1	LINE	L1
chr8:84388051-84388207	intergenic	L1PA4	LINE	L1
chr8:84466194-84466424	gene	L1PA3	LINE	L1
chr8:87390089-87390245	gene	L1PA3	LINE	L1
chr8:88151509-88151665	gene	LIHS	LINE	L1
chr8:91562451-91562629	centromere	ALR/Alpha	Satellite	centr
chr8:91796494-91796668	gene	LIHS	LINE	L1
chr8:91871107-91871263	intergenic	L1PA3	LINE	L1
chr8:9198305-9198461	gene	L1PA3	LINE	L1
chr8:9446764-9446920	intergenic	L1PA2	LINE	L1
chr8:9554526-95544682	pericentromere	L1PA3	LINE	L1
chr8:98288440-98288596	centromere	ALR/Alpha	Satellite	centr
chr8:98584930-98585086	centromere	ALR/Alpha	Satellite	centr
chr8_K127081v1_alt:151600-151786	centromere	ALR/Alpha	Satellite	centr
chr8_K127090v1_alt:28411-28625	centromere	ALR/Alpha	Satellite	centr
chr9:10137326-10137482	centromere	ALR/Alpha	Satellite	centr
chr9:102170451-102170607	centromere	ALR/Alpha	Satellite	centr
chr9:105578578-105578802	centromere	ALR/Alpha	Satellite	centr
chr9:111201176-111201332	centromere	ALR/Alpha	Satellite	centr
chr9:116501412-116501568	centromere	ALR/Alpha	Satellite	centr
chr9:125814164-125814320	centromere	ALR/Alpha	Satellite	centr
chr9:126994764-126994920	centromere	ALR/Alpha	Satellite	centr
chr9:132529013-132529169	centromere	ALR/Alpha	Satellite	centr
chr9:137608405-137608563	centromere	ALR/Alpha	Satellite	centr
chr9:13998835-13998991	gene	LIHS	LINE	L1
chr9:14874344-14874546	centromere	ALR/Alpha	Satellite	centr
chr9:16467394-16467550	centromere	ALR/Alpha	Satellite	centr
chr9:1779381-1779537	centromere	ALR/Alpha	Satellite	centr
chr9:17923689-17923871	centromere	ALR/Alpha	Satellite	centr
chr9:19536601-19536757	centromere	ALR/Alpha	Satellite	centr
chr9:21537841-21537997	centromere	ALR/Alpha	Satellite	centr
chr9:21911061-21911217	centromere	ALR/Alpha	Satellite	centr
chr9:22488017-22488173	centromere	ALR/Alpha	Satellite	centr
chr9:32212699-32212855	centromere	ALR/Alpha	Satellite	centr
chr9:40807578-40807734	centromere	ALR/Alpha	Satellite	centr
chr9:40808222-40808378	centromere	ALR/Alpha	Satellite	centr
chr9:40814219-40814375	centromere	ALR/Alpha	Satellite	centr
chr9:43318960-43319116	centromere	ALR/Alpha	Satellite	centr
chr9:43397818-43397974	centromere	ALR/Alpha	Satellite	centr
chr9:43422382-43422538	centromere	ALR/Alpha	Satellite	centr
chr9:43442240-43442396	centromere	ALR/Alpha	Satellite	centr
chr9:43446232-43446488	centromere	ALR/Alpha	Satellite	centr
chr9:43500479-43500735	centromere	ALR/Alpha	Satellite	centr
chr9:43512128-43512384	centromere	ALR/Alpha	Satellite	centr
chr9:43522027-43522183	centromere	ALR/Alpha	Satellite	centr
chr9:43578901-43579057	centromere	ALR/Alpha	Satellite	centr
chr9:43597075-43597231	centromere	ALR/Alpha	Satellite	centr
chr9:43665864-43666020	centromere	ALR/Alpha	Satellite	centr
chr9:43673229-43673485	centromere	ALR/Alpha	Satellite	centr
chr9:43695732-43695988	centromere	ALR/Alpha	Satellite	centr
chr9:43757738-43757894	centromere	ALR/Alpha	Satellite	centr
chr9:43782595-43782751	centromere	ALR/Alpha	Satellite	centr
chr9:43810285-43810441	centromere	ALR/Alpha	Satellite	centr
chr9:43811569-43811725	centromere	ALR/Alpha	Satellite	centr
chr9:43833576-43833732	centromere	ALR/Alpha	Satellite	centr

