



(12) **DEMANDE DE BREVET CANADIEN**
CANADIAN PATENT APPLICATION

(13) **A1**

(86) Date de dépôt PCT/PCT Filing Date: 2018/04/12
(87) Date publication PCT/PCT Publication Date: 2019/01/17
(85) Entrée phase nationale/National Entry: 2020/01/13
(86) N° demande PCT/PCT Application No.: CN 2018/082769
(87) N° publication PCT/PCT Publication No.: 2019/011022
(30) Priorité/Priority: 2017/07/14 (CN201710573752.0)

(51) Cl.Int./Int.Cl. *C12Q 1/68* (2018.01)
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(54) Titre : APPLICATION D'UNE PROTEINE CAS, PROCEDE DE DETECTION D'UNE MOLECULE D'ACIDE
NUCLEIQUE CIBLE ET KIT
(54) Title: USE OF CAS PROTEIN, METHOD FOR DETECTING TARGET NUCLEIC ACID MOLECULE, AND KIT

(57) Abrégé/Abstract:

Provided in the present invention are an application of a Cas protein, a method for detecting a target nucleic acid molecule and a kit, the method for detecting a target nucleic acid molecule comprising: adding a guide RNA, Cas12a and a nucleic acid probe to a reaction system comprising a target nucleic acid molecule to be detected, and carrying out detection after reaction is complete.

ABSTRACT

Provided in the present invention are use of a Cas protein, a method for detecting a target nucleic acid molecule, and a kit, the method for detecting a target nucleic acid molecule comprises adding a guide RNA, Cas12a and a nucleic acid probe into a reaction system comprising a target nucleic acid molecule to be detected, and carrying out detection after the reaction is complete.

USE OF CAS PROTEIN, METHOD FOR DETECTING TARGET NUCLEIC ACID MOLECULE, AND KIT

TECHNICAL FIELD

5 The present invention belongs to the field of biotechnology, and in particular to a method for detecting a target nucleic acid molecule.

BACKGROUND

A specific nucleic acid detection method has an important application value, such as pathogen detection, genetic disease detection, etc. In an aspect of pathogen detection, since each pathogen 10 microorganism has its unique characteristic nucleic acid molecular sequence, it is possible to develop nucleic acid molecular detection for specific species, also known as nucleic acid diagnostic (NAD), which is of great significance in the fields of food safety, environmental microorganism pollution detection, human pathogen infection, etc. Another aspect is the detection of single nucleotide polymorphism (SNP) in human or other species. Understanding the relationship 15 between a genetic variation and a biological function at the genomic level provides a new perspective for modern molecular biology. SNP is closely related to biological functions, evolution and diseases, so the development of SNP detection and analysis technologies is particularly important.

At present, many NAD methods have been established, mainly for the detection of a specific 20 DNA molecule, and there are also some methods for RNA molecules. Generally speaking, a DNA molecule is very stable, so a test sample can come from a series of complex biological samples; while RNA is very easy to degrade, so it needs to be handled with great care. In the 1970s, a detection method using restriction endonuclease digestion was established. Later, methods such as Southern, Northern and dot blot hybridization were developed for specific detection of a nucleic 25 acid molecule. In 1985, when PCR became a conventional experimental method, it led to an exponential improvement in molecular biology. Currently established specific nucleic acid molecule detection usually needs to be performed in two steps, the first step being the amplification

of a target nucleic acid and the second step being the detection of the target nucleic acid. PCR technology is an amplification method that is first established and most commonly used at present. Currently, based on the PCR method, a fluorescent-labeled probe is introduced, such that the amplification situation of a target can be detected in real time, which is called Realtime PCR. The

5 Realtime PCR is not only a fast and highly-sensitive detection method, but also a method for quantitative analysis. In addition to the PCR amplification method, many alternative methods have been established, such as ligase chain reaction, branched DNA amplification, NASBA, SDA, transcription-mediated amplification, Loop-mediated isothermal amplification (LAMP), rolling circle amplification (RCA), Recombinase Polymerase Amplification (RPA), etc. The advantage of
10 many of these alternative methods is isothermality. That is to say, only one temperature is needed to complete the reaction, without the need for a thermal cycling instrument like that used in PCR. Among nucleic acid detection methods, besides the Realtime PCR that can directly complete amplification and detection, the FISH (Fluorescence *in situ* hybridization) technology is the most commonly-used detection method - a method in which a labeled molecular probe is *in situ*
15 hybridized with a complementary target sequence. In addition, detection methods such as next-generation sequencing technologies and Oxford Nanopore sequencing technologies have also been developed, but these methods usually require expensive experimental equipment.

The detection of SNPs also first requires amplification by a method such as PCR and the like, so as to obtain sufficient SNP site-containing region fragments for further detection. Commonly
20 used methods include: primer extension, hybridization, ligation, and enzymatic cleavage. When the above methods are completed, a specific method needs to be utilized for detection, such as mass spectrometry detection, fluorescence detection, chemiluminescence detection, etc.

Although many detection methods have been developed for nucleic acid detection as described above, in certain cases, how to detect more quickly, simply and less expensively is still an
25 important development direction, such as rapid detection of pathogenic bacteria in the field, rapid detection of drug-sensitive SNPs, etc. In 2016, Collins *et al.* developed a rapid and inexpensive method for detecting the Zika virus based on the characteristic of CRISPR-Cas9 of specifically

recognizing and cleaving a target sequence. In 2017, Feng Zhang *et al.* established a rapid nucleic acid detection method utilizing a feature of “collateral effect” of CRISPR-Cas13a. The “collateral effect” means that Cas13a binds to a specific target RNA and then randomly cleaves other non-target RNAs (here RNA molecules are designed as an RNA fluorescence reporting system); rapid 5 target RNA detection is realized by combining with an isothermal amplification technology RPA; and the team of Feng Zhang called this detection method as SHERLOCK (Specific High Sensitivity Enzymatic Reporter UnLOCKing). The SHERLOCK method involves the binding to an RNA template, so if DNA detection is required, the DNA needs to be firstly transcribed into an RNA template for detection; and given the instability of RNA, this method will undoubtedly 10 increase the difficulty of operation.

In 2015, Feng Zhang *et al.* discovered a new CRISPR-related endoproteinase Cas12a (formerly known as Cpf1), which, like a commonly used Cas9 protein, is an RNA-guided specific DNA endonuclease; however, compared with Cas9, Cas12a has its own characteristics, for example, only a crRNA is needed to guide the specific cleavage of a double-stranded DNA and a sticky end is 15 produced.

SUMMARY

An objective of the present invention is to provide a method for detecting a target nucleic acid molecule.

Another objective of the present invention is to provide use of a Cas protein in a method for 20 detecting a target nucleic acid molecule.

In a first aspect of the present invention, provided is a kit including a guide RNA, a Cas protein, a nucleic acid probe, and a buffer solution.

A method for detecting a target nucleic acid molecule includes adding a guide RNA, a Cas protein, a nucleic acid probe and a buffer solution into a reaction system containing a target nucleic 25 acid molecule to be detected, and then detecting the target nucleic acid (especially by a method of detecting fluorescence intensity).

Preferably, the Cas protein is Cas12a or Cas protein having a collateral single-stranded DNA cleavage activity similar to that of the Cas12a.

Preferably, the Cas protein is Cas12a.

The Cas12a is preferably one of FnCas12a, AsCas12a, LbCas12a, Lb5Cas12a, HkCas12a,

5 OsCas12a, TsCas12a, BbCas12a, BoCas12a, or Lb4Cas12a.

Preferably, the Cas12a is LbCas12a.

Preferably, the guide RNA refers to an RNA that guides the Cas protein to specifically bind to a target DNA.

In another preferred embodiment, the nucleic acid probe is a single-stranded DNA; the single-
10 stranded DNA is preferably a fluorescently-labeled single-stranded DNA; the single-stranded DNA is preferably a fluorescent probe that is labeled with a fluorescent group HEX at a 5' terminal and labeled with a quenching group BHQ1 at a 3' terminal.

In another preferred embodiment, the method for detecting the nucleic acid probe is preferably a fluorescence detection method; and the fluorescence detection method is preferably a detection
15 method using a microplate reader or a fluorescence spectrophotometer.

Preferably, the target nucleic acid molecule to be detected in the reaction system of the target nucleic acid molecule to be detected is obtained after amplification.

Preferably, the detection method of the present invention can be used for detecting a pathogenic microorganism, gene mutation, or a specific target DNA.

20 In another preferred embodiment, the Cas protein includes Cas12b (C2c1).

In a second aspect of the present invention, provided is use of a Cas protein in a method for detecting a target nucleic acid molecule, or in preparation of a formulation for detecting a target nucleic acid molecule.

25 In another preferred embodiment, when a target DNA, a guide RNA and a Cas protein form a ternary complex, the complex will cleave other single-stranded DNA molecules in the system.

Preferably, the guide RNA refers to an RNA that guides the Cas protein to specifically bind to a target DNA.

In a third aspect of the present invention, provided is a kit including a guide RNA, a Cas protein, and a nucleic acid probe.

In another preferred embodiment, the kit further includes a buffer solution.

In a fourth aspect of the present invention, provided is a detection system for detecting a target 5 nucleic acid molecule, the system including:

(a) a Cas protein, which is Cas12a or a Cas protein having a collateral single-stranded DNA cleavage activity similar to that of the Cas12a;

(b) a guide RNA that guides the Cas protein to specifically bind to the target nucleic acid molecule; and

10 (c) a nucleic acid probe which is a single-stranded DNA;

wherein the target nucleic acid molecule is a target DNA.

In another preferred embodiment, the detection system further includes (d) a buffer solution.

In another preferred embodiment, the detection system further includes a target nucleic acid molecule to be detected.

15 In another preferred embodiment, the concentration of the target nucleic acid molecule to be detected in the detection system is 1-100 copies/microliter or 10^{15} copies/microliter, preferably 1-10 copies/microliter, and more preferably 1-5 copies/microliter.

In another preferred embodiment, in the detection system, the molar ratio of the nucleic acid probe to the target nucleic acid molecule is 10^3 : 1 to 10^{14} : 1, and preferably 10^4 : 1 to 10^7 : 1.

20 In another preferred embodiment, the detection site of the target nucleic acid molecule is located at positions 1-12 downstream of the PAM sequence of the guide RNA.

In another preferred embodiment, the length of the guide RNA is 15-30 nt, and preferably 15-18 nt.

In another preferred embodiment, the target DNA includes a cDNA.

25 In another preferred embodiment, the target DNA is selected from a group consisting of a single-stranded DNA, a double-stranded DNA, or a combination thereof.

In another preferred embodiment, the nucleic acid probe carries a fluorescent group and a quenching group.

In another preferred embodiment, the fluorescent group and the quenching group are each independently located at the 5' terminal, 3' terminal and the middle portion of the nucleic acid probe.

In another preferred embodiment, the length of the nucleic acid probe is 3-300 nt, preferably 5-100 nt, more preferably 6-50 nt, and most preferably 8-20 nt.

In another preferred embodiment, the target nucleic acid molecule includes a target nucleic acid molecule derived from a group consisting of plants, animals, insects, microorganisms, viruses, or a combination thereof.

In another preferred embodiment, the target DNA is an artificially-synthesized or naturally occurring DNA.

In another preferred embodiment, the target DNA includes a wild-type or mutant DNA.

In another preferred embodiment, the target DNA includes a DNA obtained by reverse transcription of RNA or amplification, such as a cDNA, etc.

In another preferred embodiment, the Cas12a is selected from a group consisting of FnCas12a, AsCas12a, LbCas12a, Lb5Cas12a, HkCas12a, OsCas12a, TsCas12a, BbCas12a, BoCas12a, Lb4Cas12a, or a combination thereof; and more preferably, the Cas12a is LbCas12a.

In another preferred embodiment, the Cas protein having a collateral single strand DNA cleavage activity similar to that of Cas12a is selected from a group consisting of Cas12b (i.e., C2c1).

In another preferred embodiment, the Cas12b protein is selected from a group consisting of AacCas12b (*Alicyclobacillus acidoterrestris*), Aac2Cas12b (*Alicyclobacillus acidiphilus*), AkCas12b (*Alicyclobacillus kakegawensis*), AmCas12b (*Alicyclobacillus macrosporangioides*), AhCas12b (*Alicyclobacillus herbarius*), and AcCas12b (*Alicyclobacillus contaminans*).

In another preferred embodiment, the nucleic acid probe comprises a single-stranded DNA carrying a detectable label.

In another preferred embodiment, the single-stranded DNA is a fluorescent-labeled and biotin-labeled single-stranded DNA.

In another preferred embodiment, the single-stranded DNA is a fluorescent-labeled single-stranded DNA.

5 In another preferred embodiment, the single-stranded DNA is a fluorescent probe that is labeled with a fluorescent group HEX at a 5' terminal and labeled with a quenching group BHQ1 at a 3' terminal.

In a fifth aspect of the present invention, provided is a kit for detecting a target nucleic acid molecule, the kit including:

10 i) a first container and a Cas protein in the first container, the Cas protein being Cas12a or a Cas protein having a collateral single-stranded DNA cleavage activity similar to that of the Cas12a;
ii) an optional second container and a guide RNA in the second container, the guide RNA guiding the Cas protein to specifically bind to the target nucleic acid molecule;
iii) a third container and a nucleic acid probe in the third container; and
15 iv) an optional fourth container and a buffer solution located in the fourth container;
wherein the target nucleic acid molecule is a target DNA.

In another preferred embodiment, any two, three, or four (or all) of the first, second, third, and fourth containers may be the same or different containers.

20 In another preferred embodiment, the nucleic acid probe carries a fluorescent group and a quenching group.

In a sixth aspect of the present invention, provided is a method for detecting whether a target nucleic acid molecule exists in a sample, including the following steps:

25 (a) providing the detection system for detecting a target nucleic acid molecule according to the fourth aspect of the present invention, wherein the detection system further has a sample to be detected; and
(b) detecting whether the nucleic acid probe in the detection system is cleaved by a Cas protein, wherein the cleavage is a trans-cleavage of a collateral single-stranded DNA;

where if the nucleic acid probe is cleaved by the Cas protein, then it indicates the presence of the target nucleic acid molecule in the sample; and if the nucleic acid probe is not cleaved by the Cas protein, then it indicates the absence of the target nucleic acid molecule in the sample.

In another preferred embodiment, the sample to be detected includes an un-amplified sample 5 and an amplified (or nucleic-acid-amplified) sample.

In another preferred embodiment, the sample to be detected is a sample obtained by amplification.

In another preferred embodiment, a method for amplifying the nucleic acid is selected from a group consisting of PCR amplification, LAMP amplification, RPA amplification, ligase chain 10 reaction, branched DNA amplification, NASBA, SDA, transcription-mediated amplification, rolling circle amplification, HDA, SPIA, NEAR, TMA, and SMAP2.

In another preferred embodiment, the PCR includes high temperature PCR, normal-temperature PCR, and low-temperature PCR.

In another preferred embodiment, the method is used for detecting whether SNP, point 15 mutation, deletion, and/or insertion exists in a nucleic acid at a target site.

In another preferred embodiment, when the upstream and downstream (in a range of -20 nt to +20 nt, preferably in a range of -15 nt to +15 nt, and more preferably in a range of -10 nt to +10 nt) of the target site lack a PAM sequence, nucleic acid amplification is carried out using a PAM-introducing primer.

20 In another preferred embodiment, the PAM-introducing primer has a structure of formula I in 5'-3':

P1-P2-P3 (I)

wherein,

25 P1 is a 5' segment sequence that is located at the 5' terminal and is complementary or non-complementary to the sequence of the target nucleic acid molecule;

P2 is a PAM sequence;

P3 is a 3' segment sequence that is located at the 3' terminal and is complementary to the sequence of the target nucleic acid molecule.

In another preferred embodiment, the PAM primer specifically binds to upstream or downstream of the target nucleic acid molecule.

5 In another preferred embodiment, P1 has a length of 0-20 nt.

In another preferred embodiment, P3 has a length of 5-20 nt.

In another preferred embodiment, the PAM primer has a length of 18-50 nt, and preferably 20-35 nt.

10 In another preferred embodiment, the complementation includes complete complementation and partial complementation.

In another preferred embodiment, at least one primer containing the PAM sequence is used in the nucleic acid amplification.

15 In another preferred embodiment, when the upstream and downstream (in a range of -20 nt to +20 nt, preferably in a range of -15 nt to +15 nt, and more preferably in a range of -10 nt to +10 nt) of the target site contain a PAM sequence, then a primer containing or not containing the PAM sequence can be used, and the amplified amplification product contains the PAM sequence.

In another preferred embodiment, the detection in step (b) includes a fluorescence detection method.

20 In another preferred embodiment, the fluorescence detection method uses a microplate reader or a fluorescence spectrophotometer for detection.

In a seventh aspect of the present invention, provided is use of a Cas protein in preparation of a detection reagent or kit for detecting a target nucleic acid molecule based on collateral single-stranded DNA cleavage, where the Cas protein is Cas12a or a Cas protein having a collateral single-stranded DNA cleavage activity similar to that of the Cas12a.

25 In another preferred embodiment, the Cas12a is selected from a group consisting of FnCas12a, AsCas12a, LbCas12a, Lb5Cas12a, HkCas12a, OsCas12a, TsCas12a, BbCas12a, BoCas12a, Lb4Cas12a, or a combination thereof; and more preferably, the Cas12a is LbCas12a.

In another preferred embodiment, the Cas protein having a collateral single-stranded DNA cleavage activity similar to that of Cas12a is selected from a group consisting of Cas12b (or C2c1).

In another preferred embodiment, the Cas12b protein is selected from a group consisting of AacCas12b.

5 It should be understood that, within the scope of the present invention, the above-mentioned technical features of the present invention and the technical features described in detail hereafter (e.g., in examples) can be combined with each other to form a new or preferred technical solution.

As limited by the length, it will not be repeated any more here.

BRIEF DESCRIPTION OF DRAWINGS

10 FIG. 1 shows a *cis* cleavage characteristic of Cas12a in cleaving a target single-stranded DNA.

FIG. 2 shows that when cleaving a target single-stranded DNA, Cas12a does not depend on a PAM sequence required for cleaving double strands.

FIG. 3 shows a *trans* cleavage characteristic of Cas12a in cleaving a single-stranded DNA.

15 FIG. 4 shows test Cas12as from 10 different sources, where all of these Cas12as have *cis*-cleavage and *trans*-cleavage activities on a single-stranded DNA.

FIG. 5 identifies sites possibly related to *cis*-cleavage and *trans*-cleavage activities on the single-stranded DNA in Cas12a through a single-site mutation experiment of the Cas12a.

FIG. 6 shows the structures of Cas12a and Cas12b (i.e., C2c1) monomers and their complexes with a guide RNA and a target DNA.

20 FIG. 7 shows fluorescence values obtained by different Cas12as using a specific double-stranded DNA substrate and a single-stranded DNA (HEX-N12-BHQ1) as a fluorescence detection probe. The negative control group is not added with the specific substrate.

FIG. 8 shows a schematic flow chart of a HOLMES method for detecting a target DNA based on target DNA amplification and the *trans*-cleavage activity of the Cas12a on a collateral single-stranded DNA.

25 FIG. 9 shows a sensitivity test of a target DNA by using FnCas12a or LbCas12a directly, or in combination with the HOLMES method.

FIG. 10 shows fluorescence detection values of target sequences having different single-point mutations as detected by the HOLMES method using crRNAs of different lengths of guide sequences in combination with FnCas12a or LbCas12a.

FIG. 11 tests whether a FAM-labeled single-stranded DNA probe is trans-cleaved after the 5 target single-stranded DNA is added by utilizing a FAM-labeled fluorescent probe and 10 Cas12a proteins.

FIG. 12 tests fluorescence values after the target single-stranded DNA is added by using HEX-N12-BHQ1 as a probe and 10 Cas12a proteins.

FIG. 13 (A) shows HOLMES detection values when a gyrB gene fragment is used as a target 10 sequence and different concentrations of pure cultured *Escherichia coli* MG1655 are used as positive control templates by using a single-stranded DNA fluorescent probe labeled with HEX and BHQ1 at two ends thereof. It is shown that the fluorescence response value of *Escherichia coli* MG1655 decreases with the decrease of its concentration. (B) Detection values of water samples in environments at different locations.

15 FIG. 14 shows a schematic flow chart of a HOLMES method for detecting SNP, and fluorescence detection values of 5 SNP sites.

FIG. 15 shows fluorescence detection values of key sites in a TP53 gene (a cancer-related gene) as detected by the HOLMES method.

FIG. 16 shows detection values of 5 SNP sites (related to gout) as detected by the HOLMES 20 method.

FIG. 17 shows detection values of one SNP site (related to gout) as detected by the HOLMES method, where the samples are samples from 21 volunteers.

FIG. 18 shows a primer design scheme of one example of the present invention, which can be used for HOLMES detection of SNP at any site.

25 FIG. 19 uses a combination of LAMP and HOLMES to detect *Escherichia coli* in the system. (A) An electrophoresis map of a gyrB gene of *Escherichia coli* amplified by LAMP. A total of two sets of primers gyrB-1 and gyrB-2 are used for amplification. gyrB is the characteristic gene of

Escherichia coli. (B) A HOLMES detection system is used for detecting an amplification product of LAMP. Negative control: the sample is sterile water, and a *gyrB*-1 amplification primer is used for amplifying or detecting the result of the *gyrB* gene; *gyrB*-1: the sample is *Escherichia coli* to be detected, and a first set of *gyrB* gene amplification primers are used for amplifying or detecting the result of the *gyrB* gene; and *gyrB*-2: the sample is *Escherichia coli* to be detected, and a second set of *gyrB* gene amplification primers are used for amplifying or detecting the result of the *gyrB* gene.

FIG. 20 detects the genotype of a human HEK293T cell by using a combination of LAMP and HOLMES. (A) An electrophoresis map of a corresponding SNP detection template of the human HEK293T cell as amplified by LAMP. Negative control: the sample is sterile water, and the result is a result of amplification using an rs5082 amplification primer; rs5082: the sample is a total genome of the human HEK293T cell, and the result is a result of amplification using the rs5082 amplification primer; and rs1467558: the sample is the total genome of the human HEK293T cell, and the result is a result of amplification using an rs1467558 amplification primer. (B) A HOLMES detection system is used for detecting an amplification product of LAMP. The rs5082 site was detected using two crRNAs of crRNA-G and crRNA-T respectively (Sequence Listing 5); and the rs1467558 site was detected using two crRNAs of crRNA-C and crRNA-T respectively (Sequence Listing 5).