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chr9:43924776-43924949	centromere	ALR/Alpha	Satellite	centr
chr9:43937808-43937964	centromere	ALR/Alpha	Satellite	centr
chr9:43983545-43983721	centromere	ALR/Alpha	Satellite	centr
chr9:44178332-44178499	centromere	ALR/Alpha	Satellite	centr
chr9:44195859-44196053	centromere	ALR/Alpha	Satellite	centr
chr9:44251944-44252100	centromere	ALR/Alpha	Satellite	centr
chr9:44271931-44272087	centromere	ALR/Alpha	Satellite	centr
chr9:44316315-44316471	centromere	ALR/Alpha	Satellite	centr
chr9:44321751-44321944	centromere	ALR/Alpha	Satellite	centr
chr9:44351299-44351455	centromere	ALR/Alpha	Satellite	centr
chr9:44392630-44392786	centromere	ALR/Alpha	Satellite	centr
chr9:44492002-44492158	centromere	ALR/Alpha	Satellite	centr
chr9:44526263-44526419	centromere	ALR/Alpha	Satellite	centr
chr9:44571874-44572030	centromere	ALR/Alpha	Satellite	centr
chr9:44634167-44634323	centromere	ALR/Alpha	Satellite	centr
chr9:44656673-44656846	centromere	ALR/Alpha	Satellite	centr
chr9:44703472-44703685	centromere	ALR/Alpha	Satellite	centr
chr9:44777061-44777217	centromere	ALR/Alpha	Satellite	centr
chr9:44818883-44819092	centromere	ALR/Alpha	Satellite	centr
chr9:44900486-44900642	centromere	ALR/Alpha	Satellite	centr
chr9:44906303-44906459	centromere	ALR/Alpha	Satellite	centr
chr9:44908458-44908722	centromere	ALR/Alpha	Satellite	centr
chr9:44941166-44941322	centromere	ALR/Alpha	Satellite	centr
chr9:44988161-44988317	centromere	ALR/Alpha	Satellite	centr
chr9:44991084-44991272	centromere	ALR/Alpha	Satellite	centr
chr9:44994147-44994388	centromere	ALR/Alpha	Satellite	centr
chr9:45037087-45037243	centromere	ALR/Alpha	Satellite	centr
chr9:45137884-45138040	centromere	ALR/Alpha	Satellite	centr
chr9:45142041-45142197	centromere	ALR/Alpha	Satellite	centr
chr9:45188401-45188605	centromere	ALR/Alpha	Satellite	centr
chr9:45276228-45276497	centromere	ALR/Alpha	Satellite	centr
chr9:45281173-45281372	centromere	ALR/Alpha	Satellite	centr
chr9:45292799-45293081	centromere	ALR/Alpha	Satellite	centr
chr9:45339868-45340047	centromere	ALR/Alpha	Satellite	centr
chr9:45363231-45363411	centromere	ALR/Alpha	Satellite	centr
chr9:45379670-45379930	centromere	ALR/Alpha	Satellite	centr
chr9:45395164-45395389	centromere	ALR/Alpha	Satellite	centr
chr9:45405272-45405428	centromere	ALR/Alpha	Satellite	centr
chr9:45476037-45476193	centromere	ALR/Alpha	Satellite	centr
chr9:45481781-45481967	centromere	ALR/Alpha	Satellite	centr
chr9:45500340-45500539	centromere	ALR/Alpha	Satellite	centr
chr9:45503405-45503561	centromere	ALR/Alpha	Satellite	centr
chr9:4948688-4948844	centromere	ALR/Alpha	Satellite	centr
chr9:65709554-65709710	centromere	ALR/Alpha	Satellite	centr
chr9:69480851-69481150	intergenic	L1PA3	LINE	L1
chr9:69680384-69680540	intergenic	L1PA3	LINE	L1
chr9:70038205-70038362	intergenic	L1PA5	LINE	L1
chr9:70628822-70628978	gene	L1PA2	LINE	L1
chr9:85072337-85072557	gene	L1PA2	LINE	L1
chr9:86378870-86379026	gene	L1PA3	LINE	L1
chr9:94089371-94089527	intergenic	L1PA3	LINE	L1
chr9:95257989-95258145	centromere	ALR/Alpha	Satellite	centr
chr9:95703138-95703317	intergenic	L1PA4	LINE	L1
chr9:97209835-97210041	intergenic	L1PA2	LINE	L1
chrUn_GL000216v2:149531-149687	gene	L1PA2	LINE	L1
chrUn_GL000216v2:168617-168854	gene	L1PA2	LINE	L1
chrUn_GL000216v2:17959-18115	gene	(CT)n	Simple_repeat	Simple_repeat
chrUn_GL000216v2:80035-80446	intergenic	L1PA4	LINE	L1
chrUn_GL000220v1:117024-117221	intergenic	L1PA2	LINE	L1
chrUn_GL000220v1:160993-161206	intergenic	L1PA3	LINE	L1
chrUn_GL000226v1:1399-1636	gene	L1PA2	LINE	L1
chrUn_GL000226v1:14488-14659	intergenic	L1PA3	LINE	L1
chrUn_GL000226v1:4340-4518	centromere	ALR/Alpha	Satellite	centr
chrUn_K1270334v1:114-282	gene	L1PA4	LINE	L1
chrUn_K1270340v1:1226-1382	gene	L1PA4	LINE	L1
chrUn_K1270394v1:601-757	intergenic	L1PA2	LINE	L1
chrUn_K1270438v1:104598-104981	subtelomere	(CTAACC)n	Simple_repeat	Simple_repeat
chrUn_K1270438v1:109347-109759	intergenic	norepeat	noclass	noclass
chrX:104146619-104146775	gene	norepeat	noclass	noclass
chrX:106382957-106383150	intergenic	norepeat	noclass	noclass
chrX:107159060-107159216	intergenic	L1PA4	LINE	L1
chrX:109058279-109058435	gene	L1PA4	LINE	L1
chrX:111964686-111964842	intergenic	L1PA4	LINE	L1
chrX:113449512-113449668	gene	L1PA4	LINE	L1
chrX:116312525-116312681	centromere	ALR/Alpha	Satellite	centr
chrX:117556578-117556734	intergenic	L1PA3	LINE	L1
chrX:11935590-11935746	intergenic	L1PA3	LINE	L1
chrX:121264092-121264248	centromere	ALR/Alpha	Satellite	centr
chrX:121534256-121534412	centromere	ALR/Alpha	Satellite	centr
chrX:121878842-121878998	centromere	ALR/Alpha	Satellite	centr
chrX:127161169-127161325	centromere	ALR/Alpha	Satellite	centr
chrX:127218711-127218878	centromere	ALR/Alpha	Satellite	centr
chrX:127366330-127366486	centromere	ALR/Alpha	Satellite	centr
chrX:131380933-131381089	centromere	ALR/Alpha	Satellite	centr
chrX:131992482-131992638	centromere	ALR/Alpha	Satellite	centr
chrX:133110476-133110632	centromere	ALR/Alpha	Satellite	centr
chrX:133230311-133230467	centromere	ALR/Alpha	Satellite	centr
chrX:134119019-134119175	centromere	ALR/Alpha	Satellite	centr
chrX:135757618-135757774	centromere	ALR/Alpha	Satellite	centr
chrX:136297134-136297392	centromere	ALR/Alpha	Satellite	centr
chrX:137075238-137075394	centromere	ALR/Alpha	Satellite	centr
chrX:138780947-138781103	centromere	ALR/Alpha	Satellite	centr
chrX:140411879-140412307	centromere	ALR/Alpha	Satellite	centr
chrX:150103822-150103978	centromere	ALR/Alpha	Satellite	centr
chrX:151656886-151657042	centromere	ALR/Alpha	Satellite	centr
chrX:154941894-154942188	centromere	ALR/Alpha	Satellite	centr
chrX:156030294-156030707	centromere	ALR/Alpha	Satellite	centr
chrX:17571794-17571958	centromere	ALR/Alpha	Satellite	centr
chrX:1764289-1764445	centromere	ALR/Alpha	Satellite	centr

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chrX:29582734-29582890	centromere	ALR/Alpha	Satellite	centr
chrX:29598212-29598368	centromere	ALR/Alpha	Satellite	centr
chrX:30326180-30326336	centromere	ALR/Alpha	Satellite	centr
chrX:32447240-32447396	centromere	ALR/Alpha	Satellite	centr
chrX:47669482-47669638	centromere	ALR/Alpha	Satellite	centr
chrX:49939173-49939329	centromere	ALR/Alpha	Satellite	centr
chrX:51247143-51247352	centromere	ALR/Alpha	Satellite	centr
chrX:52883550-52883706	centromere	ALR/Alpha	Satellite	centr
chrX:54668621-54668777	centromere	ALR/Alpha	Satellite	centr
chrX:54699198-54699380	centromere	ALR/Alpha	Satellite	centr
chrX:54905219-54905375	centromere	ALR/Alpha	Satellite	centr
chrX:58134555-58134730	centromere	ALR/Alpha	Satellite	centr
chrX:58634346-58634720	centromere	ALR/Alpha	Satellite	centr
chrX:58671134-58671290	centromere	ALR/Alpha	Satellite	centr
chrX:58680558-58680756	centromere	ALR/Alpha	Satellite	centr
chrX:58682332-58682488	centromere	ALR/Alpha	Satellite	centr
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chrX:58708485-58708641	centromere	ALR/Alpha	Satellite	centr
chrX:58733646-58733819	centromere	ALR/Alpha	Satellite	centr
chrX:58757333-58757489	centromere	ALR/Alpha	Satellite	centr
chrX:58766217-58766373	centromere	ALR/Alpha	Satellite	centr
chrX:58781121-58781302	centromere	ALR/Alpha	Satellite	centr
chrX:58783419-58783575	centromere	ALR/Alpha	Satellite	centr
chrX:58821655-58821811	centromere	ALR/Alpha	Satellite	centr
chrX:58838553-58838776	centromere	ALR/Alpha	Satellite	centr
chrX:58943851-58944007	centromere	ALR/Alpha	Satellite	centr
chrX:58950419-58950575	centromere	ALR/Alpha	Satellite	centr
chrX:58955801-58955957	centromere	ALR/Alpha	Satellite	centr
chrX:58980347-58980503	centromere	ALR/Alpha	Satellite	centr
chrX:58996994-58997150	centromere	ALR/Alpha	Satellite	centr
chrX:58999785-58999941	centromere	ALR/Alpha	Satellite	centr
chrX:59002054-59002210	centromere	ALR/Alpha	Satellite	centr
chrX:59040623-59040781	centromere	ALR/Alpha	Satellite	centr
chrX:59047093-59047352	centromere	ALR/Alpha	Satellite	centr
chrX:59090930-59091086	centromere	ALR/Alpha	Satellite	centr
chrX:59097786-59097989	centromere	ALR/Alpha	Satellite	centr
chrX:59114046-59114264	centromere	ALR/Alpha	Satellite	centr
chrX:59136757-59136967	centromere	ALR/Alpha	Satellite	centr
chrX:59140344-59140500	centromere	ALR/Alpha	Satellite	centr
chrX:59155372-59155528	centromere	ALR/Alpha	Satellite	centr
chrX:59174783-59174956	centromere	ALR/Alpha	Satellite	centr
chrX:59175318-59175496	centromere	ALR/Alpha	Satellite	centr
chrX:59184321-59184477	centromere	ALR/Alpha	Satellite	centr
chrX:59205412-59205620	centromere	ALR/Alpha	Satellite	centr
chrX:59226903-59227118	centromere	ALR/Alpha	Satellite	centr
chrX:59244270-59244426	centromere	ALR/Alpha	Satellite	centr
chrX:59269255-59269411	centromere	ALR/Alpha	Satellite	centr
chrX:59283041-59283212	centromere	ALR/Alpha	Satellite	centr
chrX:59313514-59313730	centromere	ALR/Alpha	Satellite	centr
chrX:59316249-59316411	centromere	ALR/Alpha	Satellite	centr
chrX:59327129-59327297	centromere	ALR/Alpha	Satellite	centr
chrX:59344604-59344760	centromere	ALR/Alpha	Satellite	centr
chrX:59348714-59348924	centromere	ALR/Alpha	Satellite	centr
chrX:59349618-59349774	centromere	ALR/Alpha	Satellite	centr
chrX:59357309-59357465	centromere	ALR/Alpha	Satellite	centr
chrX:59361391-59361547	centromere	ALR/Alpha	Satellite	centr
chrX:59414551-59414716	centromere	ALR/Alpha	Satellite	centr
chrX:59416584-59416740	centromere	ALR/Alpha	Satellite	centr
chrX:59423930-59424164	centromere	ALR/Alpha	Satellite	centr
chrX:59458204-59458372	centromere	ALR/Alpha	Satellite	centr
chrX:59485334-59485490	centromere	ALR/Alpha	Satellite	centr
chrX:59488169-59488368	centromere	ALR/Alpha	Satellite	centr
chrX:59491939-59492095	centromere	ALR/Alpha	Satellite	centr
chrX:59501127-59501369	centromere	ALR/Alpha	Satellite	centr
chrX:59506166-59506322	centromere	ALR/Alpha	Satellite	centr
chrX:59515013-59515169	centromere	ALR/Alpha	Satellite	centr
chrX:59541289-59541445	gene	L1PA3	LINE	L1
chrX:59546114-59546270	gene	L1PA2	LINE	L1
chrX:59549413-59549584	gene	L1HS	LINE	L1
chrX:59560311-59560486	intergenic	L1PA3	LINE	L1
chrX:59564389-59564545	intergenic	L1PA6	LINE	L1
chrX:59576704-59576882	intergenic	L1HS	LINE	L1
chrX:59591374-59591533	centromere	ALR/Alpha	Satellite	centr
chrX:59625168-59625324	intergenic	L1PA2	LINE	L1
chrX:59631958-59632114	intergenic	L1PA5	LINE	L1
chrX:59665208-59665393	gene	MIR3	SINE	MIR
chrX:59673255-59673599	gene	MLT1K	LTR	ERV1-MaLR
chrX:59683034-59683190	gene	L1PA4	LINE	L1
chrX:59720126-59720282	intergenic	L1PA3	LINE	L1
chrX:59728355-59728578	intergenic	(T)n	Simple_repeat	Simple_repeat
chrX:59748578-59748734	intergenic	L1PA3	LINE	L1
chrX:59765825-59765981	gene	L1PA3	LINE	L1
chrX:59779417-59779709	centromere	ALR/Alpha	Satellite	centr
chrX:59815869-59816025	gene	L1PA4	LINE	L1
chrX:59856457-59856647	intergenic	L1HS	LINE	L1
chrX:59873834-59874013	gene	L1PA3	LINE	L1
chrX:59888975-59889177	gene	L1PA2	LINE	L1
chrX:59939889-59940193	gene	L1PA4	LINE	L1
chrX:59955602-59955758	intergenic	L1PA4	LINE	L1
chrX:59955910-59956079	gene	(TC)n	Simple_repeat	Simple_repeat
chrX:59980662-59980957	intergenic	L1PA2	LINE	L1
chrX:59993890-59994105	gene	norepeat	nofamily	noclass
chrX:59999644-59999800	centromere	ALR/Alpha	Satellite	centr
chrX:60005928-60006084	gene	L1PA6	LINE	L1
chrX:60024116-60024272	gene	L1PA5	LINE	L1
chrX:60028320-60028476	gene	L1PA3	LINE	L1
chrX:60034766-60034960	intergenic	L1PA3	LINE	L1
chrX:60036666-60036989	gene	norepeat	nofamily	noclass
chrX:60042694-60042850	subtelomere	(GGGTTA)n	Simple_repeat	Simple_repeat