FIG. 21 uses a combination of RPA and HOLMES to detect *Escherichia coli* in the system.

(A) Amplification of the *gyrB* gene of *Escherichia coli* by RPA. A total of two sets of primers *gyrB*-1 and *gyrB*-2 are used for amplification. *gyrB* is a characteristic gene of *Escherichia coli*.

(B) A HOLMES detection system is used for detecting an amplification product of RPA. Negative control: the sample is sterile water, and a *gyrB*-1 amplification primer is used for amplifying or detecting the result of the *gyrB* gene; *gyrB*-1: the sample is *Escherichia coli* to be detected, and a first set of *gyrB* amplification primers are used for amplifying or detecting the result of the *gyrB* gene; and *gyrB*-2: the sample is *Escherichia coli* to be detected, and a second set of *gyrB* amplification primers are used for amplifying or detecting the result of the *gyrB* gene.

FIG. 22 shows detection of collateral single-stranded DNA cleavage activity of Cas12b when a single-stranded DNA is used as the target DNA. After the collateral cleavage reaction is completed, the reactants are separated by 12% urea-denatured gel electrophoresis, and detected by a fluorescence imaging system. The numbers in brackets represent the final concentrations of the reactants in nM; the target DNA is a 66 nt long single-stranded DNA at a dosage of 50 nM; and the single-stranded DNA probe is a single-stranded DNA carrying a FAM label at the 5' terminal at a dosage of 50 nM. As can be seen from the figure, after Cas12b, the guide RNA and the target DNA are contained, the FAM-labeled single-stranded DNA is cut into fragments, i.e., Cas12b has a collateral single-stranded DNA cleavage activity.

FIG. 23 shows detection of collateral single-stranded DNA cleavage activity of Cas12b when a single-stranded DNA and a double-stranded DNA are used as the target DNAs. After the collateral cleavage reaction is completed, the reactants are detected by using a fluorescence microplate reader. The dosages of Cas12b and the guide RNA are both 500 nM; the target DNA is a 66 nt long single-stranded DNA or double-stranded DNA at a dosage of 50 nM; and the single-stranded DNA probe is a single-stranded DNA probe (HEX-N12-BHQ1) containing a fluorescence report group and a quenching group at a dosage of 500 nM. As can be seen from the figure, regardless of whether a single-stranded DNA template or a double-stranded DNA template is used, the collateral single-stranded DNA cleavage activity can be detected after Cas12b and the guide RNA are added.

FIG. 24 shows the collateral single-stranded DNA *trans*-cleavage activity of Cas12b on a target DNA at a low concentration after the combination with LAMP amplification.

DETAILED DESCRIPTION

In order to make the objectives, technical solutions and advantages of the embodiments of the present invention clearer, the following clearly and completely describes the technical solutions in the embodiments of the present invention with reference to the accompanying drawings in the embodiments of the present invention. The described embodiments are a part rather than all of the

embodiments of the present invention. All other embodiments obtained by a person of ordinary skill in the art based on the embodiments of the present invention without creative efforts fall within the protection scope of the present invention.

The inventor has developed a technical solution for target nucleic acid detection through 5 extensive and in-depth research and through research on the cleavage characteristics of a Cas enzyme (such as Cas12a and Cas12b enzymes). The experimental results show that a nucleic acid is detected successfully and rapidly by employing the above-mentioned technical solution, for example, for the identification of whether there is a certain concentration of microorganisms such as *Escherichia coli* in water, and for the rapid identification of an SNP genotype. The present 10 invention is completed on this basis.

Terms

The term "guide RNA" refers to an RNA that guides a Cas protein to specifically bind to a target DNA sequence.

The term "crRNA" refers to a CRISPR RNA, which is a short RNA that guides Cas12a to bind 15 to a target DNA sequence.

The term "CRISPR" refers to a clustered regularly interspaced short palindromic repeat, which is the immune system of many prokaryotes.

The term "Cas protein" refers to a CRISPR-associated protein, which is a related protein in a CRISPR system.

20 The term "Cas12a" (formerly referred to as "Cpf1") refers to a crRNA-dependent endonuclease, which is a type V-A enzyme in CRISPR system classification.

The terms "Cas12b" and "C2c1" are used interchangeably, and refer to a crRNA-dependent endonuclease, which is a type V-B enzyme in CRISPR system classification.

25 The term "LAMP" is a Loop-mediated isothermal amplification technology, which is an isothermal nucleic acid amplification technology suitable for gene diagnosis.

The term "PAM" refers to a protospacer-adjacent motif, which is necessary for Cas12a cleavage. The PAM of FnCas12a is a TTN sequence, the PAM of LbCas12a is a TTTN sequence,

and the PAM of AacCas12b is TTN.

The present invention discloses a method for detecting a target nucleic acid molecule, which includes: adding a guide RNA, a Cas protein, a nucleic acid probe and a buffer solution into a reaction system containing a target nucleic acid molecule to be detected, and then performing 5 fluorescence detection of the target nucleic acid molecule.

The Cas protein is Cas12a or Cas12b.

The Cas12a is preferably one of FnCas12a, AsCas12a, LbCas12a, Lb5Cas12a, HkCas12a, OsCas12a, TsCas12a, BbCas12a, BoCas12a or Lb4Cas12a; and the Cas12a is preferably LbCas12a.

10 The Cas12b is preferably AacCas12b, Aac2Cas12b, AkCas12b, AmCas12b, AhCas12b or AcCas12b.

A guide RNA refers to an RNA that guides a Cas protein to specifically target a DNA sequence.

The target nucleic acid molecule to be detected in the reaction system of the target nucleic acid molecule to be detected is obtained by amplification.

15 The detection method can detect a pathogenic microorganism, gene mutation, or a specific target DNA.

Use of a Cas protein in a method for detecting a target nucleic acid molecule.

When a target DNA, a guide RNA and a Cas protein form a ternary complex, the complex will cleave other single-stranded DNA molecules in the system.

20 A guide RNA refers to an RNA that guides a Cas protein to specifically target a DNA sequence.

The present invention also provides a kit including a guide RNA, a Cas protein, and a nucleic acid probe. Furthermore, the kit of the present invention can also include a buffer solution.

25 The present invention provides a detection method for rapidly detecting a target nucleic acid molecule with high specificity. Once the (single-stranded or double-stranded) target DNA, the crRNA and the Cas12a protein form a ternary complex, the complex will cleave other single-stranded DNA molecules in the system. Through designing, the crRNA targets the target DNA (a segment of DNA sequence to be detected); the crRNA and the Cas12a protein are added into the

detection system; when the target DNA is present, the Cas12a forms a ternary complex with the crRNA and the target DNA, and meanwhile, the complex exerts its collateral cleavage activity and cleaves a single-stranded DNA labeled with a fluorescent signal (two ends of the single-stranded DNA are respectively connected with a luminescent group and a quenching group, and the luminescent group can emit light after being cleaved), thereby emitting fluorescence. Therefore, whether the system to be detected contains the target DNA molecule can be known by fluorescence detection. By using the method of the present invention, whether a specific DNA sequence is contained in a sample can be quickly detected. The sensitivity of the detection method can be greatly improved by combining with a PCR technology. The nucleic acid probe in the present invention is preferably a fluorescent probe.

HOLMES condition testing:

The present invention provides use of Cas12 enzymes such as Cas12a and Cas12b in nucleic acid detection. The following description will take Cas12a as an example.

Selection of Cas12a: according to research, Cas12a has a trans-cleavage activity, that is, once the target DNA, the crRNA and the Cas12a protein form a ternary complex, other single-stranded DNAs (collateral single-stranded DNAs) in the system will be cleaved. According to this principle, a specific DNA detection method is designed. First, the collateral DNA is designed as a fluorescent probe, which consists of a random sequence of 12 nt, and is labeled with a fluorescent group HEX at the 5' terminal and a quenching group BHQ1 (HEX-N12-BHQ1) at the 3' terminal. When the target DNA fragment is contained in the system, a ternary complex of the target DNA, the crRNA and the Cas12a protein will be formed. At this time, the probe will be cleaved, and meanwhile, the HEX fluorescent group will emit fluorescence (with an excitation light at 535 nM and an emission light at 556 nM) as detected by a fluorescence detector. Next, 10 different Cas12as are tested, and the target sequence is a double-stranded DNA as shown in FIG. 7. It can be seen that the complex composed of the target double-stranded DNA and each Cas12a protein can realize the *trans* cleavage activity.

HOLMES response sensitivity: then, the response sensitivities of FnCas12a and LbCas12a

to the target DNA are tested, that is to say, the lowest concentration of the target DNA at which the response can occur is investigated. As shown in FIG. 9, when the test target is directly added, they can respond to the target DNA with a concentration above 0.1 nM, and the response is remarkable when the concentration is above 1 nM. If a PCR technology (the HOLMES method) is 5 combined, as shown in FIG. 8, i.e., amplification of the fragment of interest through PCR followed by a Cas12a cleavage reaction, the response sensitivity can be as low as 10 aM, as shown in FIG. 9.

SNP Test: next, whether the HOLMES method can detect an SNP genotype is tested. T1 is taken as a target sequence, PAM at this site is mutated or positions 1-18 of the target sequence are 10 respectively subjected to single-point mutation, and the detection differences between a non-mutated sequence and a mutated sequence by crRNAs of different lengths are compared.

As shown in FIG. 10, when the complementary sequence of the target is a crRNA of 24 nt (crRNA-24nt), the single-point mutation at the positions 8-18 is not much different from the wild type, while the fluorescence value decreases obviously after the PAM mutation and the mutation 15 of positions 1-7. When the crRNA is truncated and the length of a paired target sequence is 18 nt, the fluorescence value of the mutation positions of 8-16 nt is obviously decreased compared with that of a target sequence having a length of 24 nt; when the length of the crRNA continues to be shortened to 16 nt or 17 nt, the fluorescence value of the mutated target sequence decreases more significantly; and when it is further shortened to 15 nt, the fluorescence value of the mutated target 20 sequence is weaker as compared with that of this target sequence, but the fluorescence intensity of the mutated target sequence may still be higher as compared with those of other target sequences, and thus can be used for detection. Taken together, the crRNAs of 15 nt, 16 nt and 17 nt are the most suitable for SNP detection.

In the present invention, the Cas12a cleaves the single-stranded DNA in a PAM-sequence 25 independent programmed cleaving manner, which is called *cis* cleavage; but once the ternary complex Cas12a/crRNA/target DNA is formed, it will show a *trans*-cleavage activity, i.e., exhibiting an activity of cleaving any non-target single-stranded DNA in the system.

Based on the characteristics of Cas12a, a method for specific nucleic acid molecule detection is developed, which is called HOLMES (one HOur Low-cost Multipurpose Efficient Simple assay). Just like the name of the technology, it is characterized by a fast speed (1 hour), a low price, multiple channels, high efficiency and a simple test method. The method can be used in the fields 5 of rapid pathogen detection, SNP detection and the like.

Nucleic acid detection based on the collateral cleavage activity

The present invention also provides a nucleic acid detection method based on the collateral cleavage activity of the Cas12 enzyme (including Cas12a or Cas12b).

Preferably, the detection of the present invention can be performed for SNP, and in particular 10 PCR amplification is performed first followed by detection.

Referring to FIG. 18, a primer design scheme is given.

Case 1. When there is a PAM site near the SNP site, and a crRNA synthesized based on a guide sequence designed according to the PAM site can be used for HOLMES detection. When the HOLMES method is used for detection, it shows a relatively low background signal; and for the 15 same guide sequence, signal differences between different SNP templates are quite large.

Case 2. When there is no PAM site or no suitable PAM site near the SNP site, a PAM site can be introduced according to the above experimental scheme.

A typical step includes designing a primer near the SNP site, and carrying a PAM site on the primer, where the sequence located at the 3' terminal of the PAM site should be paired with the 20 template DNA. There is no special requirement on the primer at the other terminal, as long as the primer can be paired with template DNA and can be used for PCR amplification. As shown in FIG. 18, PAM sites can be successfully introduced after PCR amplification.

Referring to FIG. 10, in the present invention, when designing introduction of the PAM site, the SNP site is usually located at the first 16 bases of the 5' terminal of the crRNA guide sequence, 25 preferably at positions 1-14, more preferably at positions 1-12, still more preferably at positions 1-11 or 1-10, and most preferably at positions 1-8 or 1-7.

The present invention has the following main advantages:

(1) Fast speed: when the test conditions are ready, it only takes about 1 hour from the time of obtaining a sample to the time of obtaining test results.

(2) Low cost: there are no special materials or enzymes in the experiment, and it involves a small quantity of materials and reagents, and thus it can be used for trace analysis.

5 (3) High efficiency: the present invention has extremely high sensitivity and can detect DNA at a concentration of 10 aM.

(4) Multiple uses: it can detect different nucleic acid samples, including DNA samples and RNA samples.

10 (5) Simplicity: there are no special or complicated steps, and if a kit is prepared and a program is set, only simple operations such as adding a sample are required.

The present invention will be described in detail below in connection with specific examples. It should be understood that the following examples are only intended to illustrate the present invention, rather than limiting the scope of the present invention. The experimental methods in the following examples which are not specified with specific conditions are generally carried out 15 according to conventional conditions, such as those described in Sambrook *et al.*, Molecular Cloning: Laboratory Manual (New York: Cold Spring Harbor Laboratory Press, 1989), or those recommended by manufacturers. Unless otherwise stated, percentages and parts are weight percentages and parts by weight.

Unless otherwise stated specifically, the experimental materials involved in the present 20 invention can be obtained from commercial channels.

Materials

1. The RNase inhibitor is purchased from TaKaRa, and the high-fidelity DNA polymerase KOD FX is purchased from ToYoBo; the primers (oligonucleotides) are synthesized by Sangon Biotech (Shanghai) Co., Ltd.; the T7 RNA polymerase is purchased from Thermo; the RNA 25 purification and concentration kit (RNA Clean&ConcentratorTM_5) is purchased from Zymo Research; the Wizard® SV Gel and PCR Clean-Up System is purchased from Promega; and the media (e.g., Tryptone, Yeast Extract, etc.) are all purchased from OXOID.

2. Medium formula: a liquid LB (1% Tryptone, 0.5% Yeast extract, 1% NaCl), and only 2% agar needs to be added into the liquid LB when a solid LB is prepared.

Example 1 Cas12a protein detection capable of detecting a single-stranded DNA target (the probe being labeled with FAM)

5 A single-stranded DNA (target-T1-R) was selected as a target sequence to test the response values of its detection by different Cas12a proteins.

1. Preparation of crRNA: first, a transcription template was prepared by annealing T7-crRNA-F to a synthesized oligonucleotide T7-T1-24-R as shown in Table 5. Specifically, the paired oligonucleotide (4 μ M) was annealed in a 1X PCR buffer (Transgen Biotech) at a total volume of 10 50 μ L, and then subjected to an annealing procedure: initially denaturing at 95°C for 5 minutes, and then cooling from 95°C to 20°C at a rate of 1°C per minute using a thermal cycler. crRNA was synthesized using a T7 high-throughput transcription kit, and the reaction was carried out overnight at 37°C (for about 16 h). Then RNA was purified using the RNA purification and concentration kit, quantified with NanoDrop 2000C (Thermo Fisher Scientific), diluted to a concentration of 15 10 μ M, and stored in a refrigerator at -80°C.

2. Cas12a reaction: a 20 μ L reaction system was added with the crRNA (0.5 μ M) purified in step 1, a Cas12a (0.25 μ M), a target single-stranded DNA (target-T1-R) (0.01 μ M), a nucleic acid probe (N25-5' FAM) (0.01 μ M), a buffer solution of NEB buffer 3.1, and 0.5 μ L of an RNase inhibitor. The blank control reaction was a reaction in which all other components were added 20 except the single-stranded DNA target sequence. Reaction was conducted at 37°C for 15 min, and then terminated at 98°C for 2 min.

3. Fluorescence detection: the reaction was subjected to urea-acrylamide gel electrophoresis (Urea-PAGE), and then detected with a fluorescence luminescence imager. As shown in FIG. 11, different Cas12as have different detection effects on the target. For example, for HkCas12a, etc., 25 cleavage of the probe was caused even when no target single-stranded DNA was added. LbCas12a and the like are better candidates of Cas12a proteins because the cleavage of the probe occurred only when the target single-stranded DNA was added.

**Example 2 Cas12a protein detection capable of detecting a single-stranded DNA target
(the probe being labelled with two labels of HEX and BHQ1)**

A single-stranded DNA (target-T1-R) was selected as a target sequence to test the response values of its detection by different Cas12a proteins.

5 1. Preparation of crRNA: first, a transcription template was prepared by annealing T7-crRNA-F to a synthesized oligonucleotide T7-T1-24-R (Table 5). Specifically, the paired oligonucleotide (4 μ M) was annealed in a 1X PCR buffer (Transgen Biotech) at a total volume of 50 μ L, and then subjected to an annealing procedure: initially denaturing at 95°C for 5 minutes, and then cooling from 95°C to 20°C at a rate of 1°C per minute using a thermal cycler. crRNA was synthesized 10 using a T7 high-throughput transcription kit, and the reaction was carried out overnight at 37°C (for about 16 h). Then RNA was purified using the RNA purification and concentration kit, quantified with NanoDrop 2000C, diluted to a concentration of 10 μ M, and stored in a refrigerator at -80°C.

15 2. Cas12a reaction: a 20 μ L reaction system was added with the crRNA (0.5 μ M) purified in step 1, a Cas12a (0.25 μ M), a target single-stranded DNA (target-T1-R) (0.01 μ M), a fluorescence probe (HEX-N12-BHQ1, i.e., a 12 nt single-stranded DNA that is labeled with HEX at the 5' terminal and with the BHQ1 at the 3' terminal) (0.5 μ M), a buffer solution of NEB buffer 3.1, and 0.5 μ L of an RNase inhibitor. The control reaction was a reaction in which all other components were added except the single-stranded DNA target sequence. Reaction was conducted at 37°C for 20 15 min, and then terminated at 98°C for 2 min.

25 3. Fluorescence detection: 20 μ L of the inactivated reaction solution was added into a 96-well plate, and then detected by a microplate reader (with an excitation light at 535 nm and an emission light at 556 nm). As shown in FIG. 12, different Cas12as have different detection effects on the target. For example, for HkCas12a, etc., cleavage of the probe was caused even when no target single-stranded DNA was added. FnCas12a and the like are better candidates of Cas12a proteins because the cleavage of the probe occurred only when the target single-stranded DNA was added.

Example 3 Cas12a protein detection capable of detecting a double-stranded DNA target

A double-strand DNA (target-T1) was selected as a target sequence to test the response values of its detection by different Cas12a proteins.

1. Preparation of crRNA: first, a transcription template was prepared by annealing T7-crRNA-F to a synthesized oligonucleotide T7-T1-24-R (Table 5). Specifically, the paired oligonucleotide 5 (4 μ M) was annealed in a 1X PCR buffer (Transgen Biotech) at a total volume of 50 μ L, and then subjected to an annealing procedure: initially denaturing at 95°C for 5 minutes, and then cooling from 95°C to 20°C at a rate of 1°C per minute using a thermal cycler. crRNA was synthesized using a T7 high-throughput transcription kit, and the reaction was carried out overnight at 37°C (for about 16 h). Then RNA was purified using the RNA purification and concentration kit, 10 quantified with NanoDrop 2000C, diluted to a concentration of 10 μ M, and stored in a refrigerator at -80°C.

2. Cas12a reaction: a 20 μ L reaction system was added with the crRNA (0.5 μ M) purified in step 1, a Cas12a (0.25 μ M), a target double-stranded DNA (target-T1, obtained by annealing primers target-T1-F to target-T1-R) (0.01 μ M), a fluorescence probe (HEX-N12-BHQ1) (0.5 μ M), 15 a buffer solution of NEB buffer 3.1, and 0.5 μ L of an RNase inhibitor. Reaction was conducted at 37°C for 15 min, and then terminated at 98°C for 2 min.

3. Fluorescence detection: 20 μ L of the inactivated reaction solution was added into a 96-well plate, and then detected by a microplate reader (with an excitation light at 535 nm and an emission light at 556 nm). As shown in FIG. 7, different Cas12as have different detection effects on the 20 target. LbCas12a and the like are better candidates of Cas12a proteins because the cleavage of the probe occurred only when the target double-stranded DNA was added.

Example 4 Testing of different concentrations of the target with FnCas12a and LbCas12a
 target-T1 was selected as the target DNA, and then diluted to different concentrations at a gradient to test the response sensitivity of FnCas12a and LbCas12a thereto. In order to increase the 25 sensitivity, a PCR amplification step was added.

1. Preparation of crRNA: first, a transcription template was prepared by annealing T7-crRNA-F to a synthesized oligonucleotide T7-T1-24-R (Table 5). Specifically, the paired oligonucleotide

(4 μ M) was annealed in a 1X PCR buffer (Transgen Biotech) at a total volume of 50 μ L, and then subjected to an annealing procedure: initially denaturing at 95°C for 5 minutes, and then cooling from 95°C to 20°C at a rate of 1°C per minute using a thermal cycler. crRNA was synthesized using a T7 high-throughput transcription kit, and the reaction was carried out overnight at 37°C 5 (for about 16 h). Then RNA was purified using the RNA purification and concentration kit, quantified with NanoDrop 2000C, diluted to a concentration of 10 μ M, and stored in a refrigerator at -80°C.

2. PCR amplification (optional): a plasmid containing the target target-T1 (pUC18-T1) was used as the template, diluted at a gradient, and then used for the PCR reaction. The total volume of 10 each reaction system was 20 μ L, 0.25 μ M of M13F-47 and M13R-48 each were used as primers (Table 4), and a high fidelity enzyme KOD FX (ToYoBo) was used for the PCR reaction. The PCR reaction procedure was 95°C for 2 min, and then starting 35 cycles of 98°C for 10 s, 60°C for 15 s, and 68°C for 10 s. After completion of the PCR, the PCR amplification product was directly used for a Cas12a reaction.

15 3. Cas12a reaction: a 20 μ L reaction system was added with the crRNA (0.5 μ M) purified in step 1, FnCas12a or LbCas12a (0.25 μ M), 1 μ L of a PCR product (or target DNAs that are directly diluted into different concentrations), a fluorescent probe (HEX-N12-BHQ1) (0.5 μ M), a buffer solution of NEB buffer 3.1, and 0.5 μ L of a RNase inhibitor. Reaction was conducted at 37°C for 15 min, and then terminated at 98°C for 2 min.