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chrX:60047508-60047664	Unplaced_chr	L1HS	LINE	L1
chrX:60050979-60051135	centromere	ALR/Alpha	Satellite	centr
chrX:60070438-60070594	centromere	ALR/Alpha	Satellite	centr
chrX:60074580-60074736	centromere	ALR/Alpha	Satellite	centr
chrX:60076527-60076795	centromere	ALR/Alpha	Satellite	centr
chrX:60079529-60079747	centromere	ALR/Alpha	Satellite	centr
chrX:60091794-60092019	centromere	ALR/Alpha	Satellite	centr
chrX:60106396-60106589	centromere	ALR/Alpha	Satellite	centr
chrX:60128359-60128583	centromere	ALR/Alpha	Satellite	centr
chrX:60141821-60142205	centromere	ALR/Alpha	Satellite	centr
chrX:60159860-60160016	centromere	ALR/Alpha	Satellite	centr
chrX:60183114-60183270	centromere	ALR/Alpha	Satellite	centr
chrX:60219604-60219853	centromere	ALR/Alpha	Satellite	centr
chrX:60228827-60228983	centromere	ALR/Alpha	Satellite	centr
chrX:60237327-60237496	centromere	ALR/Alpha	Satellite	centr
chrX:60245601-60245822	centromere	ALR/Alpha	Satellite	centr
chrX:60262820-60263030	centromere	ALR/Alpha	Satellite	centr
chrX:60267752-60267908	centromere	ALR/Alpha	Satellite	centr
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chrX:60722439-60722595	centromere	ALR/Alpha	Satellite	centr
chrX:60734800-60735021	gene	HSATI	Satellite	Satellite
chrX:60798153-60798405	gene	L1P1	LINE	L1
chrX:60847369-60847525	gene	L1PA4	LINE	L1
chrX:60847631-60847787	gene	L1PA2	LINE	L1
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chrX:61200522-61200678	gene	MIR3	SINE	MIR
chrX:61214444-61214641	intergenic	L1PA3	LINE	L1
chrX:61222644-61222817	intergenic	L1PA3	LINE	L1
chrX:61235627-61235841	intergenic	SSU-rRNA_Hsa	rRNA	rRNA
chrX:61237144-61237391	centromere	ALR/Alpha	Satellite	centr
chrX:61238736-61238892	centromere	ALR/Alpha	Satellite	centr
chrX:61245201-61245357	centromere	ALR/Alpha	Satellite	centr
chrX:61269709-61269930	centromere	ALR/Alpha	Satellite	centr
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chrX:61296739-61296895	gene	L1PA3	LINE	L1
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chrX:61369009-61369165	centromere	ALR/Alpha	Satellite	centr
chrX:61380056-61380218	centromere	ALR/Alpha	Satellite	centr
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chrX:61485207-61485363	centromere	ALR/Alpha	Satellite	centr
chrX:61504309-61504525	centromere	ALR/Alpha	Satellite	centr