20 4. Fluorescence detection: 20 μ L of the inactivated reaction solution was added into a 96-well plate, and then detected by a microplate reader (with an excitation light at 535 nm and an emission light at 556 nm). As shown in FIG. 9, when the test target was directly added, all the target DNAs with a concentration above 0.1 nM could respond, and the response was remarkable when the concentration was above 1 nM. If a PCR technology was combined, i.e., amplification of the 25 fragment of interest through PCR followed by a Cas12a cleavage reaction, the response sensitivity could be as low as 10 aM.

Example 5 Testing of single-point mutant target with FnCas12a and LbCas12a

target-T1 was selected as the target, and it was subjected to single-point mutation in a PAM region and positions 1-18 respectively, so as to test response values of several crRNAs of different lengths to the wild type and the same after single-point mutation.

1. Preparation of crRNA: first, a transcription template was prepared by respectively annealing 5 T7-crRNA-F to synthesized oligonucleotides T7-T1-24-R, T7-T1-15-R, T7-T1-16-R, T7-T1-17-R, and T7-T1-18-R (Table 5). Specifically, the paired oligonucleotide (4 μ M) was annealed in a 1X PCR buffer (Transgen Biotech) at a total volume of 50 μ L, and then subjected to an annealing procedure: initially denaturing at 95°C for 5 minutes, and then cooling from 95°C to 20°C at a rate of 1°C per minute using a thermal cycler. crRNA was synthesized using a T7 high-throughput 10 transcription kit, and the reaction was carried out overnight at 37°C (for about 16 h). Then RNA was purified using the RNA purification and concentration kit, quantified with NanoDrop 2000C, diluted to a concentration of 10 μ M, and stored in a refrigerator at -80°C.

2. PCR amplification: a plasmid containing the target target-T1 (pUC18-T1) was used as the template. The total volume of each reaction system was 20 μ L, 0.25 μ M of the primer M13R-48 15 and respective mutation primers for Target-T1-F each were used (Table 4), and a high fidelity enzyme KOD FX (ToYoBo) was used for the PCR reaction. The PCR reaction procedure was 95°C for 2min, and then starting 35 cycles of 98°C for 10 s, 60°C for 15 s, and 68°C for 10 s. After completion of the PCR, the product was directly used for a Cas12a reaction.

3. Cas12a reaction: a 20 μ L reaction system was added with the crRNA (0.5 μ M) purified in 20 step 1, FnCas12a or LbCas12a (0.25 μ M), 1 μ L of a PCR product, a fluorescent probe (HEX-N12-BHQ1) (0.5 μ M), a buffer solution of NEB buffer 3.1, and 0.5 μ L of a RNase inhibitor. Reaction was conducted at 37°C for 15 min, and then terminated at 98°C for 2 min.

4. Fluorescence detection: 20 μ L of the inactivated reaction solution was added into a 96-well plate, and then detected by a microplate reader (with an excitation light at 535 nm and an emission 25 light at 556 nm). As shown in FIG. 10, when the complementary sequence of the target was a crRNA of 24 nt (crRNA-24nt), the single-point mutations at the positions 8-18 were not much different from the wild type, while the fluorescence value decreased obviously after the PAM

mutation and the point mutation of positions 1-7. When the crRNA was truncated and the length of a paired target sequence was 18 nt, the fluorescence value of the mutation positions of 8-16 nt was obviously decreased compared with that of 24 nt; when the length was 16 nt or 17 nt, the decrease of the fluorescence value of the mutated target sequence is more obvious; and when the 5 length was 15 nt, the fluorescence values of both the target sequence and the mutated target sequence were very weak, but the fluorescence intensity of the mutated target sequence might still be higher as compared with those of other target sequences, and thus could be used for detection. Taken together, the crRNAs of 15 nt, 16 nt and 17 nt are the most suitable for SNP detection.

Example 6 Testing of *Escherichia coli* and the like microorganisms in environmental 10 water

The gyrB gene of *Escherichia coli* was selected as the detection target to indirectly test the concentrations of *Escherichia coli* and the like microorganisms in water. Taking *Escherichia coli* MG1655 as a positive control, the content of microorganisms in water (such as sewage and tap water) in the environment was determined.

15 1. Preparation of crRNA: first, a transcription template was prepared by annealing T7-crRNA-F to a synthesized oligonucleotide T7-crRNA-gyrB (Table 5). Specifically, the paired oligonucleotide (4 μ M) was annealed in a 1X PCR buffer (Transgen Biotech) at a total volume of 50 μ L, and then subjected to an annealing procedure: initially denaturing at 95°C for 5 minutes, and then cooling from 95°C to 20°C at a rate of 1°C per minute using a thermal cycler. crRNA was 20 synthesized using a T7 high-throughput transcription kit, and the reaction was carried out overnight at 37°C (for about 16 h). Then RNA was purified using the RNA purification and concentration kit, quantified with NanoDrop 2000C, diluted to a concentration of 10 μ M, and stored in a refrigerator at -80°C.

25 2. PCR amplification: when the positive control sample *Escherichia coli* MG1655 was cultured until the OD₆₀₀ was about 0.5, it was diluted at a 10-fold gradient respectively, and then used as the template, and the sample was ambient water (including tap water and muddy water in the environment). The total volume of each reaction system was 20 μ L, 0.25 μ M of primers gyrB-F

and *gyrB-R* each were used (Table 4), and a high fidelity enzyme KOD FX (ToYoBo) was used for the PCR reaction. The PCR reaction procedure was 95°C for 2 min, and then starting 35 cycles of 98°C for 10 s, 60°C for 15 s, and 68°C for 10 s. After completion of the PCR, the PCR product was directly used for a Cas12a reaction.

5 3. Cas12a reaction: a 20 μ L reaction system was added with the crRNA (0. 5 μ M) purified in step 1, LbCas12a (0.25 μ M), 1 μ L of a PCR product, a fluorescence probe (HEX-N12-BHQ1) (0.5 μ M), a buffer solution of NEB buffer 3.1, and 0.5 μ L of an RNase inhibitor. Reaction was conducted at 37°C for 15 min, and then terminated at 98°C for 2 min .

10 4. Fluorescence detection: 20 μ L of the inactivated reaction solution was added into a 96-well plate, and then detected by a microplate reader (with an excitation light at 535 nm and an emission light at 556 nm). As shown in FIG. 13, the fluorescence response value of *Escherichia coli* MG1655 decreases with the concentration decrease. Among them, microorganisms were detected more obviously in samples 2, 4, 5 and 6.

Example 7 Testing of Human SNP

15 The SNP test selected 5 sites of human SNP, namely rs5082, rs1467558, rs2952768, rs4363657, and rs601338, to test the feasibility of the HOLMES method.

1. Preparation of crRNA: first, a transcription template was prepared by annealing T7-crRNA-F to a synthesized oligonucleotide (Table 5). Specifically, the paired oligonucleotide (4 μ M) was annealed in a 1X PCR buffer (Transgen Biotech) at a total volume of 50 μ L, and then subjected to 20 an annealing procedure: initially denaturing at 95°C for 5 minutes, and then cooling from 95°C to 20°C at a rate of 1°C per minute using a thermal cycler. crRNA was synthesized using a T7 high-throughput transcription kit, and the reaction was carried out overnight at 37°C (for about 16 h). RNA was purified using the RNA Clean & ConcentratorTM-5 (Zymo Research), quantified with NanoDrop 2000C, diluted to a concentration of 10 μ M, and stored in a refrigerator at -80°C.

25 2. PCR amplification: the total volume of the reaction system was 20 μ L, 0.25 μ M of primers each were used (table 4), 1 ng of a human genome (HEK293T) or directly-scraped oral epithelial mucosa was used as the template, and a high fidelity enzyme KOD FX (ToYoBo) was used for the

PCR reaction. The PCR reaction procedure was 95°C for 2 min, and then starting 35 cycles of 98°C for 10 s, 60°C for 15 s, and 68°C for 10 s. After completion of the PCR, the product was directly used for a Cas12a reaction. (Primers 1-rs5082-F-T, 2-rs1467558-F-T, and 3-rs2952768-R-C were directly introduced to the corresponding mutation products of the SNP)

5 3. Cas12a reaction: a 20 μ L reaction system was added with corresponding crRNA (1 μ M), LbCas12a (0.5 μ M), 1 μ L of a PCR product, and a fluorescent probe (HEX-N12-BHQ1) (0.5 μ M). Reaction was conducted at 37°C for 15 min, and then terminated at 98°C for 2 min .

10 4. Fluorescence detection: 20 μ L of the inactivated reaction solution was added into a 96-well plate, and then detected by a microplate reader (with an excitation light at 535 nm and an emission light at 556 nm). As shown in FIG. 14, only when the crRNA corresponded to the corresponding target sequence, there would be a higher fluorescence response value, and if there was one point mutation, its response value would be greatly reduced. The genotype of the corresponding SNP could be determined by the fluorescence value, and these results were confirmed by sequencing results.

15 **Example 8 Testing of a cancer-related gene**

A TP53 gene was selected as the test gene. TP53 gene has a nonsense mutation in a human T24 cell, which leads to inactivation of the gene. A cell with normal gene at this site (HEK293T), an individual gene and a mutant cell T24 were tested respectively.

1. Preparation of crRNA: first, a transcription template was prepared by annealing T7-crRNA-F to synthesized oligonucleotides T7-crRNA-34-TP53-T24-C-16nt and T7-crRNA-34-TP53-T24-G-16nt (Table 5). Specifically, the paired oligonucleotide (4 μ M) was annealed in a 1X PCR buffer (Transgen Biotech) at a total volume of 50 μ L, and then subjected to an annealing procedure: initially denaturing at 95°C for 5 minutes, and then cooling from 95°C to 20°C at a rate of 1°C per minute using a thermal cycler. crRNA was synthesized using a T7 high-throughput transcription kit, and the reaction was carried out overnight at 37°C (for about 16 h). RNA was purified using the RNA Clean & ConcentratorTM-5 (Zymo Research), quantified with NanoDrop 2000C, diluted to a concentration of 10 μ M, and stored in a refrigerator at -80°C.

2. PCR amplification: the total volume of the reaction system was 20 μ L, 0.25 μ M of primers 34-TP53-T24-F and 34-TP53-T24-R each were used (Table 4), 1 ng of a human genome (HEK293T, T24) or directly-scraped oral epithelial mucosa was used as the template, and a high fidelity enzyme KOD FX (ToYoBo) was used for the PCR reaction. The PCR reaction procedure 5 was 95°C for 2 min, and then starting 35 cycles of 98°C for 10 s, 60°C for 15 s, and 68°C for 10 s. After completion of the PCR, the product was directly used for a Cas12a reaction.

3. Cas12a reaction: a 20 μ L reaction system was added with corresponding crRNA (1 μ M), LbCas12a (0.5 μ M), 1 μ L of a PCR product, and a fluorescent probe (HEX-N12-BHQ1) (0.5 μ M). Reaction was conducted at 37°C for 15 min, and then terminated at 98°C for 2 min .

10 4. Fluorescence detection: 20 μ L of the inactivated reaction solution was added into a 96-well plate, and then detected by a microplate reader (with an excitation light at 535 nM and an emission light at 556 nM). As shown in FIG. 15, when the TP53 gene that was normal at this site was the template, the detected value of crRNA-C was significantly higher than that of crRNA-G, while the crRNA-G of the mutant cell T24 was significantly increased.

15 **Example 9 Testing of Human SNP (Gout-Related Genes)**

The SNP test selected 5 sites of human SNP that were related to a gout risk, namely rs1014290, rs6449213, rs737267, rs1260326, and rs642803, to test the HOLMES method.

1. Preparation of crRNA: first, a transcription template was prepared by annealing T7-crRNA-F to a synthesized oligonucleotide (Table 5). Specifically, the paired oligonucleotide (4 μ M) was 20 annealed in a 1X PCR buffer (Transgen Biotech) at a total volume of 50 μ L, and then subjected to an annealing procedure: initially denaturing at 95°C for 5 minutes, and then cooling from 95°C to 20°C at a rate of 1°C per minute using a thermal cycler. crRNA was synthesized using a T7 high-throughput transcription kit, and the reaction was carried out overnight at 37°C (for about 16 h). RNA was purified using the RNA Clean & ConcentratorTM-5 (Zymo Research), quantified with 25 NanoDrop 2000C, diluted to a concentration of 10 μ M, and stored in a refrigerator at -80°C.

2. PCR amplification: the total volume of the reaction system was 20 μ L, 0.25 μ M of primers each were used (Table 4), 1 ng of a human genome (HEK293T) or directly-scraped oral epithelial

mucosa was used as the template, and a high fidelity enzyme KOD FX (ToYoBo) was used for the PCR reaction. The PCR reaction procedure was 95°C for 2 min, and then starting 35 cycles of 98°C for 10 s, 60°C for 15 s, and 68°C for 10 s. After completion of the PCR, the product was directly used for a Cas12a reaction. (Primers 1-rs5082-F-T, 2-rs1467558-F-T, and 3-rs2952768-

5 R-C were directly introduced to the corresponding mutation products of the SNP)

3. Cas12a reaction: a 20 μ L reaction system was added with the corresponding crRNA (1 μ M), LbCas12a (0.5 μ M), 1 μ L of a PCR product, and a fluorescence probe (HEX-N12-BHQ1) (0.5 μ M). Reaction was conducted at 37°C for 15 min, and then terminated at 98°C for 2 min .

4. Fluorescence detection: 20 μ L of the inactivated reaction solution was added into a 96-well plate, and then detected by a microplate reader (with an excitation light at 535 nm and an emission light at 556 nm). As shown in FIG. 16, only when the crRNA corresponded to the corresponding target sequence, there would be a higher fluorescence response value, and if there was one point mutation, its response value would be greatly reduced. The genotype of the corresponding SNP could be determined by the fluorescence value, and these results were confirmed by sequencing 15 results.

Example 10 SNP Testing of clinical samples of volunteers (a gout related gene) by a kit

A pre-mixed solution was added into a 96-well plate to prepare a kit, and then the kit was added with genomic DNAs of 21 volunteers to test the rs1014290 site, which was related to a gout risk.

1. Preparation of a kit: first, a transcription template was prepared by annealing T7-crRNA-F 20 to a synthesized oligonucleotide (Table 5). Specifically, the paired oligonucleotide (4 μ M) was annealed in a 1X PCR buffer (Transgen Biotech) at a total volume of 50 μ L, and then subjected to an annealing procedure: initially denaturing at 95°C for 5 minutes, and then cooling from 95°C to 20°C at a rate of 1°C per minute using a thermal cycler. crRNA was synthesized using a T7 high-throughput transcription kit, and the reaction was carried out overnight at 37°C (for about 16 h). 25 RNA was purified using the RNA Clean &ConcentratorTM-5 (Zymo Research), quantified with NanoDrop 2000C, and diluted to a concentration of 10 μ M.

2. Pre-mixing in a 96-well plate for PCR: a 19 μ L system was added with reagents required for

a PCR reaction, the primers being 41-rs1014290-F and 41-rs1014290-R.

3. Pre-mixing in a 96-well plate for fluorescence detection: the 19 μ L system was added with a crRNA (1 μ M), LbCas12a (0.5 μ M) and a fluorescence probe (HEX-N12-BHQ1) (0.5 μ M) and was added in the 96-well plate.

5 4. PCR amplification: the pre-mixed 96-well plate for PCR was added with the genomic DNAs of the volunteers, and then subjected to the PCR reaction. The PCR reaction procedure was 95°C for 2min, and then starting 35 cycles of 98°C for 10 s, 60°C for 15 s, and 68°C for 10 s.

5. Cas12a reaction: 1 μ L of a PCR reaction solution was taken and added into the pre-mixed 96-well plate for fluorescence detection, reacted at 37°C for 15 min, and then the reaction was 10 terminated at 98°C for 2 min.

6. Fluorescence detection: it was detected by a microplate reader (with an excitation light at 535 nm and an emission light at 556 nm). As shown in FIG. 17, because a population with a genotype A:A had a higher risk of gout, people other than volunteers Nos. 5, 7 and 9 are of the genotype A:G or G:G, so more attention should be paid to the risk of gout.

15 **Example 11 Detection of *Escherichia coli* and the like microorganisms in environmental water by LAMP combined with a Cas protein**

The gyrB gene of *Escherichia coli* was selected as the detection target to indirectly test whether *Escherichia coli* or the like microorganisms exist in water.

1. Preparation of crRNA: first, a transcription template was prepared by annealing T7-crRNA-F 20 to a synthesized oligonucleotide T7-crRNA-gyrB (Table 5). Specifically, the paired oligonucleotide (4 μ M) was annealed in a 1 X Taq DNA polymerase reaction buffer (Transgen Biotech) at a total volume of 50 μ L, and then subjected to an annealing procedure: initially denaturing at 95°C for 5 minutes, and then cooling from 95°C to 20°C at a rate of 1°C per minute using a thermal cycler. crRNA was synthesized using a T7 high-throughput transcription kit, and 25 the reaction was carried out overnight at 37°C (for about 16 h). Then RNA was purified using the RNA purification and concentration kit, quantified with NanoDrop 2000C, finally diluted to a concentration of 10 μ M, and stored in a refrigerator at -80°C for later use.

2. LAMP amplification: sterile water and a contaminated liquid containing *Escherichia coli* were used as a negative control and a sample to be detected respectively. The total volume of each reaction system was 25 μ L, primers of 1.6 μ M of LAMP-FIP and LAMP-BIP each, 0.2 μ M of LAMP-F3 and LAMP-B3 each, 0.4 μ M of LAMP-LoopF and LAMP-LoopB each were used, and 5 the kit used for the LAMP reaction was a WarmStart[®] LAMP Kit (NEB). The LAMP reaction procedure was 65°C for 30 min. After the LAMP was completed, annealing was conducted at 80°C for 10 min, and then the product was directly used for a Cas12a reaction.

3. Cas12a reaction: a 20 μ L reaction system was added with the crRNA (0.5 μ M) purified in step 1, a Cas12a (0.25 μ M), 1 μ L of a LAMP product, a fluorescence probe (HEX-N12-BHQ1) 10 (0.5 μ M), a buffer solution of NEB buffer 3.1, and 0.5 μ L of a RNase inhibitor. Reaction was conducted at 37°C for 15 min.

4. Fluorescence detection: 20 μ L of the inactivated reaction solution was added into a 96-well plate, and then detected by a microplate reader (with an excitation light at 535 nm and an emission light at 556 nm). The results were as shown in FIG. 19.

15 **Example 12 Detecting SNP by using LAMP amplification combined with a Cas protein**

1. Preparation of crRNA: first, a transcription template was prepared by annealing T7-crRNA-F to a synthesized oligonucleotide T7-crRNA-rs5082-T/T7-crRNA-rs5082-G/T7-crRNA-rs1467558-T/T7-crRNA-rs14 67558-C (Table 5). Specifically, the paired oligonucleotide (4 μ M) was annealed in a 1 X Taq DNA polymerase reaction buffer (Transgen Biotech) at a total volume 20 of 50 μ L, and then subjected to an annealing procedure: initially denaturing at 95°C for 5 minutes, and then cooling from 95°C to 20°C at a rate of 1°C per minute using a thermal cycler. crRNA was synthesized using a T7 high-throughput transcription kit, and the reaction was carried out overnight at 37°C (for about 16 h). Then RNA was purified using the RNA purification and concentration 25 kit, quantified with NanoDrop 2000C, finally diluted to a concentration of 10 μ M, and stored in a refrigerator at -80°C for later use.

2. LAMP amplification: a human genome HEK293T was taken as a sample. The total volume of each reaction system was 25 μ L, primers of 1.6 μ M of LAMP-FIP and LAMP-BIP each, 0.2 μ M

of LAMP-F3 and LAMP-B3 each, 0.4 μ M of LAMP-LoopF and LAMP-LoopB each were used, and a WarmStart[®] LAMP Kit (NEB) was used for a LAMP reaction. The LAMP reaction procedure was 65°C for 30 min. After the LAMP was completed, annealing was conducted at 80°C for 10 min, and then the product was directly used for a Cas12a reaction.

5 3. Cas12a reaction: a 20 μ L reaction system was added with the crRNA (0.5 μ M) purified in step 1, a Cas12a (0.25 μ M), 1 μ L of a LAMP product, a fluorescence probe (HEX-N12-BHQ1) (0.5 μ M), a buffer solution of NEB buffer 3.1, and 0.5 μ L of a RNase inhibitor. Reaction was conducted at 37°C for 15 min.

10 4. Fluorescence detection: 20 μ L of the inactivated reaction solution was added into a 96-well plate, and then detected by a microplate reader (with an excitation light at 535 nm and an emission light at 556 nm). The results were as shown in FIG. 20.

Example 13 Detection of *Escherichia coli* and the like microorganisms in environmental water by RPA amplification combined with a Cas protein

The gyrB gene of *Escherichia coli* was selected as the detection target to indirectly test whether 15 *Escherichia coli* and the like microorganisms exist in water.

1. Preparation of crRNA: first, a transcription template was prepared by annealing T7-crRNA-F to a synthesized oligonucleotide T7-crRNA-gyrB (Table 5). Specifically, the paired oligonucleotide (4 μ M) was annealed in a 1X PCR buffer (Transgen Biotech) at a total volume of 50 μ L, and then subjected to an annealing procedure: initially denaturing at 95°C for 5 minutes, 20 and then cooling from 95°C to 20°C at a rate of 1°C per minute using a thermal cycler. crRNA was synthesized using a T7 high-throughput transcription kit, and the reaction was carried out overnight at 37°C (for about 16 h). Then RNA was purified using the RNA purification and concentration kit, quantified with NanoDrop2000C, finally diluted to a concentration of 10 μ M, and stored in a refrigerator at -80°C for later use.

25 2. RPA amplification: sterile water and a contaminated liquid containing *Escherichia coli* were used as a negative control and a sample to be detected respectively. The total volume of each reaction system was 25 μ L, 0.5 μ M of primers RPA-gyrB-F (or RPA-gyrB-F2) and RPA-gyrB-R2

each were used, and a TwistAmp® Basic kit (TwistDX) was used for the RPA reaction. The RPA reaction procedure was 37°C for 30 min. After the RPA was completed, annealing was conducted at 80°C for 10 min, and then the product was directly used for a Cas12a reaction.

3. Cas12a reaction: a 20 μ L reaction system was added with the crRNA (0.5 μ M) purified in 5 step 1, a Cas12a (0.25 μ M), 1 μ L of a RPA product, a fluorescence probe (HEX-N12-BHQ1) (0.5 μ M), a buffer solution of NEB buffer 3.1, and 0.5 μ L of a RNase inhibitor. Reaction was conducted at 37°C for 15 min.

4. Fluorescence detection: 20 μ L of the inactivated reaction solution was added into a 96-well plate, and then detected by a microplate reader (with an excitation light at 535 nm and an emission 10 light at 556 nm). The results were as shown in FIG. 21.

Example 14: Cas12b having a collateral cleavage activity

1. Preparation of a guide RNA (sgRNA)

Firstly, a plasmid pUC18-guide RNA-T1 was constructed by using pUC18 as the skeleton of 15 the plasmid. In the plasmid, a T7 promoter and a template DNA sequence for transcription of the guide RNA were inserted on the pUC18 (Note: the guide RNA transcribed from this template targeted a sequence called T1 in this study). The method was firstly carrying out a round of PCR by using the pUC18 plasmid as a template and PUC18-1-F and pUC18-1-R as primers; linking PCR products with a T4 DNA Ligase, transforming the product into DH10b, and sequencing to obtain the correct clone, which was called pUC18-guide RNA-T1-pre. Then, a second round of 20 PCR was carried out by using the pUC18-guide RNA-T1-pre as a template and pUC18-2-F and pUC18-2-R as primers, linking and transforming the PCR products in the same way, to finally obtain the plasmid pUC18-guide RNA-T1 which was correct as sequenced.

Next, by using the plasmid pUC18-guide RNA-T1 as a template, a guide RNA was synthesized 25 using a T7 high-throughput transcription kit (Thermo), and the reaction was carried out overnight at 37°C (for 12-16 h).

Finally, the transcription system was added with a DNase I (2 μ L of the DNase I was added per 50 μ L of the transcription system), subjected to a water bath at 37°C for 30 min to eliminate a

plasmid DNA, and the RNA was purified using the RNA purification and concentration kit, quantified with the NanoDrop 2000C, diluted to a concentration of 10 μ M, and stored in a refrigerator at -80°C for later use.

2. Preparation of a Target DNA

5 (1) If the target DNA was a single strand, a 66 bp long oligonucleotide was directly synthesized as the target DNA (target-T1-R), which contained the 20 bp target sequence (T1) recognized by the guide RNA.

(2) If the target DNA was double-stranded, two 66 bp long complementary oligonucleotides (target-T1-F; target-T1-R) were directly synthesized, which contained the 20 bp target sequence

10 (T1) identified by the guide RNA. The two oligonucleotides were annealed to obtain a short target DNA. Specifically, the paired oligonucleotide (1 μ M) was annealed in a 1X PCR buffer (Transgen Biotech) at a total volume of 20 μ L, and then subjected to an annealing procedure: initially denaturing at 95°C for 5 minutes, and then cooling from 95°C to 20°C at a rate of 1°C per minute using a thermal cycler.

15 3. Cas12b reaction

(1) annealing of the guide RNA: the guide RNA was diluted to an appropriate concentration (10 μ M), and annealed in the PCR instrument. The annealing procedure: denaturing at 75°C for 5 min, and then cooling from 75°C to 20°C at a decreasing rate of 1°C per minute.

20 (2) incubation of the guide RNA with C2c1: the annealed guide RNA was mixed with C2c1 at an equal molar concentration, and allowed to stand at 30°C for 20-30 min.

(3) Cas12b reaction: a 20 μ L reaction system was added with a mixture of the guide RNA and C2c1 incubated in step (2) (the final concentrations of them were both 250 μ M or 500 μ M), a target DNA (with a final concentration of 50 nM), a FAM-labeled oligonucleotide (target-DNMT1-3-R-FAM-5') or a fluorescence quenching probe (HEX-N12-BHQ1 with the final concentration of 500 nM), 2 μ L of a 10 X NEB Buffer 3.1, and 0.5 μ L of an RNase inhibitor (40 U/ μ L). After mixing homogeneously, the reaction was conducted at 48°C for 30 min. After that, it was inactivated by heating at 98°C for 5 min in a PCR instrument.

4. Detection of trans-cleavage activity of Cas12b by urea-denatured gel electrophoresis: 20 μ L of the inactivated reaction solution was separated by a urea-denatured gel electrophoresis method, and then imaged by a fluorescence imaging system ImageQuant LAS 4000 mini (GE Healthcare). The results were as shown in FIG. 22.

5 5. Detection of trans-cleavage activity of Cas12b by a fluorescence microplate reader method: 20 μ L of the inactivated reaction solution was added into a 96-well plate, and detected by a microplate reader (with an excitation light at 535 nm and an emission light at 556 nm). The results were as shown in FIG. 23.

Example 15: Sensitivity testing of a Cas12b reaction (trans-cleavage)

10 By detecting the excited fluorescence intensity of the fluorescence probe (HEX-N12-BHQ1), the target DNA concentration required for Cas12b to exert the trans-cleavage activity, i.e., the sensitivity of a Cas12b trans-cleavage reaction, was determined.

1. Preparation of a guide RNA

Firstly, by using the pUC18-guide RNA-T1 as a template and guide RNA-DNMT1-3-F and 15 guide RNA-DNMT1-3-R as primers, 20 bases of the guide RNA that target the target DNA of T1 were replaced by a guide RNA targeting DNMT1-3 through PCR, so as to obtain another plasmid pUC18-guide RNA-DNMT1-3.

Then, by using the plasmid pUC18-guide RNA-DNMT1-3 as a template, a guide RNA was synthesized using a T7 high-throughput transcription kit (Thermo), and the reaction was carried 20 out overnight at 37°C (for 12-16 h).

Finally, the transcription system was added with a DNase I (2 μ L of the DNase I was added per 50 μ L of the transcription system), subjected to a water bath at 37°C for 30min to eliminate a plasmid DNA, and the RNA was purified using the RNA purification and concentration kit, quantified with the NanoDrop 2000C, and stored in a refrigerator at -80°C for later use.

25 **2. Preparation of a Target DNA**

For the target DNA, the first one is that the target DNA was directly added into a Cas12b reaction system without amplification. The method was as follows:

(1) If the target DNA was a single strand, a 50 bp long oligonucleotide was directly synthesized as the target DNA (DNMT1-3 (TTC PAM)-R), which contained the 20 bp target sequence (DNMT1-3) recognized by the guide RNA.

(2) If the target DNA was double-stranded, two 50 bp long complementary oligonucleotides 5 (DNMT1-3 (TTC PAM)-F; DNMT1-3 (TTC PAM)-R) were directly synthesized, which contained the 20 bp target sequence (DNMT1-3) recognized by the guide RNA. The two oligonucleotides were annealed to obtain a short target DNA. Specifically, the paired oligonucleotide (2 μ M) was annealed in a 1X PCR buffer (Transgen Biotech) at a total volume of 20 μ L, and then subjected to an annealing procedure: denaturing at 95°C for 5 minutes, and then cooling from 95°C to 20°C at 10 a rate of 1°C per minute using a thermal cycler.

(3) the single-stranded or double-stranded target DNA was diluted at a gradient to 2 μ M, 0.2 μ M, 0.02 μ M, 0.002 μ M and 0.0002 μ M for later use.

The second one was inserting a fragment containing the target sequence (DNMT1-3) into a plasmid vector for amplification by the LAMP reaction.

15 (1) the fragment containing the target sequence (DNMT1-3) was inserted into a pEasy-Blunt Zero Cloning Vector using a pEasy-Blunt Zero Cloning Kit from Transgen, so as to obtain the correct clone after verified by sequencing.

(2) A LAMP expansion reaction

Using the above plasmid as a template, the LAMP amplification reaction was carried out. The 20 templates were added respectively at 0 nM, 1 nM, and 0.1 nM, and diluted at a 10-fold gradient to 10^{-11} nM. The total volume of each reaction system was 25 μ L, primers of 1.6 μ M of LAMP-DNM-FIP and LAMP-DNM-BIP each, 0.2 μ M of LAMP-DNM-F3 and LAMP-DNM-B3 each, 0.4 μ M of LAMP-DNM-LoopF and LAMP-DNM-LoopB each were used, and the kit used for the LAMP reaction was the WarmStart® LAMP Kit (NEB). The LAMP reaction procedure was 65°C 25 for 30 min. After the LAMP was completed, inactivation was conducted at 80°C for 10 min, and then the product was directly used for a Cas12b reaction.

3. Cas12b reaction

(1) annealing of the guide RNA: the guide RNA was diluted to an appropriate concentration (5 μ M), and annealed in the PCR instrument. The annealing procedure: denaturing at 75°C for 5 min, and then cooling from 75°C to 20°C at a decreasing rate of 1°C per minute.

(2) incubation of the guide RNA with Cas12b: the annealed guide RNA was mixed with Cas12b 5 at an equal molar concentration, and allowed to stand at 30°C for 20-30 min.

(3) Cas12b reaction: a 20 μ L reaction system was added with the mixture of the guide RNA and Cas12b incubated in step (2) (the final concentrations of the guide RNA and Cas12b were both 250 μ M), 1 μ L of a target DNA or 1 μ L of a LAMP product, a fluorescence probe (HEX-N12-BHQ1) (with a final concentration of 500 nM), 2 μ L of a 10X NEB Buffer 3.1, and 0.5 μ L of an 10 RNase inhibitor (40 U/ μ L). After mixing homogenously, the reaction was conducted at 48°C for 30min. After that, it was inactivated fire heating at 98°C for 5 min in a PCR instrument.

4. Detection of trans-cleavage activity of Cas12b by a fluorescence microplate reader method:

20 μ L of the inactivated reaction solution was added into a 96-well plate, and detected by a microplate reader (with an excitation light at 535 nm and an emission light at 556 nm). Combined 15 with the LAMP amplification, Cas12b could produce a significant collateral single-stranded DNA trans-cleavage activity for a target DNA concentration as low as 10 aM. The results were as shown in FIG. 24.

Cis-cleavage characteristics of Cas12a in cleaving a target single-stranded DNA:

First, in order to test the single-stranded DNA cleavage characteristics of Cas12a, several 20 crRNAs targeting a short single-stranded DNA (DNMT1-3) (Table 1) are designed, which are labeled with 5(6)-carboxyfluorescein (FAM) at the 3' terminal. After the cleavage by FnCas12a, the reaction product is analyzed by denatured urea-polyacrylamide gel electrophoresis (urea-PAGE). It is found that the single strand DNA cleavage by Cas12a is programmed. That is, the 25 cleavage site is near the 22nd base (21st to 23rd bases) of the target sequence counted from the 3' end base to the 5' end of the first target sequence paired with the crRNA guide sequence, as shown in FIGs. 1A and 1C. The cleavage of a double-stranded DNA by Cas12a requires a PAM sequence, while the cleavage of a single-stranded DNA by Cas12a does not require the PAM sequence (FIGs.

1A, 1B and 2), which is similar to the single-stranded DNA cleavage mediated by Cas9. However, the single-stranded DNA cleavage activity mediated by Cas12a depends on a stem-loop structure in crRNA, as shown in FIG. 1A, while Cas9 still shows weak cleavage activity for a single-stranded DNA with only a 20-nt complementary RNA sequence. The stem-loop structure of the 5 crRNA is important for stabilizing the structure of Cas12a, which is the reason why the ring structure of the crRNA is necessary for the cleavage of the single-stranded DNA by Cas12a. It is further tested whether a shorter lead sequence crRNA can pass through the single-stranded DNA cleavage site of Cas12a in such a manner that the cleavage is outside the recognition site. When the length of the guide sequence is 16 nt, 18 nt and 20 nt, all of these crRNAs lead to cleavage by 10 Cpf1 near the 22nd base, as shown in FIGs. 1B and 1D, meaning that the cleavage site is 4 nt, 2 nt or 0 nt outside the recognition site. Next, the cleavage efficiency of Cas12a on different substrates is tested by using substrates of a double-stranded DNA and a single-stranded DNA respectively, as shown in FIG. 1F. Similar to the situation of Cas9 cleavage, the cleavage of the single-stranded DNA is slower than that of the double-stranded DNA, as shown in FIGs. 1E to 1G. These results 15 indicate that the mechanism of recognizing and cleaving a single-stranded DNA by Cas12a may be different from that of a double-stranded DNA, which is a low-efficiency recognition and cleavage manner independent of PAM; and the PAM sequence accelerates the recognition and/or cleavage of the target double-stranded DNA by Cas12a.

Trans-cleavage characteristics of Cas12a in cleaving a single-stranded DNA:

20 When the target single-stranded DNA is labeled at the 3' terminal, Cas12a cleaves at the vicinity of the 22nd base, as shown in FIG. 1. However, when it is labeled at the 5' terminal, no cleavage product band of predicted size is observed, but a short (< 6 nt) FAM-labeled product is produced, as shown in FIG. 3B. Through detailed experiments, once the ternary complex Cas12a/crRNA/target single-stranded DNA is formed, the target single-stranded DNA (DNMT1- 25 3) (Table 1) labeled at 5'-terminal is cleaved, and a short FAM-labeled product is produced, as shown in FIG. 3C. In addition, the ternary complex also cleaves a single-stranded DNA that has no sequence that is complementary with the crRNA (i.e., a collateral single-stranded DNA) in any

other reaction system, as shown in FIGs. 3C and 3D. This cleavage phenomenon is called trans-cleavage, which is different from programmable cis-cleavage. When the target single-stranded DNA is labeled at the 3' terminal, trans-cleavage is also observed, but many cis-cleavage products are left, as shown in FIG. 3B, This may be due to the complex formed by Cas12a/crRNA/target 5 single-stranded DNA, and the target single-stranded DNA is protected, such that its labeled 3' terminal is protected from exposure to a nuclease active site of the ternary complex. These cleavage processes can be as shown in FIG. 3A.

In addition to the FnCas12a tested above, 9 Cas12as from other species sources are also tested (Table 2 and FIG. 4A). Except Lb4Cas12a, all Cas12as have good endonuclease activity to the 10 plasmid DNA (as shown in FIG. 4B), and all Cas12a ternary complexes show cis and trans cleavage activities on the single strand (as shown in FIGs. 4C and 4D). This shows that cis and trans activity of Cas12a on the single-stranded DNA is a common phenomenon.

The cis and trans key sites and mechanism for cleaving a single-stranded DNA by Cas12a.

In order to determine the key amino acid residues related to cis and trans activities on the 15 single-stranded DNA in Cas12a, several candidate residues of Cas12a are mutated to conduct the activity test. First, three single-amino-acid mutants of FnCas12a (H843A, K852A and K869A) are purified and tested, and their residues are related to an RNase activity. The results of the study of the trans-activity on the single-stranded DNA show that no obvious difference in cis- and trans-cleavage activities on the single-stranded DNA between the wild-type FnCas12a and the three 20 mutants is found, as shown in FIGs. 5A and 5C.

Next, when endonuclease active sites in the FnCas12a, i.e., the RuvC domain (D917A, E1006A or D1255A) and the Nuc domain (R1218A) sites are mutated, the cis and trans cleavage activities of these mutated Cas12a on the single-stranded DNA are both affected, as shown in FIGs. 5B and 5D. These results indicate that the key site of Cas12a for cleavage of a target double-stranded 25 DNA is closely related to cis and trans cleavage activities on the single-stranded DNA.

Recent structural studies of Cas12b (i.e., C2c1) (including complexes with an extended target DNA or an extended non-target DNA) show that both strands are located in an RuvC pocket, as shown in FIGs. 6A and 6B. By comparing the endonuclease catalytic residues of Cas12b (i.e. C2c1) and Cas12a, these sites are most likely to play similar roles in the cleavage and functions of

5 Cas12b (i.e., C2c1) and Cas12a. The results of an in vitro single amino acid mutation experiment show that it is consistent with the above hypothesis. That is, Cas12a is likely to cleave two strands

t h r o u g h o n l y o n e R u v C c a t a l y t i c p o c k e t .

The trans-cleavage activity of a Cas12a complex: in the structure of a complex of Cas12b (i.e., C2c1) with an additional single-stranded DNA, a sequence-independent single-stranded DNA is

10 also located on the surface of a catalytic pocket, as shown in FIG. 6C, which is similar to that of a collateral single-stranded DNA substrate in Cas12a. Combined with a single-amino-acid mutation experiment, it is proposed that the target DNA, non-target DNA and collateral single-stranded DNA are all cleaved in the single RuvC pocket in Cas12a, as shown in FIGs. 6D, 6E and 6F. The ternary Cas12a complex has a collateral single-stranded DNA trans-cleavage activity, while the

15 reason why a monomer or a binary complex does not have the collateral single-stranded DNA trans-cleavage activity can be explained by comparing the structures of the monomer, binary and ternary complexes. The structure of a monomer Cas12a is disordered, the binary complex Cas12a/crRNA has a triangular structure, as shown in FIG. 6G, while the ternary complex Cas12a/crRNA/target DNA is converted into a double-leaf structure, thus exposing the catalytic

20 pocket to realize trans-cleavage of the collateral single-stranded DNA (as shown in FIG. 6H).

Establishment of a nucleic acid detection method

Based on the characteristics of Cas12a, a specific nucleic acid molecule detection method was developed, which was called HOLMES (one HOur Low-cost Multipurpose Efficient Simple assay). Just like the name of the technology, it was characterized by a simple test method that is

25 one hour and has low cost, multiple uses and high efficiency.

In the whole reaction system, the method can be divided into two major steps, one is the amplification of a template nucleic acid, and the other is the specific nucleic acid detection by a Cas12a protein. Here, a PCR method is used for nucleic acid amplification, but in fact, any amplification method can be combined with the nucleic acid detection in the second step, such as

5 the isothermal amplification method RPA, etc. The initial nucleic acid is not limited to a double-stranded DNA, but may also be a single-stranded DNA; or even an RNA still can be detected after reverse transcription, so this method is suitable for various types of nucleic acid molecules. For the nucleic acid detection phase, three components are the keys to the experiment, namely Cas12a, crRNA and a nucleic acid probe. In addition to the 10 Cas12as mentioned in the example (these

10 10 proteins are randomly selected), other Cas12a proteins are also suitable for this method. In addition, other types of Cas proteins (e.g., a C2c1 protein) are also suitable for the claimed scope of the present invention: as shown by the experimental results, *Alicyclobacillus acidoterrestris* Cas12b (i.e., C2c1) also has a collateral single-stranded DNA trans-cleavage activity similar to that of Cas12a, and its complex with crRNA/target DNA can also cleave a collateral single-

15 s t r a n d e d D N A .

For crRNA serving as a guide, it will be more stable in the system after being engineered, for example being modified manually. With regard to the selection of nucleic acid probes, the present invention selects a short single-stranded DNA labeled with HEX and BHQ1, and any other detectable labeling method is theoretically applicable, as long as the nucleic acid probe is cleaved

20 to produce detectable differences. Alternatively, the nucleic acid probe can also be designed to fluoresce after binding to a compound, so as to detect whether the probe is cleaved.

Furthermore, it should be understood that after reading the above teachings of the present invention, those skilled in the art can make various changes or modifications to the present invention, and these equivalent forms also fall within the scope defined by the appended claims of

25 the present application.

Table 1 Substrate sequences of Cas12a characteristic experiment-related cleavage

Oligo Name	Sequence (5'-3')	SEQ ID No. :
target-DNMT1-3-F	aatgtttcctgtatggccatgtctgttactgc ctgtcaagtggcgtgac	1
target-DNMT1-3-R	gtcaegccacttgacagggcagtaacagacatg gaccatcaggaaacatt	2
target-DNMT1-3-R-FA M-3'	gtcacggccacttgacagggcagtaacagacatg gaccatcaggaaacatt-FAM	3
target-DNMT1-3-R-FA M-5'	FAM-gtcacggccacttgacagggcagtaacaga catggaccatcaggaaacatt	4
target-T1-F	tttctgttttatacgcaactttctactgaatt caagctttactctagaaagaggagaaaggatcc	5
target-T1-R	ggatcctttctctttcttagatgtaaagcttg aattcaagttactctagaaagaggagaaaggatcc	6
target-T1-F-FAM	FAM-tttctgttttatacgcaactttctactg aattcaagttactctagaaagaggagaaagg atcc	7
target-T1-R-FAM	ggatcctttctctttcttagatgtaaagcttg aattcaagttactctagaaaggttgcgataacaaacagaaaa -FAM	8
target-T1-FAM-3' -F	tttctgttttatacgcaactttctactgaatt caagctttactctagaaagaggagaaaggatcc -FAM	9
target-T1-FAM-5' -R	FAM-ggatcctttctctttcttagatgtaaag cttgaattcttagaaagttgcgataacaaaca	10

Table 2. Names and GI numbers of the Cas12a protein and the Cas12b (i.e., C2c1) protein

Name	GI number	Species
FnCas12a	489130501	<i>Francisella tularensis</i>
AsCas12a	545612232	<i>Acidaminococcus</i> sp. BV3L6
LbCas12a	917059416	<i>Lachnospiraceae</i> bacterium ND2006
Lb5Cas12a	652820612	<i>Lachnospiraceae</i> bacterium NC2008
HkCas12a	491540987	<i>Helcrococcus kunzii</i> ATCC 51366
OsCas12a	909652572	<i>Oribacterium</i> sp. NK2B42
TsCas12a	972924080	<i>Thiomicrospira</i> sp. XS5
BbCas12a	987324269	<i>Bacteroidales</i> bacterium KA00251
BoCas12a	496509559	<i>Bacteroidetes</i> oral taxon 274 str. F0058
Lb4Cas12a	769130406	<i>Lachnospiraceae</i> bacterium MC2017
C2c1	1076761101	<i>Alicyclobacillus acidoterrestris</i>