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chrX:61531734-61531990	centromere	ALR/Alpha	Satellite	centr
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chrX:61911785-61911943	centromere	ALR/Alpha	Satellite	centr
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chrX:62350496-62350700	gene	L1PA4	LINE	L1
chrX:62366026-62366346	gene	L1HS	LINE	L1
chrX:62368260-62368423	intergenic	L1PA3	LINE	L1
chrX:62401185-62401385	intergenic	norepeat	nofamily	noclass
chrX:64515821-64516035	centromere	ALR/Alpha	Satellite	centr
chrX:66184938-66185161	gene	MER67B	LTR	ERV1
chrX:68222436-68222592	gene	norepeat	nofamily	noclass
chrX:69986724-69986880	intergenic	L1PA3	LINE	L1
chrX:71883091-71883247	intergenic	L1PA2	LINE	L1
chrX:73096145-73096370	gene	norepeat	nofamily	noclass
chrX:73441069-73441225	Unplaced_chr	BSR/Beta	Satellite	Satellite
chrX:75044083-75044285	Unplaced_chr	BSR/Beta	Satellite	Satellite
chrX:76664491-76664647	Unplaced_chr	BSR/Beta	Satellite	Satellite
chrX:82548217-82548373	Unplaced_chr	BSR/Beta	Satellite	Satellite
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chrX:83726828-83726984	Unplaced_chr	BSR/Beta	Satellite	Satellite
chrX:85791121-85791347	Unplaced_chr	BSR/Beta	Satellite	Satellite
chrX:86448127-86448345	Unplaced_chr	L1PA4	LINE	L1
chrX:91360805-91360961	Unplaced_chr	L1PA2	LINE	L1
chrX:93031280-93031436	centromere	ALR/Alpha	Satellite	centr
chrX:93618464-93618620	centromere	ALR/Alpha	Satellite	centr
chrX:95131914-95132105	centromere	ALR/Alpha	Satellite	centr
chrX_KI270881v1_alt:32514-32670	centromere	ALR/Alpha	Satellite	centr