Table 3 Plasmid Information

Plasmids or Strains	Relevant properties or genotypes	Sources
Plasmids		
pET28a-TEV	pET28a with the thrombin cleavage site changed to the TEV protease cleavage site	(Carneiro, Silva et al. 2006)
pET28a-TEV-FnCas12a	pET28a-TEV carrying FnCas12a	(Li, Zhao et al. 2016)
pET28a-TEV-AsCas12a	pET28a-TEV carrying AsCas12a	(Li, Zhao et al. 2016)
pET28a-TEV-LbCas12a	pET28a-TEV carrying LbCas12a	(Lei, Li et al. 2017)
pET28a-TEV-Lb5Cas12a	pET28a-TEV carrying Lb5Cas12a	The present invention
pET28a-TEV-HkCas12a	pET28a-TEV carrying HkCas12a	The present invention
pET28a-TEV-OsCas12a	pET28a-TEV carrying OsCas12a	The present invention
pET28a-TEV-TsCas12a	pET28a-TEV carrying TsCas12a	The present invention
pET28a-TEV-BbCas12a	pET28a-TEV carrying BbCas12a	The present invention
pET28a-TEV-BoCas12a	pET28a-TEV carrying BoCas12a	The present invention
pET28a-TEV-Lb4Cas12a	pET28a-TEV carrying Lb4Cas12a	The present invention

pET28a-TEV-FnCas12a-K869A	pET28a-TEV carrying FnCas12a-K869A	The present invention
pET28a-TEV-FnCas12a-K852A	pET28a-TEV carrying FnCas12a-K852A	The present invention
pET28a-TEV-FnCas12a-H843A	pET28a-TEV carrying FnCas12a-H843A	The present invention
pET28a-TEV-FnCas12a-R1218A	pET28a-TEV carrying FnCas12a-R1218A	The present invention
pET28a-TEV-FnCas12a-E1006A	pET28a-TEV carrying FnCas12a-E1006A	The present invention
pET28a-TEV-FnCas12a-D917A	pET28a-TEV carrying FnCas12a-D917A	The present invention
pET28a-TEV-FnCas12a-D1255A	pET28a-TEV carrying FnCas12a-D1255A	The present invention
pET28a-TEV-C2c1	pET28a-TEV carrying C2c1	The present invention

Table 4 Primers used in the test of the HOLMES method

Target-T1-F-8T	agttttgttatcgtacttttactgaattc	39
Target-T1-F-9T	agttttgttategeaTttttactgaattc	40
Target-T1-F-10G	agttttgttatcgtcaaaGttttactgaattc	41
Target-T1-AAAN-F	aaaagttatcgtcaacttttactgaattc	42
Target-T1-F-11A	agttttgttatcgtcaacAttttactgaattcggtc atag	43
Target-T1-F-12A	agttttgttatcgtcaactAtttactgaattcggtc atag	44
Target-T1-F-13A	agttttgttatcgtcaacttActttactgaattcggtc atag	45
Target-T1-F-14G	agttttgttatcgtcaactttGttactgaattcggtc atag	46
Target-T1-F-15A	agttttgttatcgtcaacttttAactgaattcggtc atag	47
Target-T1-F-16T	agttttgttatcgtcaacttttTttactgaattcggtc atag	48
Target-T1-F-17G	agttttgttatcgtcaactttttaGttactgaattcggtc atag	49
Target-T1-F-18A	agttttgttatcgtcaactttttaGttactgaattcggtc atag	50
Target-T1-PAM1A-F	agtttAgttatcgtcaacttttactgaattc	51
Target-T1-PAM2A-F	agttAtgttatcgtcaacttttactgaattc	52
Target-T1-PAM3A-F	agtAtgttatcgtcaacttttactgaattc	53
gyrB-F	AGTTGTCGTTCTCAACTCCGGCGTTTC	54
gyrB-R	TCGACGCCAATACCGTCTTTTCAGTGG	55
1-5082-F	CTGCCTTGCTTCTACCTTGCCTGT	56
1-5082-F-T	TTGCTTCTACCTTGCCTGTTCTGG	57
1-5082-R	TTTCTGGCTGGGATGGCCGATGG	58
2-rs1467558-F	AGCAATAACACTAATATTGATTCTTCAGATATGG ACTCCTTCATAGTA	59

2-rs1467558-F-T	TTGATTCTTCAGATATGGACTCCTTCAGTAT AACG	60
2-rs1467558-R	TGAGCATCGTTATTCTTACCGCGTGTCAATTGAAAG AG	61
3-rs2952768-F	AGCCTGGGCAACGAGTGAAACTCTG	62
3-rs2952768-R	ACAGGAGGGACAAAGGCCTAAGTGTCC	63
3-rs2952768-R-C	CATCATAGGATTGGAAAAGGACATTCAGTCATT CAG	64
4-rs4363657-F	AGAGTCCTCTTCTCAATTTTCAGAATAATTAGTAC TGTACTTTGGGTAC	65
4-rs4363657-R	CAGTACTGAAAAAACCTGCCTATCAATAAAAGCCC TAGAC	66
5-rs601338-F	GCTTCACCGGCTACCTTGCTCCT	67
5-rs601338-R	TTCACCTGCAGGCCCGCAGG	68
34-TP53-T24-F	CCTGACTTTCAACTCTGTCTCCTTCCTTTTAC AGTA	69
34-TP53-T24-R	TGCTGTGACTGCTTGTAGATGGCCATGG	70
41-rs1014290-F	AGTTTCCAGACCTCAGTGCACAAGATACTTTCTA C	71
41-rs1014290-F-G	ACCTCAGTGCACAAGATACTTTCTACGTCA C	72
41-rs1014290-R	AGCTCCAGTGGATGGAAGATCTTGAGATCCAG	73
42-rs6449213-F	AGTCAAAGAGATTCATGCCTGGACTTTAATCACA TTTAT	74
42-rs6449213-F-C	ATGCCTGGACTTTAATCACATTATCGGAAGG	75
42-rs6449213-R	CAAATCTGTCTCCACCTCTCAGCTCACCTG	76
43-rs737267-F	TTCTGAACCCAAACTCACCTGGCATTAAACTG	77
43-rs737267-F-A	AAACTCACCTGGCATTAAACTGACTCTGTAAAG	78
43-rs737267-F-T	AAACTCACCTGGCATTAAACTGTCTCTGTAAAG	79
43-rs737267-R	TGCCGAGGCTGAGTCAGCTACTCTCC	80

44-rs1260326-F	ACACAGCACCGTGGTCAGACCTTGC	81
44-rs1260326-F-C	TGGGTCAGACTTGGCCGGTGAGAGTC	82
44-rs1260326-F-T	TGGGTCAGACTTGGCTGGTGAGAGTC	83
44-rs1260326-R	AGCAGTGGCATGTGATGCTGATGATG	84
45-rs642803-F	CCCCGGCTCTGTTGGCTTGAGAATTG	85
45-rs642803-F-C	CTCTGTTGGCTTGAGAATTGCTGTCGTGTC	86
45-rs642803-F-T	CTCTGTTGGCTTGAGAATTGCTGTCGTGTC	87
45-rs642803-R	ACCGATAACCTGGCAGCCCTGGATG	88
HEX-N12-BHQ1	HEX-NNNNNNNNNNNN-BHQ1	89

Table 5 Template sequences for transcription of crRNA

Oligo Name	Sequence (5'-3')	SEQ ID No. :
T7-crRNA-F	GAAATTAATACGACTCACTATAGGG	90
T7-T1-24-R	gaattcagtagaaagtggataaATCTACAAACAGTAGA AATTCCTATAGTGAGTCGTATTAATTTC	91
T7-T1-15-R	agaaaagggttgcgataaATCTACAAACAGTAGAAATTCCCTA TAGTGACTCGTATTAATTTC	92
T7-T1-16-R	tagaaaagggttgcgataaATCTACAAACAGTAGAAATTCCCT ATAGTGAGTCGTATTAATTTC	93
T7-T1-17-R	gtagaaaagggttgcgataaATCTACAAACAGTAGAAATTCCC TATACTGAGTCGTATTAATTTC	94
T7-T1-18-R	agtagaaaagggttgcgataaATCTACAAACAGTAGAAATTCC CTATACTGAGTCGTATTAATTTC	95
T7-crRNA-DNM	GAGTAACAGACATGGACCACATCAGATCTACAAACAGTAGAA	96
T-23nt-R	ATTCCCTATAGTGAGTCGTATTAATTTC	
T7-crRNA-DNM	gacatggaccatcgaaaaacattATCTACAAACAGTAGAA	97
T-(-8)-R	ATTCCCTATAGTGAGTCGTATTAATTTC	
T7-crRNA-DNM	aggcgagtaacagacatggaccaATCTACAAACAGTAGAA	98
T-(+4)-R	ATTCCCTATAGTGAGTCGTATTAATTTC	
T7-crRNA-DNM	tgacaggcgagtaacagacatggATCTACAAACAGTAGAA	99

T- (+8) -R	ATTCCCTATAGTGAGTCGTATTAATTTC	
T7-crRNA-DNM T-16nt-R	agacatggaccatcgATCTACAAACAGTAGAAATTCCCT ATAGTGAGTCGTATTAATTTC	100
T7-crRNA-DNM T-18nt-R	acagacatggaccatcgATCTACAAACAGTAGAAATTCC CTATAGTGAGTCGTATTAATTTC	101
T7-crRNA-DNM T-20nt-R	taacagacatggaccatcgATCTACAAACAGTAGAAATT CCCTATAGTGAGTCGTATTAATTTC	102
T7-DNMT- (-8) -no loop-R	gacatggaccatcgaaacattCCCTATAGTGAGTCGT ATTAATTTC	103
T7-DNMT- (+4) -no loop-R	aggegagtaacagacatggaccaCCCTATAGTGAGTCGT ATTAATTTC	104
T7-DNMT- (+8) -no loop-R	tgacaggcgagtaacagacatggCCCTATAGTGAGTCGT ATTAATTTC	105
T7-crRNA-rs50 82-T	CCTCTTCCCAGAACAGGATCTACAAACAGTAGAAATTCCCT ATAGTGAGTCGTATTAATTTC	106
T7-crRNA-rs50 82-G	CCTCTTCCCAGCACAGGATCTACAAACAGTAGAAATTCCCT ATAGTGAGTCGTATTAATTTC	107
T7-crRNA- rs1467558-T	CTGAAGCGTTATACTATATCTACAAACAGTAGAAATTCCCT ATAGTGAGTCGTATTAATTTC	108
T7-crRNA- rs1467558-C	CTGAAGCGTTGTACTATATCTACAAACAGTAGAAATTCCCT ATAGTGAGTCGTATTAATTTC	109
T7-crRNA-rs29 52768-T-16nt	TTTTATCTGAATGATTATCTACAAACAGTAGAAATTCCCTA TAGTGAGTCGTATTAATTTC	110
T7-crRNA-rs29 52768-C-16nt	TTTTATCTGAATGACTATCTACAAACAGTAGAAATTCCCTA TAGTGAGTCGTATTAATTTC	111
T7-crRNA- rs4363657-T	AAAAAAAGAGTGAGTACCATCTACAAACAGTAGAAATTCCCT ATAGTGAGTCGTATTAATTTC	112
T7-crRNA- rs4363657-C	AAAAAAAGAGTGGGTACCATCTACAAACAGTAGAAATTCCCT ATAGTGAGTCGTATTAATTTC	113
T7-crRNA-rs60	GGTAGAAGGTCCAGGAGATCTACAAACAGTAGAAATTCCCT	114

1338-G	ATAGTGAGTCGTATTAATTTC	
T7-crRNA-rs60	GGTAGAAGGTCTAGGAGATCTACAAACAGTAGAAATTCCCT	115
1338-A	ATAGTGAGTCGTATTAATTTC	
T7-crRNA-34-T	GGGCAGGGGAGTACTGATCTACAAACAGTAGAAATTCCCTA	
P53-T24-C-16n	TAGTGAGTCGTATTAATTTC	116
t		
T7-crRNA-34-T	GGGCAGGGGACTACTGATCTACAAACAGTAGAAATTCCCTA	
P53-T24-G-16n	TAGTGAGTCGTATTAATTTC	117
t		
T7-crRNA-41-r	TCAGTGGATGATGTAATCTACAAACAGTAGAAATTCCCTAT	
s1014290-A-15	AGTGAGTCGTATTAATTTC	118
nt		
T7-crRNA-41-r	TCAGTGGATGACGTAATCTACAAACAGTAGAAATTCCCTAT	
s1014290-G-15	AGTGAGTCGTATTAATTTC	119
nt		
T7-crRNA-42-r	GGAAATTCTCCTTCCGAATCTACAAACAGTAGAAATTCCCT	
s6449213-C	ATACTGAGTCGTATTAATTTC	120
T7-crRNA-42-r	GGAAATTCTCCTTCCAATCTACAAACAGTAGAAATTCCCT	
s6449213-T	ATAGTGAGTCGTATTAATTTC	121
T7-crRNA-43-r	TCTTACAGAGTCAGTTATCTACAAACAGTAGAAATTCCCTA	
s737267-A-16n	TAGTGAGTCGTATTAATTTC	122
t		
T7-crRNA-43-r	TCTTACAGAGCCAGTTATCTACAAACAGTAGAAATTCCCTA	
s737267-G-16n	TAGTGAGTCGTATTAATTTC	123
t		
T7-crRNA-43-r	GTCTTACAGAGACAGTTATCTACAAACAGTAGAAATTCCCT	
s737267-T	ATAGTGAGTCGTATTAATTTC	124
T7-crRNA-44-r	CTGGACTCTCACCGGATCTACAAACAGTAGAAATTCCCTAT	
s1260326-C-15	AGTGAGTCGTATTAATTTC	125
nt		

T7-crRNA-44-r s1260326-T-15 nt	CTGGACTCTCACCAAGATCTACAAACAGTAGAAATTCCCTAT AGTGAGTCGTATTAATTTC	126
T7-crRNA-45-r s642803-C	CACAGACAGGCAATTCTATCTACAAACAGTAGAAATTCCCT ATAGTGAGTCGTATTAATTTC	127
T7-crRNA-45-r s642803-T	CACAGACAGACAATTCTATCTACAAACAGTAGAAATTCCCT ATAGTGAGTCGTATTAATTTC	128
T7-crRNA- gyrB	TCGCGCTTGTGCGCAGACGAATGATCTACAAACAGTAGAA ATTCCCTATAGTGAGTCGTATTAATTTC	129

Primers used for detection by DNA amplification through LAMP combined with Cas12a:

Table 6 Primers used for amplifying gyrB-1

Name	Sequence	SEQ ID No. :
LAMP-gyrB-1-F3	CATGGTGCCTTCTGGCC	130
LAMP-gyrB-1-B3	CGCGTCTTGTCTTGTCA	131
LAMP-gyrB-1-FIP	ACAACTCACGCAGACGTTCGAACCTCA CCAATGTGACCG	132
LAMP-gyrB-1-BIP	GTTCCCTCAACTCCGGCTTCCGATGCCGC CTTCATAGTGG	133
LAMP-gyrB-1-LoopF	CAGAATTTCATATTGAACT	134
LAMP-gyrB-1-LoopB	GACGGCAAAGAAGACCACTT	135

5

Table 7 Primers used for amplifying gyrB-2

Name	Sequence	SEQ ID No. :
LAMP-gyrB-2-F3	CGACGGCAAAGAAGACCA	136
LAMP-gyrB-2-B3	AGCCTGCCAGGTGAGTAC	137
LAMP-gyrB-2-FIP	CGGGTGGATCGGCCTTGTCACTATGAA GGCGGCATCA	138
LAMP-gyrB-2-BIP	GTATTGGCGTCGAAGTGGCGTTCGCTGCGG AATGTTGTTG	139
LAMP-gyrB-2-LoopF	TTGTTCAGATATTCAACGAACG	140
LAMP-gyrB-2-LoopB	GTGGAACGATGGCTTCCAGG	141

Table 8 Primers used for amplifying a rs1467558 site

Name	Sequence	SEQ ID No. :
LAMP-rs1467558-F3	CAGCTGTAGACCATAAGCC	142
LAMP-rs1467558-B3	GTGGCTGAGCATCGTTAT	143
LAMP-rs1467558-F1 P	ACTATGAAAGGAGTCCATATCTGAAGGAAT TCAGGTAGTGGTTGGGA	144
LAMP-rs1467558-B1 P	GCTTCAGCCTACTGCAAATCCTACCGCGTTG TCATTGAAAG	145
LAMP-rs1467558-Lo opF	TCAATATTAGTGTATTGCTTG	146
LAMP-rs1467558-Lo opB	TGCTGGAAGATTGGACAGGAC	147

Table 9 Primers used for amplifying a rs5082 site

Name	Sequence	SEQ ID No. :
LAMP-rs5082-F3	GCTCGAAAGGTCAAGGGAC	148
LAMP-rs5082-B3	GGGGTTTGTGCACAGTCC	149
LAMP-rs5082-F1P	CAAAGGTAGAAGCAAAGGCAGGAGGTTGC CCAAGGTACACAG	150
LAMP-rs5082-B1P	CTGGGAAGAGGGAGGGCTCAGTGTGCCAC ACTTCACTGG	151
LAMP-rs5082-LoopF	GTGAGCGGGTGGGTGCT	152
LAMP-rs5082-LoopB	TCTAAGTCTTCCAGCACGGGATC	153

5

Table 10 Primers used for Detection by RPA Amplification combined with Cas12

Name	Sequence	SEQ ID No. :
RPA-gyrB-1-F	ATATGAAATTCTGGCGAAACGTCTGCGTGAGTTG	154
RPA-gyrB-2-F	AAACGTCTGCGTGAGTTGTCGTTCTCAACTCC	155
RPA-gyrB-R	ACTTCGACGCCAATACCGTCTTTTCAGTGGAG	156

Table 11 Primers used for determining Cas12b having a trans-cleavage activity:

Oligo Name	Sequence (5'-3')	SEQ ID No. :
pUC18-1-F	ATCTGAGAAGTGGCACTTATCGCAACTTCTACTGAGGTC ATAGCTTTCCCTGTGTGA	157
pUC18-1-R	GTCCTCTAGACCCCTATAGTGAGTCGTATTAATTTCAT GATTACGAATTGAGCTCGGT	158
pUC18-2-F	CCACTTCCAGGTGCCAAAGCCCGTTGAGCTCTCAA TCTGAGAAGTGGCACTTATC	159
pUC18-2-R	TGGAAAGTGGCATTGGCACACCCGTTGAAAAATTCTG TCCTCTAGACCCCTATAGTGA	160
T7-crRNA-F	GAAATTAATACGACTCACTATAGGG	161
ZL-sgRNA-T1-R	TCAGTAGAAAGTTGCGATAAGTGC	162
ZLsgRNA-DNMT1-3-R	AACAGACATGGACCATCAGGGTG	163
target-T1-F	TTTCTGTTGTTATCGCACTTCTACTGAATTCAAGC TTTACTCTAGAAAGAGGGAGAAAGGATCC	164
target-T1-R	GGATCCTTCTCCTTTCTAGAGTAAAGCTTGAATT AGTAGAAAGTTGCGATAACAAACAGAAA	165
target-DNMT1-3-R-FAM-5'	GTCACGCCACTTGACAGGCGAGTAACAGACATGGACCA TCAGGAAACATT	166
target-T1-R	GGATCCTTCTCCTTTCTAGAGTAAAGCTTGAATT AGTAGAAAGTTGCGATAACAAACAGAAA	167
target-T1-F	TTTCTGTTGTTATCGCACTTCTACTGAATTCAAGC TTTACTCTAGAAAGAGGGAGAAAGGATCC	168

Table 12 Primers used for sensitivity test of trans reaction of Cas12b

Oligo Name	Sequence (5'-3')	SEQ ID No.:
sgRNA-DNMT1-3-F	CCTGATGGTCCATGTCCTGGTCATAGCTTTCCCTGTG TG	169
sgRNA-DNMT1-3-R	TGGACCATCAGGGTGCCACTTCTCAGATTGAGAAG	170
T7-crRNA-F	GAAATTAAATACGACTCACTATAGGG	171
ZLsgRNA-DNMT1-3-R	AACAGACATGGACCATCAGGGTG	172
DNMT1-3 (TTC PAM) -F	AATGTTCCCTGATGGTCCATGTCCTGTTACTCGCCTGTC AAGTGGCGTGAC	173
DNMT1-3 (TTC PAM) -R	GTCACGCCACTTGACAGGGGAGTAACAGACATGGACCA TCAGGGAACATT	174
LAMP-DNM-F3	gtgaacgttcccttagact	175
LAMP-DNM-B3	gggagggcagaactagtee	176
LAMP-DNM-F1P	cgcacattgacaggcgagtaactgecaacttattggtc age	177
LAMP-DNM-B1P	gcgtgtccccagagtgacttagcagcttccctccct t	178
LAMP-DNM-LoopF	aggaaacattaaegtactgatg	179
LAMP-DNM-LoopB	ttcctttattccctcage	180
DNMT1-3 (TTC PAM) -R	GTCACGCCACTTGACAGGGGAGTAACAGACATGGACCA TCAGGGAACATT	181
DNMT1-3 (TTC PAM) -F	AATGTTCCCTGATGGTCCATGTCCTGTTACTCGCCTGTC AAGTGGCGTGAC	182

Table 13 Other Sequences Involved in the present invention

Name	Sequence	SEQ ID No.:
AacCas12b sgRNA sequence	GTCTAGAGGACAGAATTTCAACGGGTGTGCCAATGG CCACTTCCAGGTGGCAAAGCCCCTTGAGCTCTCAA TCTGAGAAGTGGCACctgatggccatgtctgtt	183
A guide sequence targeting a target DNMT-1-3	cctgatggccatgtctgtt	184
Single-stranded target sequence	gtcactggccatgtacaggcggagtaacagacatggacca tcagggaacatt	185
Double-stranded target sequence:	gtcactggccatgtacaggcggagtaacagacatggacca tcagggaacatt	186
Amino acid sequence of the AacCas12b protein	MAVKSIVKLRLDDMPEIRAGLWKLHKEVNAGVRYYTE WLSLLRQENLYRRSPNGDGEQECDKTAEECKAELLRL RARQVENGHRGPGAGSDDELLQLARQLYELLVPQAIGAK GDAQQIARKIFLSPLAGDKDAVGGLGIAKAGNKPWRWVRMR EAGEPGWEEEKEKAETRKSADRTADVLRALADFGLKPL MRVYTDSEMSSVEWKPLRKQAVRTWDRDMPQQAIERM MSWESWNQRVGQEYAKLVEQKNRFEQKNFVGQEHILVHL VNQLQQDMKEASPGLESKEQTAHYVTGRALRGSDKVFE KWKGLAPDAPFDLYDAEIKNVQRRNTRRGSHDLFAKL AEPEYQALWREDASFLTRYAVYNSTLRKLNHAKMFATF TLPDATAHP1WTRFDKLGGLHQYTFLNEPGERRHAI RFHKLLKVENGVAREVDDVTVP1SMSEQLDNLLPRDPN EPTIALYFRDYGAEQHFTGEFGGAK1QCRRDQLAHMHRR RGARDVYLNVSVRVQSQSEARGERRPPYAAVFRLVGDN HRAFVHFDKLSDYLAEPDDGKLGSEGLLSGLRVMVSD LGLRTSASISVFRVARKDELKPNSKGRVPFFFP1KGND	187

All documents mentioned in the present invention are hereby incorporated by reference as if each document is individually incorporated by reference. Furthermore, it should be understood that after reading the above teachings of the present invention, those skilled in the art can make various

changes or modifications to the present invention, and these equivalent forms also fall within the scope defined by the appended claims of the present application.

CLAIMS

1. A method for detecting a target nucleic acid molecule, comprising adding a guide RNA, a Cas protein, a nucleic acid probe and a buffer solution into a system comprising the target nucleic acid molecule to be detected, and then detecting the nucleic acid probe.
- 5 2. The method for detecting a target nucleic acid molecule according to claim 1, wherein the Cas protein is Cas12a or a Cas protein having a collateral single-stranded DNA cleavage activity similar to that of the Cas12a;
the Cas12a is preferably one of FnCas12a, AsCas12a, LbCas12a, Lb5Cas12a, HkCas12a, OsCas12a, TsCas12a, BbCas12a, BoCas12a or Lb4Cas12a; and the Cas12a is preferably
10 LbCas12a.
3. The method for detecting a target nucleic acid molecule according to claim 1, wherein the guide RNA refers to an RNA that guides the Cas protein to specifically bind to a target DNA.
4. The method for detecting a target nucleic acid molecule according to claim 1, wherein the nucleic acid probe is a single-stranded DNA; the single-stranded DNA is preferably a
15 fluorescently-labeled single-stranded DNA; the single-stranded DNA is preferably a fluorescent probe that is labeled with a fluorescent group HEX at a 5' terminal and labeled with a quenching group BHQ1 at a 3' terminal; preferably,
the method for detecting the nucleic acid probe is preferably a fluorescence detection method;
and the fluorescence detection method is preferably a detection method using a microplate reader
20 or a fluorescence spectrophotometer.
5. The method for detecting a target nucleic acid molecule according to any one of claims 1 to 4, wherein the target nucleic acid molecule to be detected in the reaction system of the target nucleic acid molecule to be detected is obtained by amplification.
6. The method for detecting a target nucleic acid molecule according to claim 5, wherein the
25 detection method can detect a pathogenic microorganism, gene mutation, or a specific target DNA.
7. The method according to claim 1, wherein the Cas protein comprises Cas12b (i.e., C2c1).
8. Use of a Cas protein in a method for detecting a target nucleic acid molecule.

9. The use according to claim 8, wherein when a target DNA, a guide RNA and a Cas protein form a ternary complex, the complex cleaves other single-stranded DNA molecules in the system; and preferably, the guide RNA refers to an RNA that guides the Cas protein to specifically bind to the target DNA.

5 10. A kit for detecting a target nucleic acid molecule, comprising a guide RNA, a Cas protein and a nucleic acid probe.

11. A detection system for detecting a target nucleic acid molecule, comprising:

(a) a Cas protein, which is Cas12a or a Cas protein having a collateral single-stranded DNA cleavage activity similar to that of the Cas12a;

10 (b) a guide RNA that guides the Cas protein to specifically bind to the target nucleic acid molecule; and

(c) a nucleic acid probe which is a single-stranded DNA;

wherein the target nucleic acid molecule is a target DNA.

12. The detection system according to claim 11, wherein the Cas protein having a collateral single-stranded DNA cleavage activity similar to that of Cas12a is selected from a group consisting of Cas12b (i.e., C2c1).

13. The detection system according to claim 11, wherein the nucleic acid probe comprises a single-stranded DNA carrying a detectable label.

14. A kit for detecting a target nucleic acid molecule, comprising:

20 i) a first container and a Cas protein in the first container, the Cas protein being Cas12a or

Cas protein having a collateral single-stranded DNA cleavage activity similar to that of the Cas12a;

ii) an optional second container and a guide RNA in the second container, the guide RNA guiding the Cas protein to specifically bind to the target nucleic acid molecule;

iii) a third container and a nucleic acid probe in the third container;

25 iv) an optional fourth container and a buffer solution in the fourth container;

wherein the target nucleic acid molecule is a target DNA.

15. A method for detecting whether a target nucleic acid molecule exists in a sample, comprising the following steps:

(a) providing the detection system for detecting a target nucleic acid molecule according to claim 11, wherein the detection system further comprises a sample to be detected; and

5 (b) detecting whether the nucleic acid probe in the detection system is cleaved by a Cas protein, wherein the cleavage is a trans-cleavage of a collateral single-stranded DNA;

wherein if the nucleic acid probe is cleaved by the Cas protein, then it indicates the presence of the target nucleic acid molecule in the sample; and if the nucleic acid probe is not cleaved by the Cas protein, then it indicates the absence of the target nucleic acid molecule in the sample.

10 16. The method according to claim 15, wherein a method for amplifying the nucleic acid is selected from a group consisting of PCR amplification, LAMP amplification, RPA amplification, ligase chain reaction, branched DNA amplification, NASBA, SDA, transcription-mediated amplification, rolling circle amplification, HDA, SPIA, NEAR, TMA, and SMAP2.

17. The method according to claim 15, wherein when the upstream and downstream (in a 15 range of -20 nt to +20 nt, preferably in a range of -15 nt to +15 nt, and more preferably in a range of -10 nt to +10 nt) of a target site lack a PAM sequence, nucleic acid amplification is carried out using a PAM-introducing primer.

18. The method according to claim 17, wherein the PAM-introducing primer has a structure of formula I in 5'-3':

20 P1-P2-P3 (I)

wherein,

P1 is a 5' segment sequence that is located at the 5' terminal and is complementary or non-complementary to the sequence of the target nucleic acid molecule;

P2 is a PAM sequence; and

25 P3 is a 3' segment sequence that is located at the 3' terminal and is complementary to the sequence of the target nucleic acid molecule.

19. The method according to claim 15, wherein when the upstream and downstream (in a range of -20 nt to +20 nt, preferably in a range of -15 nt to +15 nt, and more preferably in a range of -10 nt to +10 nt) of the target site contain the PAM sequence, then a primer containing or not containing the PAM sequence can be used, and the amplified amplification product contains the

5 PAM sequence.

20. Use of a Cas protein in preparation of a detection reagent or a kit for detecting a target nucleic acid molecule based on collateral single-stranded DNA cleavage, wherein the Cas protein is Cas12a or a Cas protein having a collateral single-stranded DNA cleavage activity similar to that of the Cas12a.

10 21. The use according to claim 20, wherein the Cas protein having a collateral single-stranded DNA cleavage activity similar to that of the Cas12a is selected from a group consisting of Cas12b (or C2c1).

FIGURES

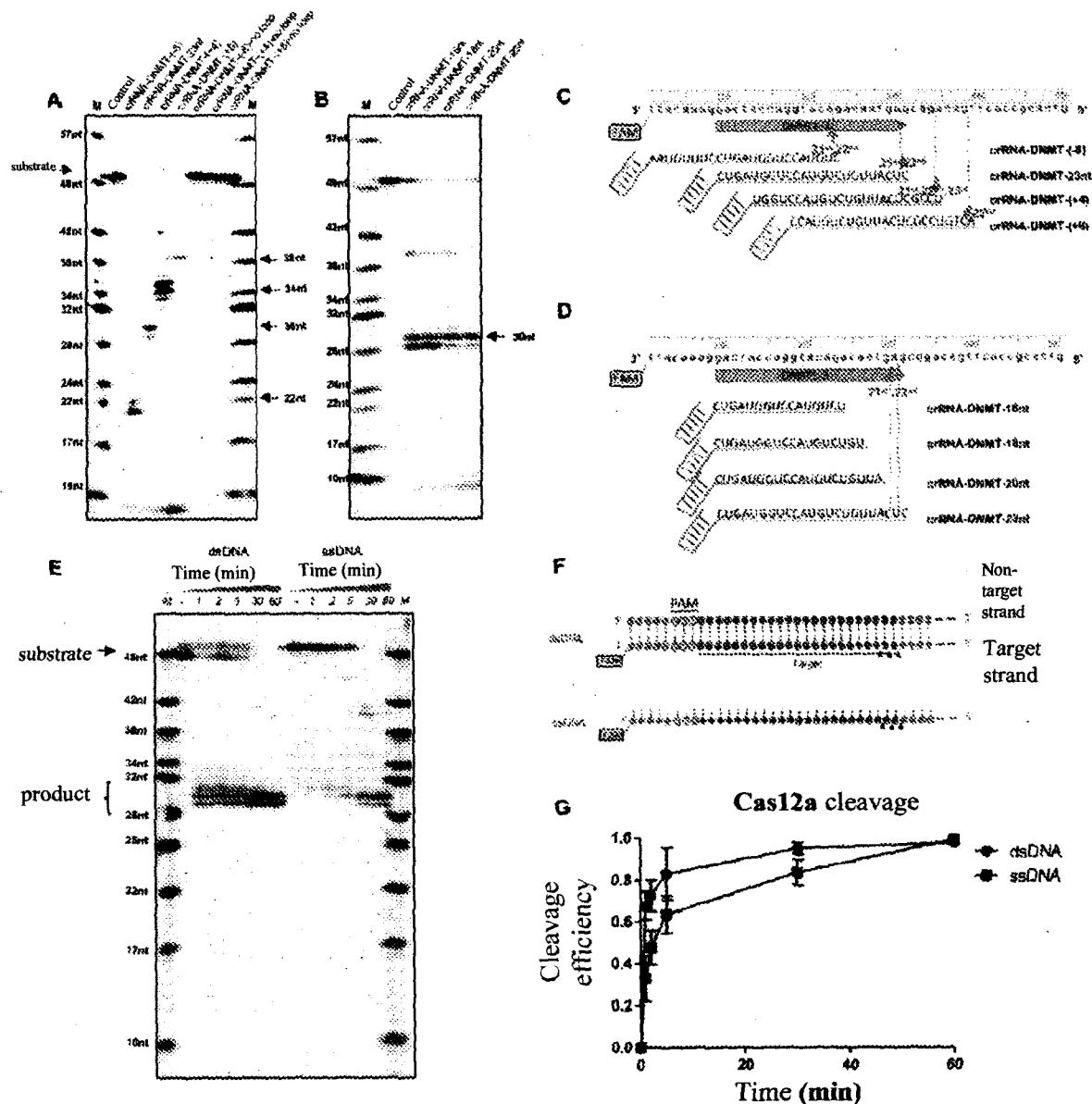


FIG. 1

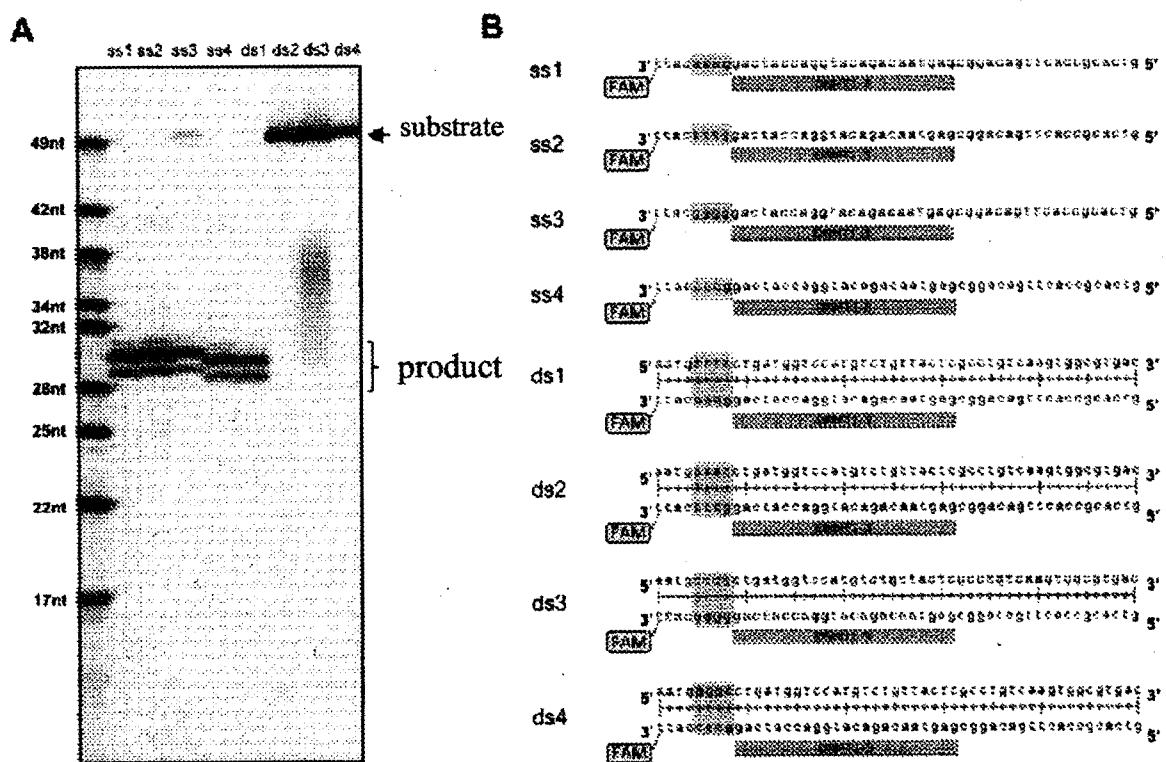


FIG. 2

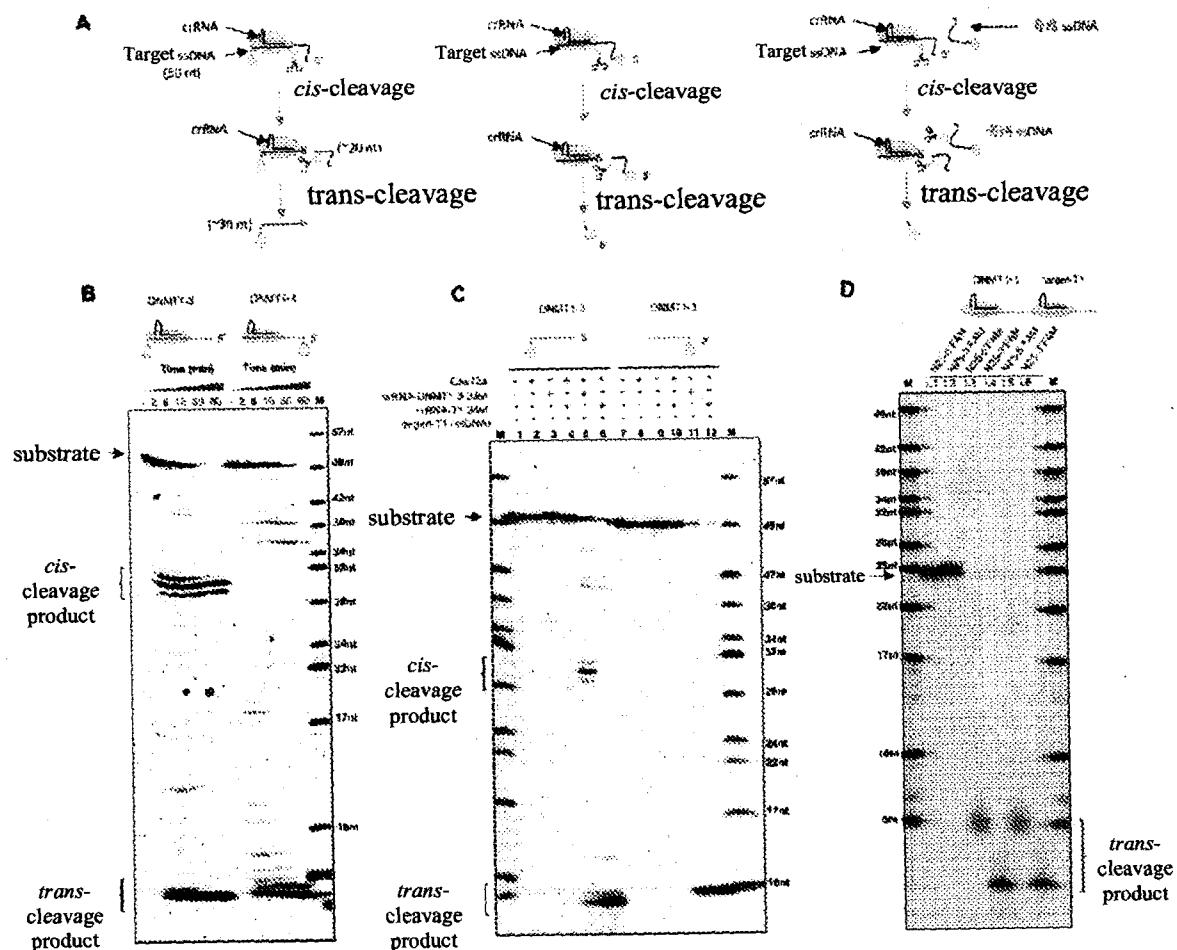


FIG. 3

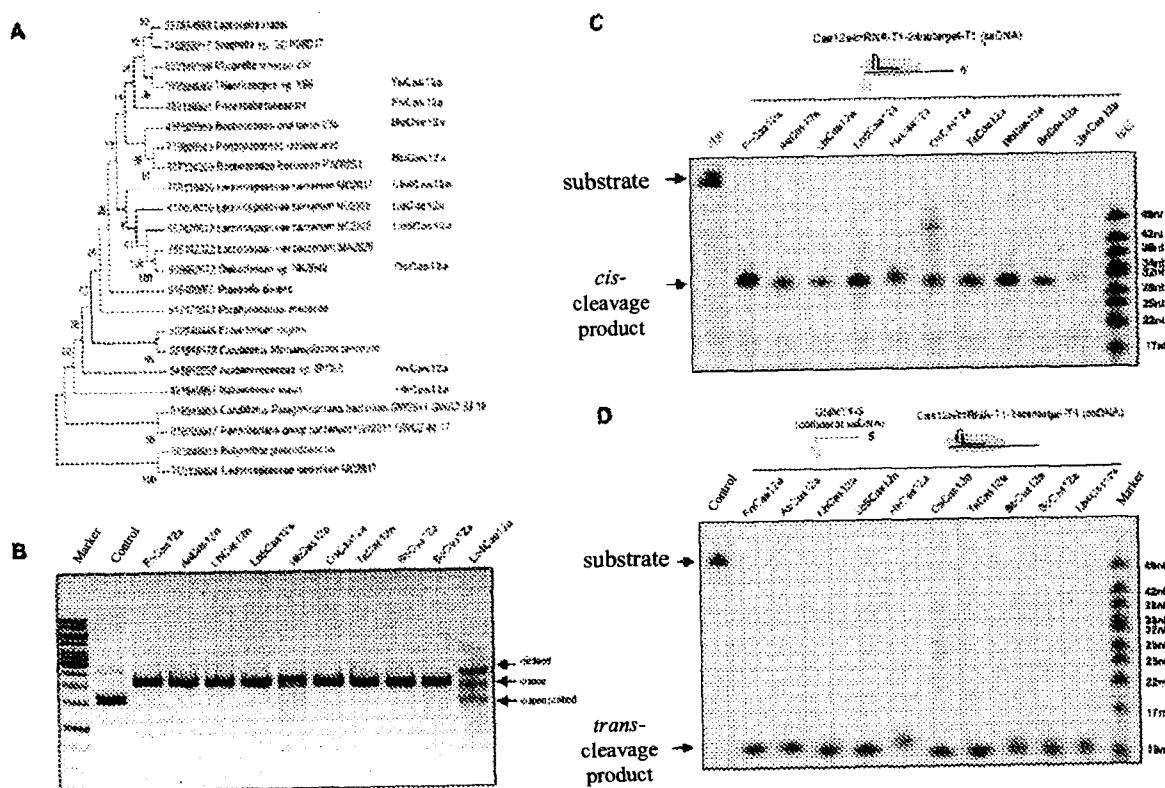


FIG. 4

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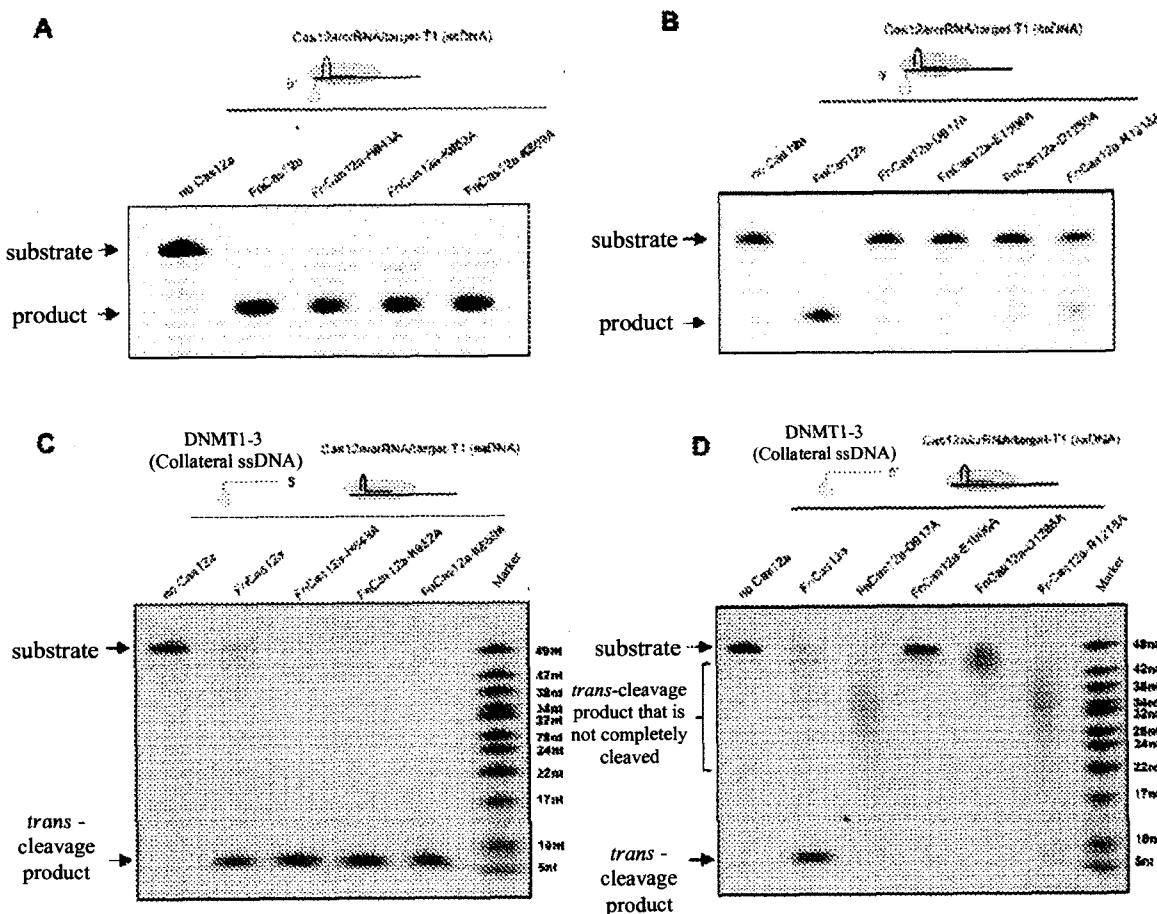