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6.2 Proteins with Ratios above 1.25 in Both Label Swap Experiments for the Identification of ZBTB24 Interaction Partners

Majority protein IDs	Protein names	Gene names	Ratio H/L normalized FWD	Ratio H/L normalized REV
O43167	Zinc finger and BTB domain-containing protein 24	ZBTB24	85.37	0.01
Q9HBE1;Q9HBE1-3;Q9HBE1-2	POZ-, AT hook-, and zinc finger-containing protein 1	PATZ1	44.92	0.02
Q13105;Q13105-2	Zinc finger and BTB domain-containing protein 17	ZBTB17	36.02	0.19
Q9H5J0	Zinc finger and BTB domain-containing protein 3	ZBTB3	20.12	0.10
Q15154-2;Q15154	Pericentriolar material 1 protein	PCM1	12.68	0.15
O14867	Transcription regulator protein BACH1	BACH1	12.39	0.34
P98164	Low-density lipoprotein receptor-related protein 2	LRP2	7.77	0.12
P35556;P35556-2	Fibrillin-2	FBN2	7.40	0.13
O95625	Zinc finger and BTB domain-containing protein 11	ZBTB11	6.63	0.10
Q92673	Sortilin-related receptor	SORL1	6.49	0.13
P08107;P08107-2	Heat shock 70 kDa protein 1A/1B	HSPA1A	5.78	0.13
O95365	Zinc finger and BTB domain-containing protein 7A	ZBTB7A	5.63	0.11
Q96IR2;A2RRD8	Zinc finger protein 845;Zinc finger protein 320	ZNF845;ZNF320	5.25	0.21
Q9NZR2	Low-density lipoprotein receptor-related protein 1B	LRP1B	5.08	0.18
P35555	Fibrillin-1	FBN1	4.94	0.21
P17066;P48741	Heat shock 70 kDa protein 6;Putative heat shock 70 kDa protein 7	HSPA6;HSPA7	4.51	0.19
Q07954	Pro-low-density lipoprotein receptor-related protein 1;Low-density lipoprotein receptor-related protein 1 85 kDa subunit;Low-density lipoprotein receptor-related protein 1 515 kDa subunit;Low-density lipoprotein receptor-related protein 1 intracellular domain	LRP1	4.47	0.23
Q92628	Uncharacterized protein KIAA0232	KIAA0232	4.30	0.25
P52737	Zinc finger protein 136	ZNF136	4.19	0.16

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P11142;P11142-2	Heat shock cognate 71 kDa protein	HSPA8	3.94	0.24
Q15072	Zinc finger protein OZF	ZNF146	3.89	0.43
O75096	Low-density lipoprotein receptor-related protein 4	LRP4	3.80	0.30
O75467;Q6AW86-2;Q6AW86	Zinc finger protein 324A;Zinc finger protein 324B	ZNF324;ZNF324 B	3.71	0.14
Q9UHF1	Epidermal growth factor-like protein 7	EGFL7	3.63	0.25
P14625	Endoplasmin	HSP90B1	3.61	0.12
P11021	78 kDa glucose-regulated protein	HSPA5	3.53	0.28
Q13263;Q13263-2	Transcription intermediary factor 1-beta	TRIM28	3.48	0.26
Q99435-4;Q99435;Q99435-2;Q99435-3	Protein kinase C-binding protein NELL2	NELL2	3.44	0.39
Q9UM47	Neurogenic locus notch homolog protein 3;Notch 3 extracellular truncation;Notch 3 intracellular domain	NOTCH3	3.40	0.48
Q6ZN55;Q6ZN55-2	Zinc finger protein 574	ZNF574	3.13	0.64
Q8N2S1-3;Q8N2S1;Q8N2S1-2	Latent-transforming growth factor beta-binding protein 4	LTBP4	3.01	0.46
Q9NT22	EMILIN-3	EMILIN3	2.86	0.45
Q86XX4-2;Q86XX4	Extracellular matrix protein FRAS1	FRAS1	2.86	0.33
Q6NSZ9-2;Q6NSZ9	Zinc finger and SCAN domain-containing protein 25	ZSCAN25	2.84	0.34
Q12797	Aspartyl/asparaginyl beta-hydroxylase	ASPH	2.65	0.38
Q01105-3;Q01105-2;Q01105	Protein SET	SET	2.48	0.19
Q3ZCQ8;Q3ZCQ8-2	Mitochondrial import inner membrane translocase subunit TIM50	TIMM50	2.45	0.47
P27708	CAD protein;Glutamine-dependent carbamoyl-phosphate synthase;Aspartate carbamoyltransferase;Dihydroorotase	CAD	2.34	0.54
Q9H9D4	Zinc finger protein 408	ZNF408	2.20	0.23
Q07021	Complement component 1 Q subcomponent-binding protein, mitochondrial	C1QBP	2.19	0.28
Q99496;Q06587-2;Q06587	E3 ubiquitin-protein ligase RING2;E3 ubiquitin-protein ligase RING1	RNF2;RING1	2.17	0.12

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Q93008-1;Q93008	Probable ubiquitin carboxyl-terminal hydrolase FAF-X	USP9X	2.16	0.48
O95163	Elongator complex protein 1	IKBKAP	2.12	0.36
Q9Y2K1-2;Q9Y2K1	Zinc finger and BTB domain-containing protein 1	ZBTB1	2.12	0.48
Q9UKA4	A-kinase anchor protein 11	AKAP11	2.06	0.38
PI0644	cAMP-dependent protein kinase type I-alpha regulatory subunit;cAMP-dependent protein kinase type I-alpha regulatory subunit, N-terminally processed	PRKAR1A	2.04	0.38
Q04721	Neurogenic locus notch homolog protein 2;Notch 2 extracellular truncation;Notch 2 intracellular domain	NOTCH2	1.95	0.53
Q9ULX6-2;Q9ULX6	A-kinase anchor protein 8-like	AKAP8L	1.87	0.45
Q13347	Eukaryotic translation initiation factor 3 subunit I	EIF3I	1.82	0.29
Q9H0W5	Coiled-coil domain-containing protein 8	CCDC8	1.80	0.63
Q9NS15-2;Q9NS15	Latent-transforming growth factor beta-binding protein 3	LTBP3	1.80	0.66
Q9ULX3	RNA-binding protein NOB1	NOB1	1.74	0.20
Q9H5H4	Zinc finger protein 768	ZNF768	1.73	0.47
O14654	Insulin receptor substrate 4	IRS4	1.73	0.53
O94776	Metastasis-associated protein MTA2	MTA2	1.72	0.74
Q96GA3	Protein LTV1 homolog	LTV1	1.71	0.35
Q15776	Zinc finger protein with KRAB and SCAN domains 8	ZKSCAN8	1.69	0.34
P50402	Emerin	EMD	1.65	0.42
Q2NL82	Pre-rRNA-processing protein TSR1 homolog	TSR1	1.62	0.20
Q13895	Bystin	BYSL	1.61	0.21
Q9UKM9-2;Q9UKM9	RNA-binding protein Raly	RALY	1.55	0.26
O15371	Eukaryotic translation initiation factor 3 subunit D	EIF3D	1.54	0.50
P61978-3;P61978;P61978-2	Heterogeneous nuclear ribonucleoprotein K	HNRNPK	1.53	0.50
Q13330-3;Q13330;Q13330-2	Metastasis-associated protein MTA1	MTA1	1.52	0.54
P55209	Nucleosome assembly protein 1-like 1	NAP1L1	1.51	0.23