FIG. 5

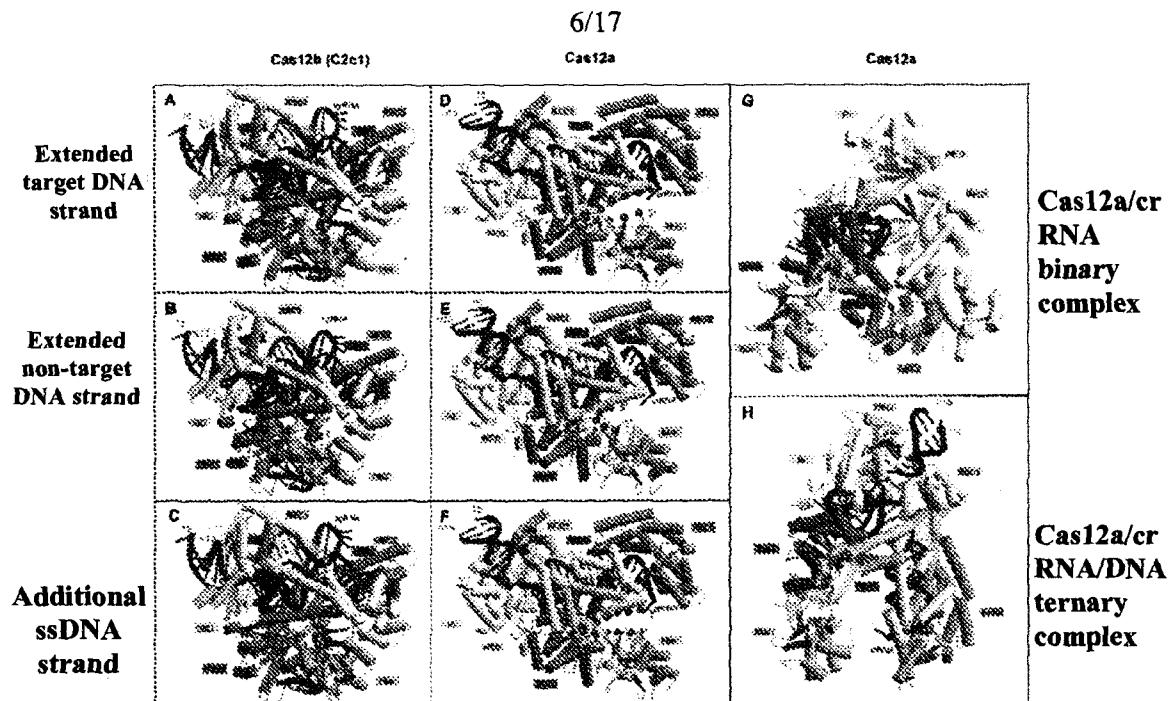


FIG. 6

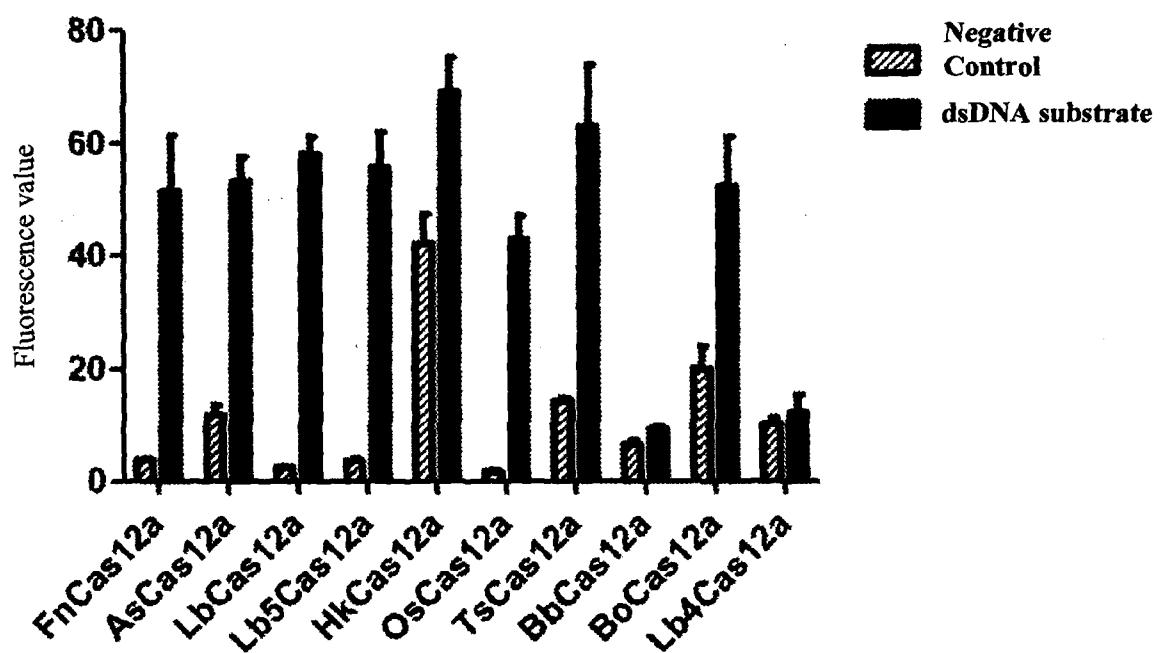


FIG. 7

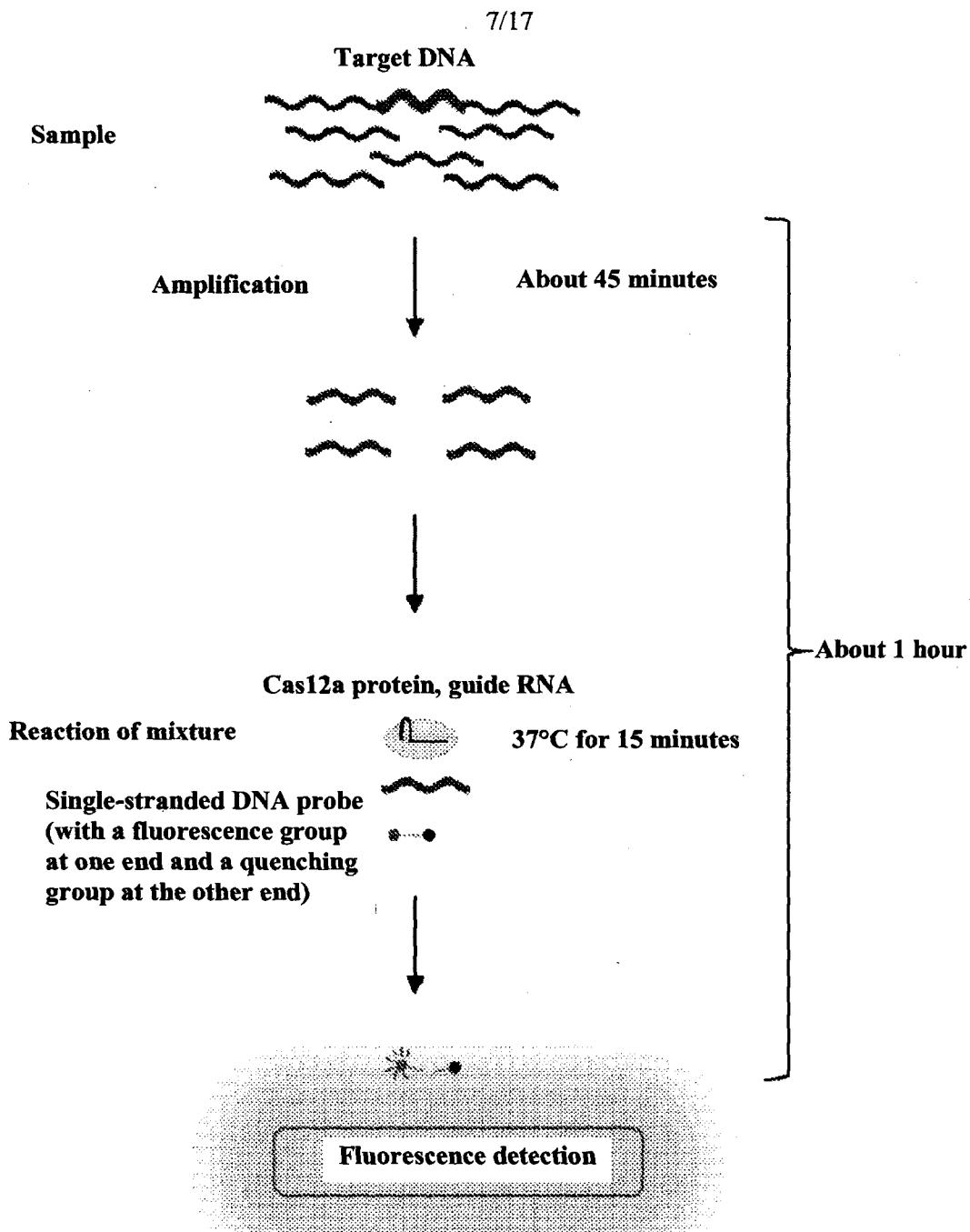
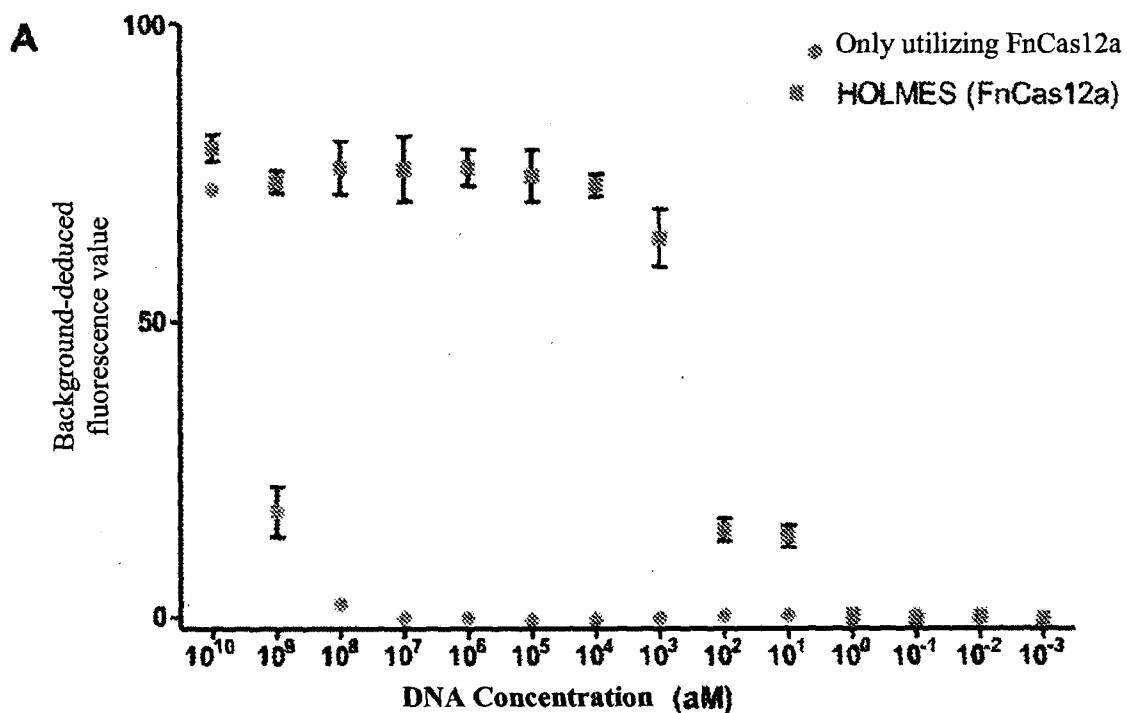
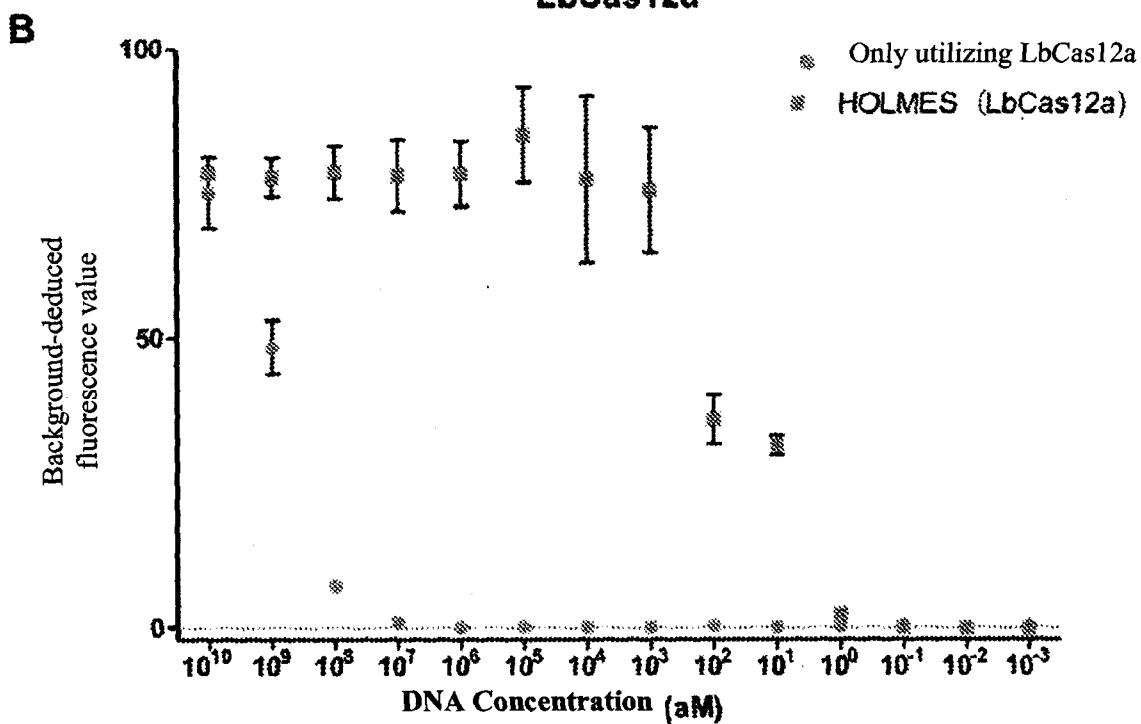
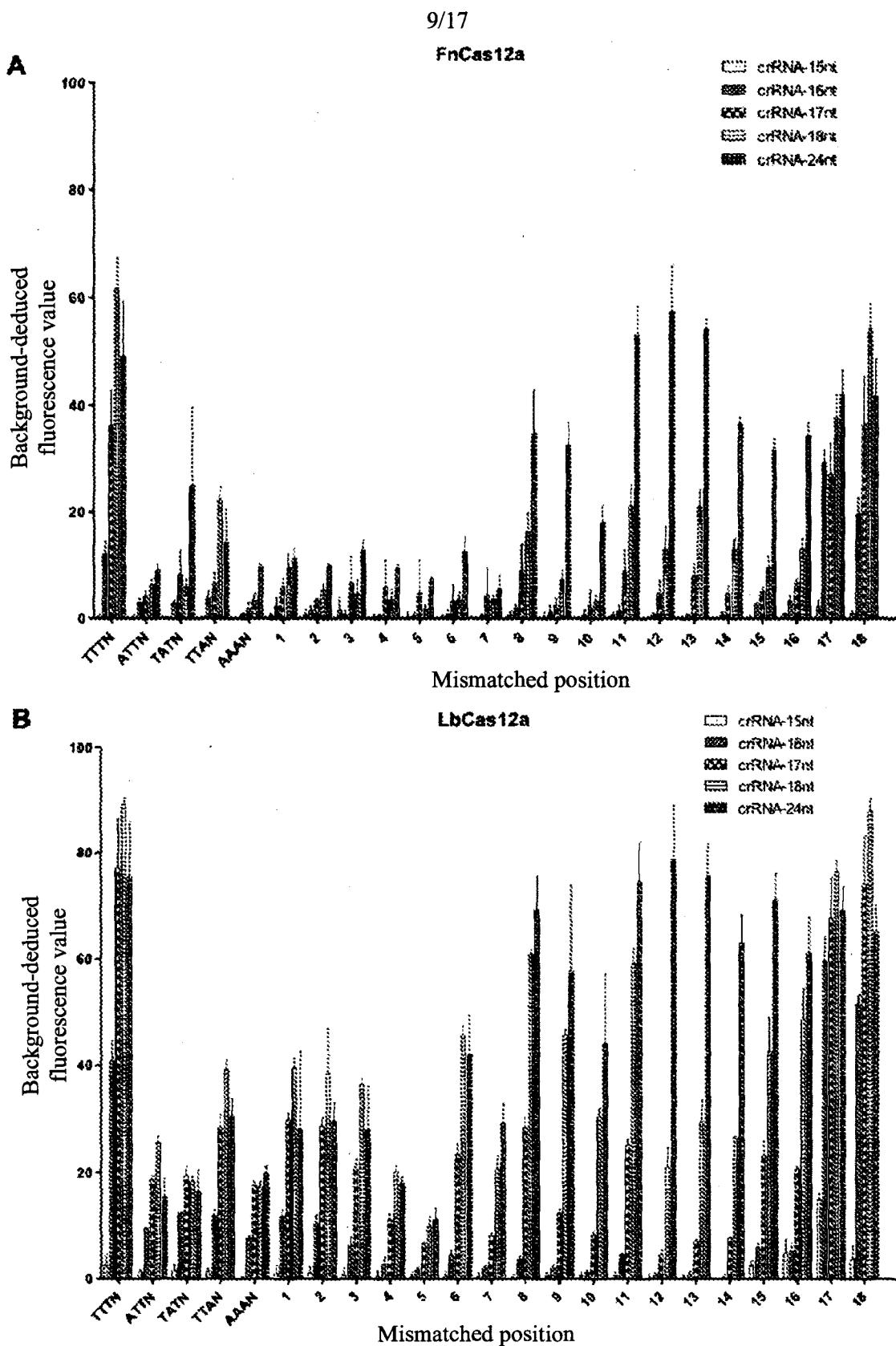


FIG. 8

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FnCas12a**LbCas12a****FIG. 9**

**FIG. 10**

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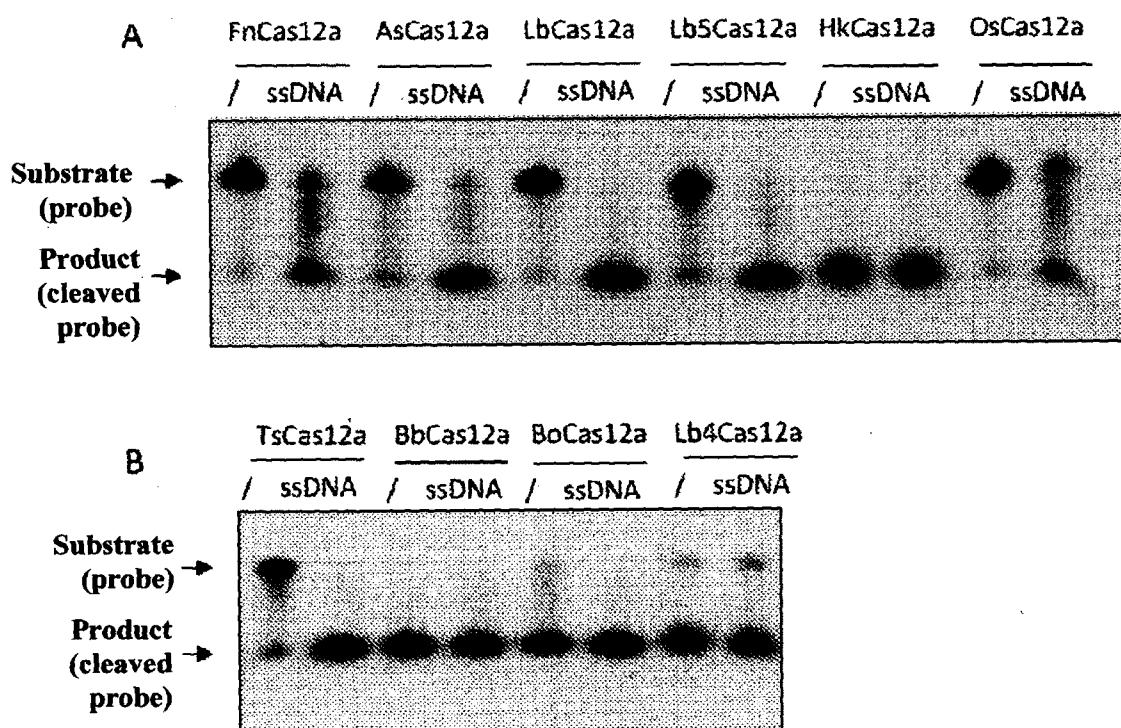