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Q14257	Reticulocalbin-2	RCN2	1.49	0.78
Q92769	Histone deacetylase 2	HDAC2	1.47	0.58
Q09028-3;Q09028;Q09028-4;Q09028-2	Histone-binding protein RBBP4	RBBP4	1.47	0.63
O00303	Eukaryotic translation initiation factor 3 subunit F	EIF3F	1.41	0.28
Q9Y265;Q9Y265-2	RuvB-like 1	RUVBL1	1.38	0.44
Q6P1J9	Parafibromin	CDC73	1.37	0.28
P07910-2;P07910-4;P07910;P07910-3	Heterogeneous nuclear ribonucleoproteins C1/C2	HNRNPC	1.37	0.12
Q15365	Poly(rC)-binding protein 1	PCBP1	1.36	0.72
O95714	E3 ubiquitin-protein ligase HERC2	HERC2	1.35	0.72
Q5JTH9-2;Q5JTH9-3;Q5JTH9	RRP12-like protein	RRP12	1.34	0.32
Q16576;Q16576-2	Histone-binding protein RBBP7	RBBP7	1.28	0.59
Q3KQU3-2;Q3KQU3-4;Q3KQU3	MAP7 domain-containing protein 1	MAP7D1	1.27	0.41
P18583-5;P18583-7;P18583;P18583-9;P18583-2;P18583-10;P18583-4;P18583-3	Protein SON	SON	1.26	0.80
O75147-2;O75147-1;O75147	Obscurin-like protein 1	OBSL1	1.25	0.63

Publications

1. **Du H**, Zhang B, Weigt M, Lüthen M, Fröhler S, Mastrobuoni G, Kempa S, Rahn HP, von Bernuth H, Kaindl AM, Hu Y, Chen W. *ZBTB24, a gene associated with human immunodeficiency-centromere instability-facial anomalies (ICF) syndrome, regulates centromeric and pericentromeric heterochromatin formation*. EMBO Rep. (Waiting for Revision)
2. von Bernuth H, Ravindran E, **Du H**, Fröhler S, Strehl K, Krämer N, Issa-Jahns L, Amulic B, Ninnemann O, Xiao MS, Eirich K, Kölsch U, Hauptmann K, John R, Schindler D, Wahn V, Chen W, Kaindl AM: *Combined immunodeficiency develops with age in Immunodeficiency-centromeric instability-facial anomalies syndrome 2 (ICF2)*. Orphanet J Rare Dis. 2014 Oct 21;9(1):116. (advance online)
3. Li N, You X, Chen T, Mackowiak SD, Friedländer MR, Weigt M, **Du H**, Gogol-Döring A, Chang Z, Dieterich C, Hu Y, Chen W. *Global profiling of miRNAs and the hairpin precursors: insights into miRNA processing and novel miRNA discovery*. Nucleic Acids Res. 2013 Feb 8. [Epub ahead of print]

Curriculum Vitae

For reasons of data protection, the curriculum vitae is not published in the electronic version.

Curriculum Vitae

Declaration

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The project was conceived and performed in the Laboratory for Systems Biology and Functional Genomics in Berlin Institute for Medical Systems Biology at Max-Delbrück-Center for Molecular Medicine under the supervision of Prof. Dr. Wei Chen. I hereby declare that this thesis is the results of my own original research work. Contributions from others involved are clearly and specifically indicated in the acknowledgement. The thesis is submitted to Department of Biology, Chemistry and Pharmacy of Freie Universität Berlin to obtain the academic degree of Doctor rerum naturalium (Dr. rer. nat.) and has not been submitted to anywhere else for any degree.

Hang Du

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