FIG. 11

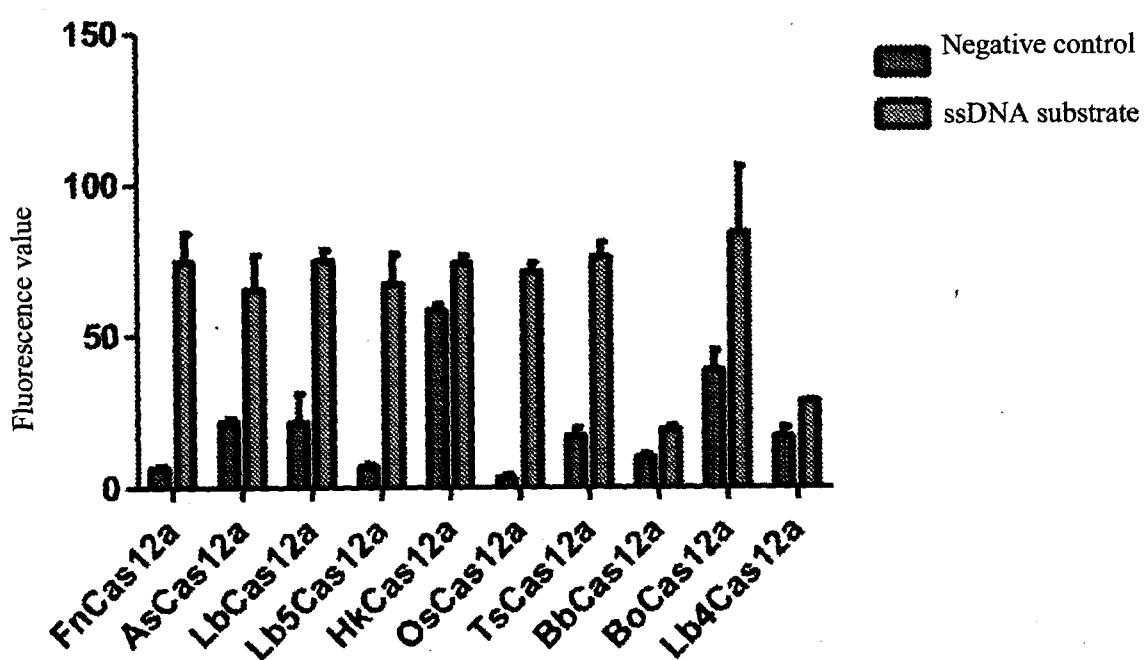
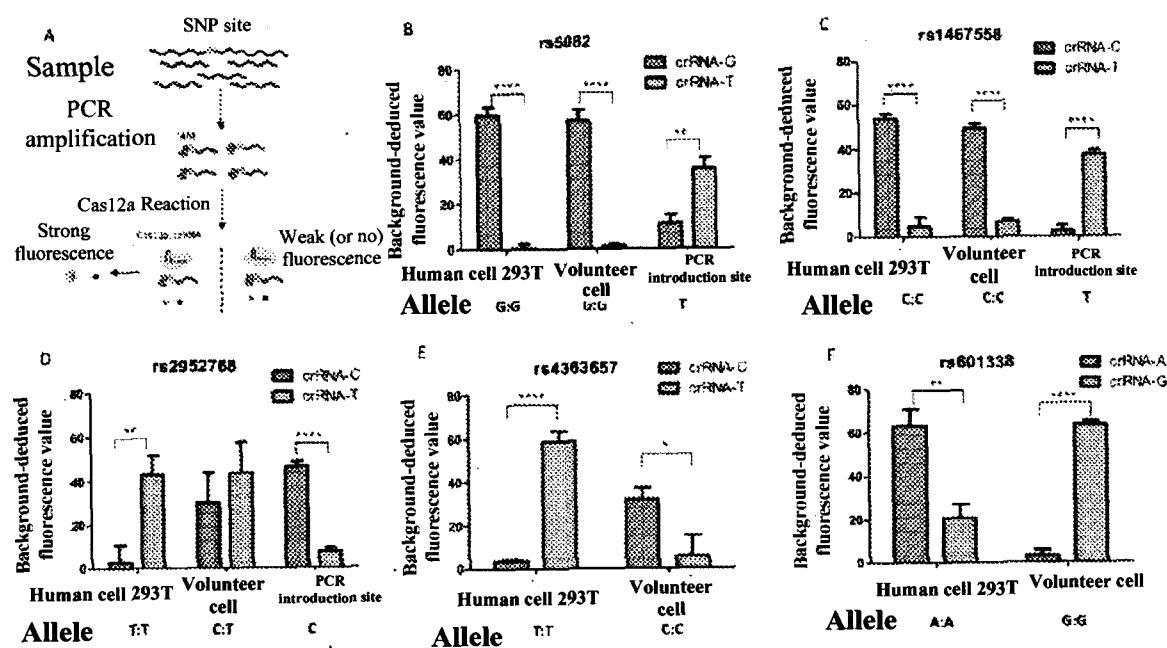
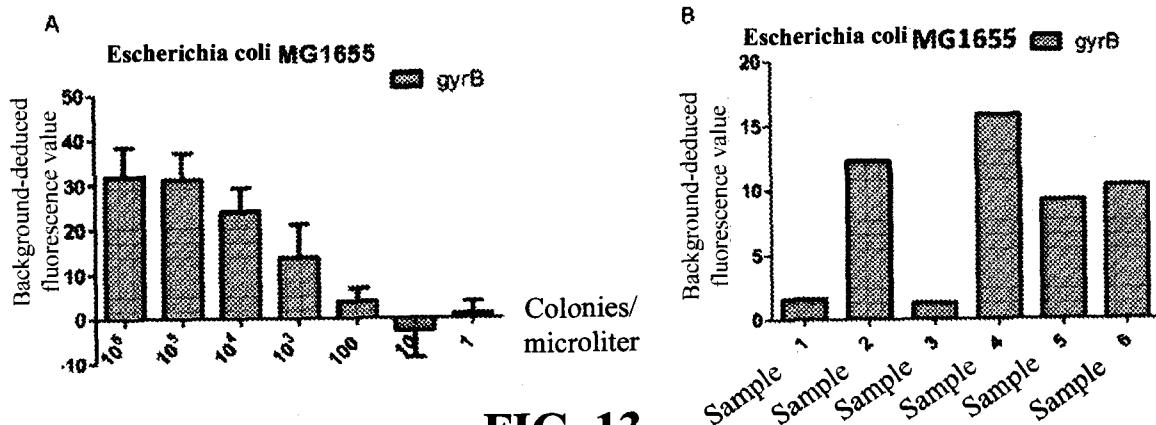
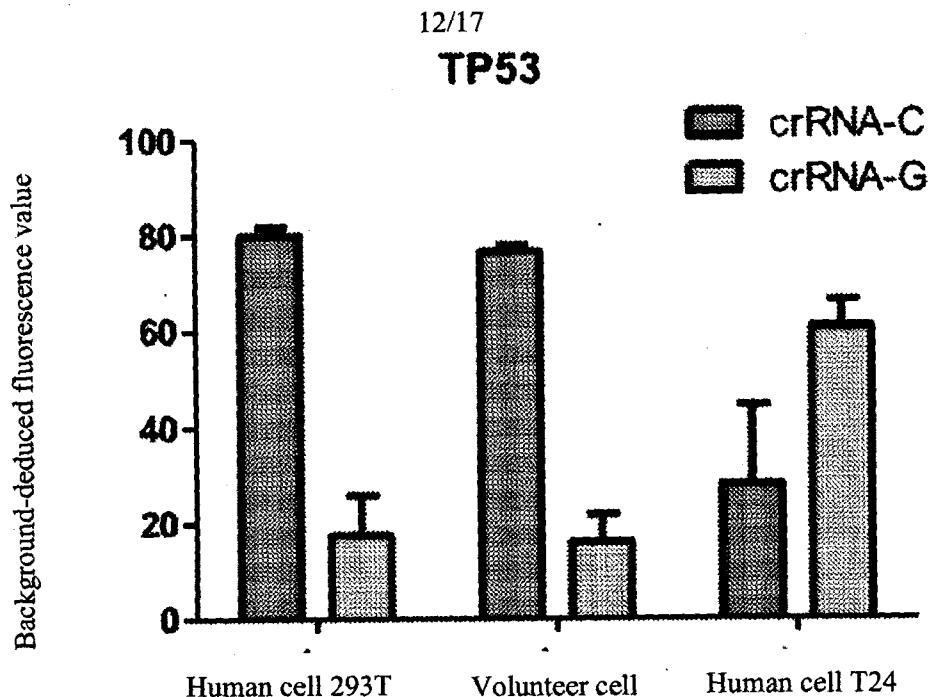


FIG. 12

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Allele C:C C:C G:G

FIG. 15

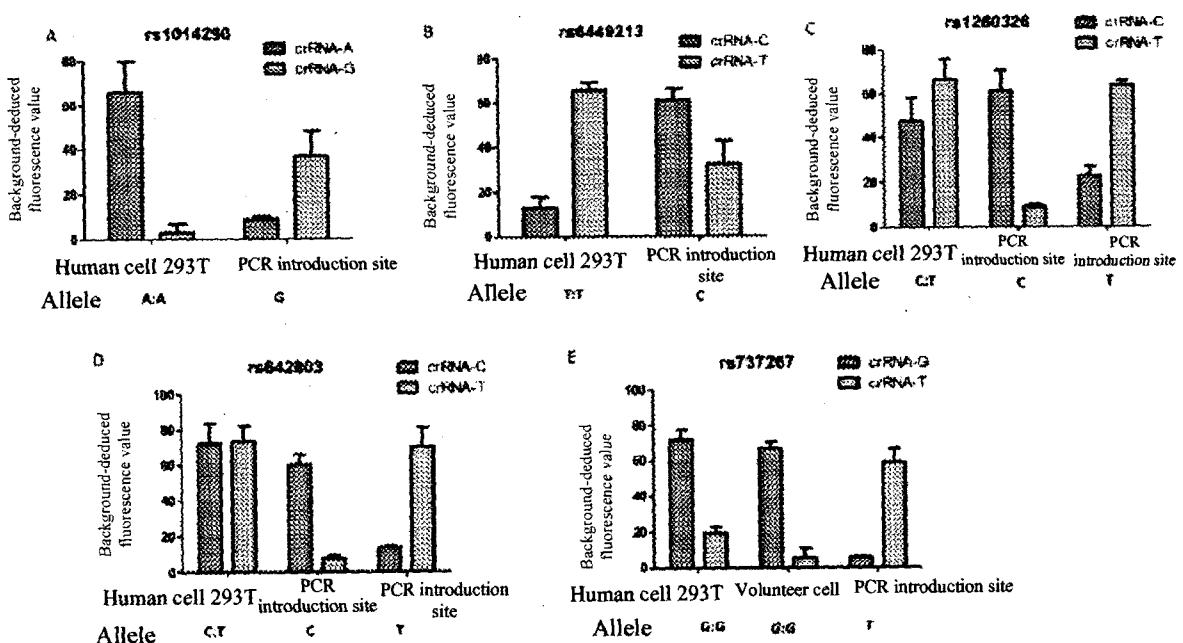
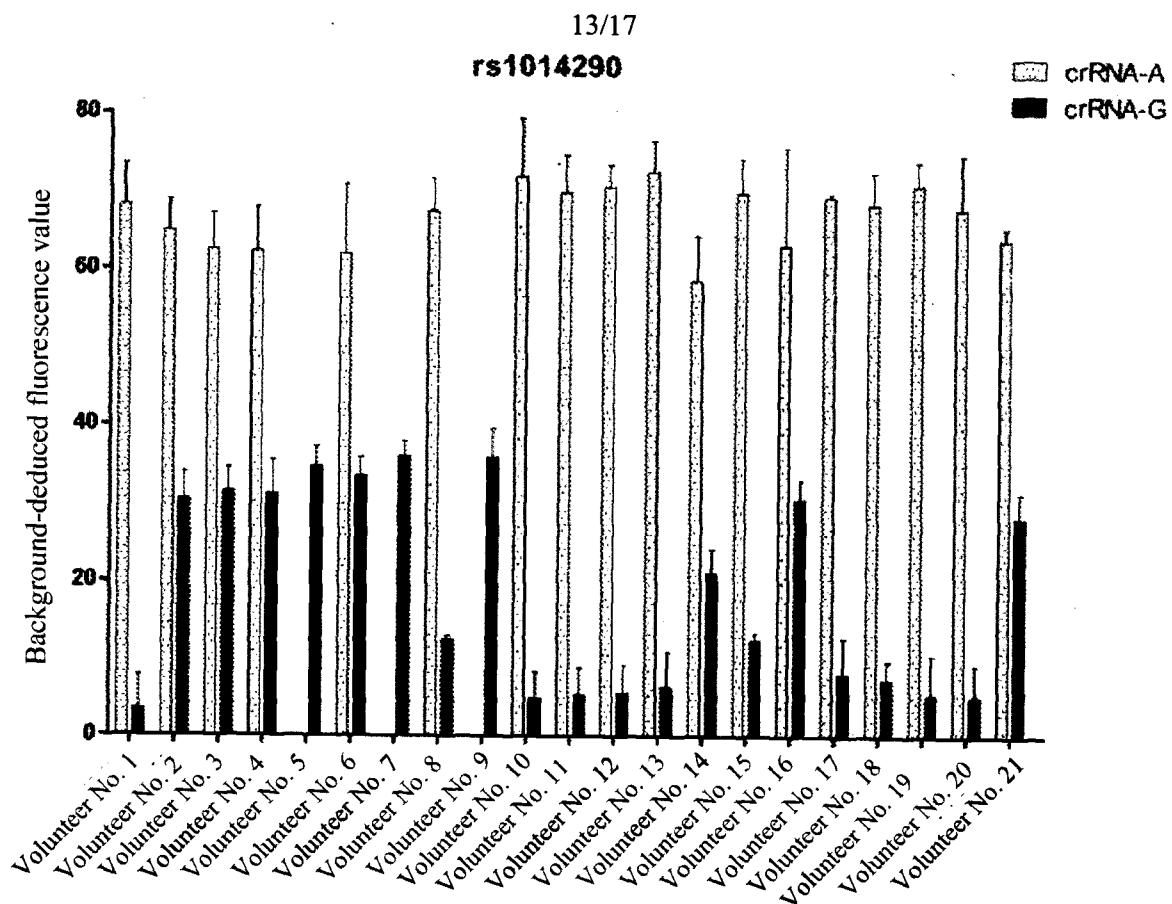
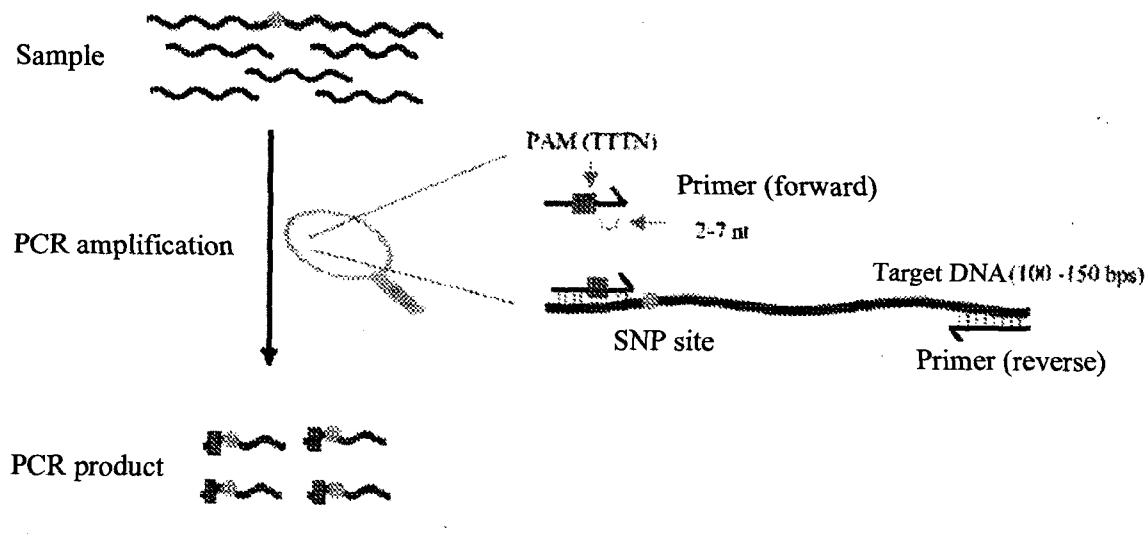
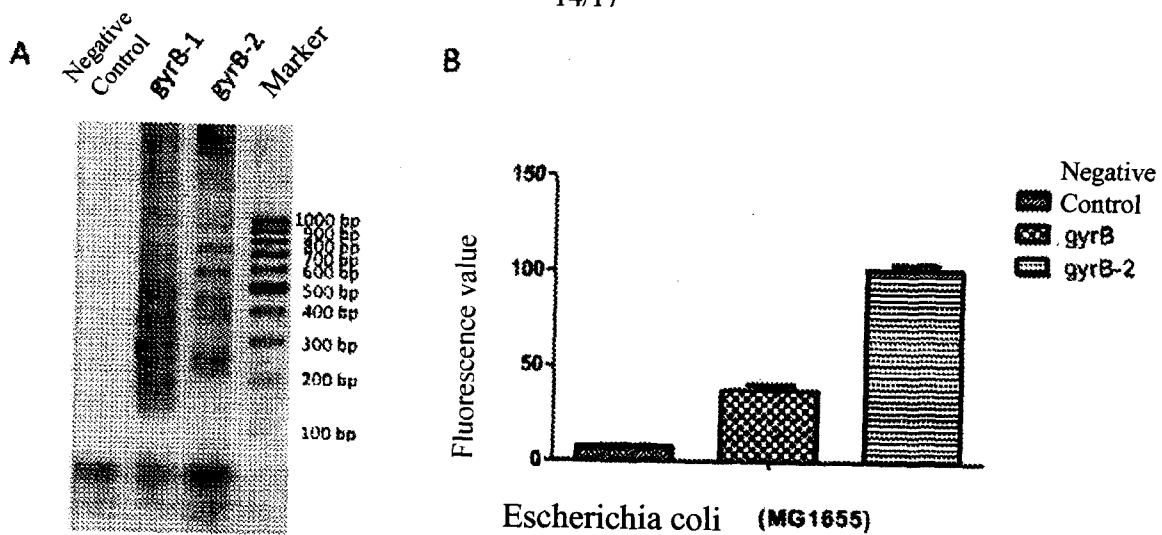
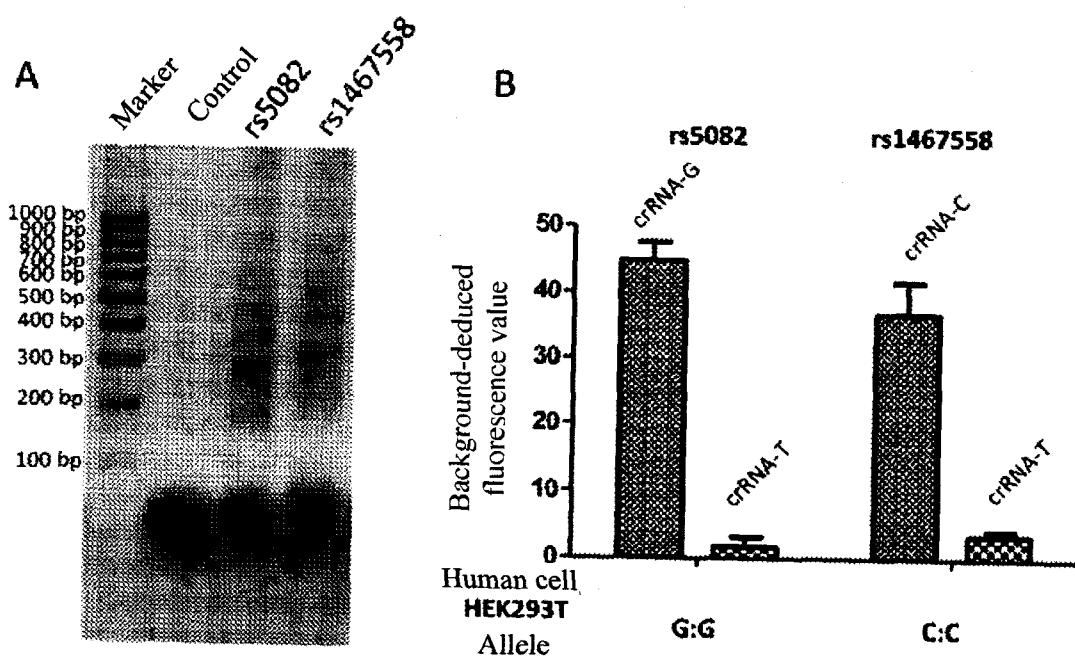


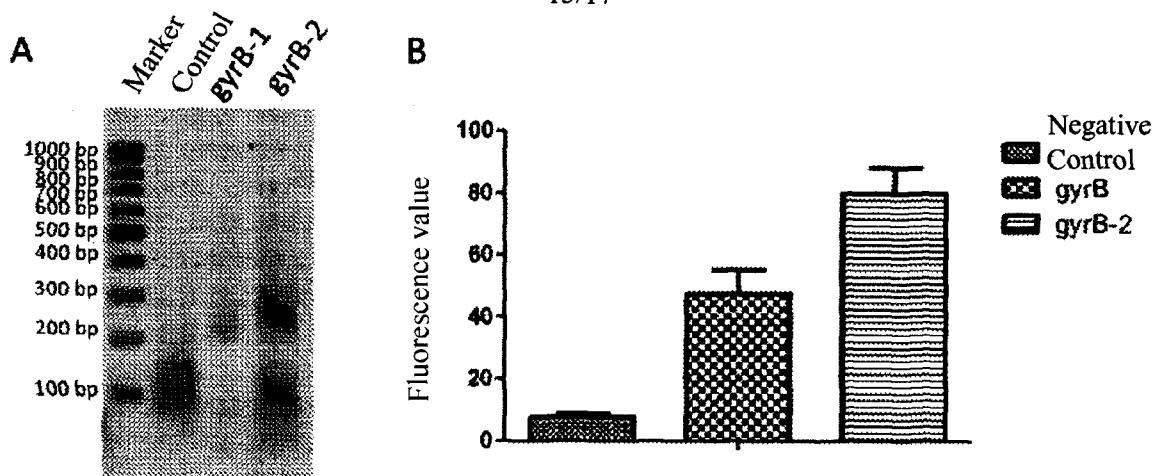
FIG. 16

**FIG. 17****FIG. 18**

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**FIG. 19****FIG. 20**

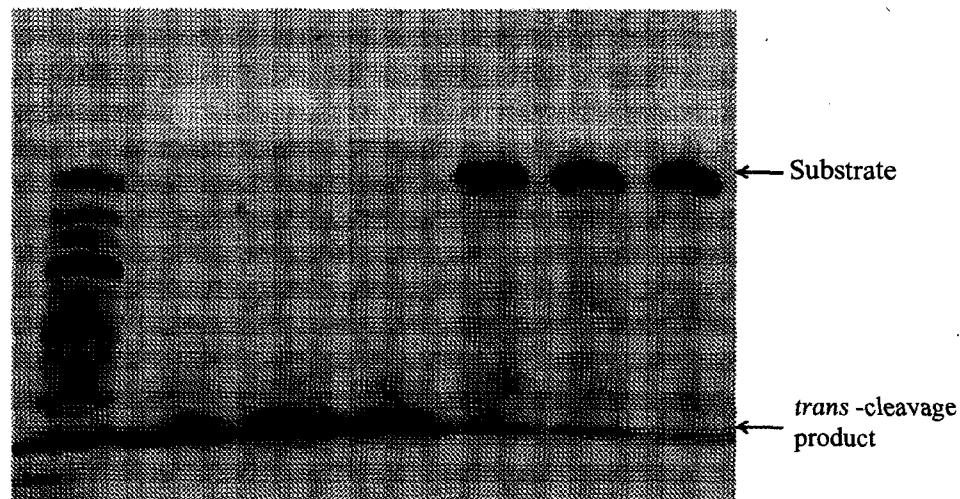
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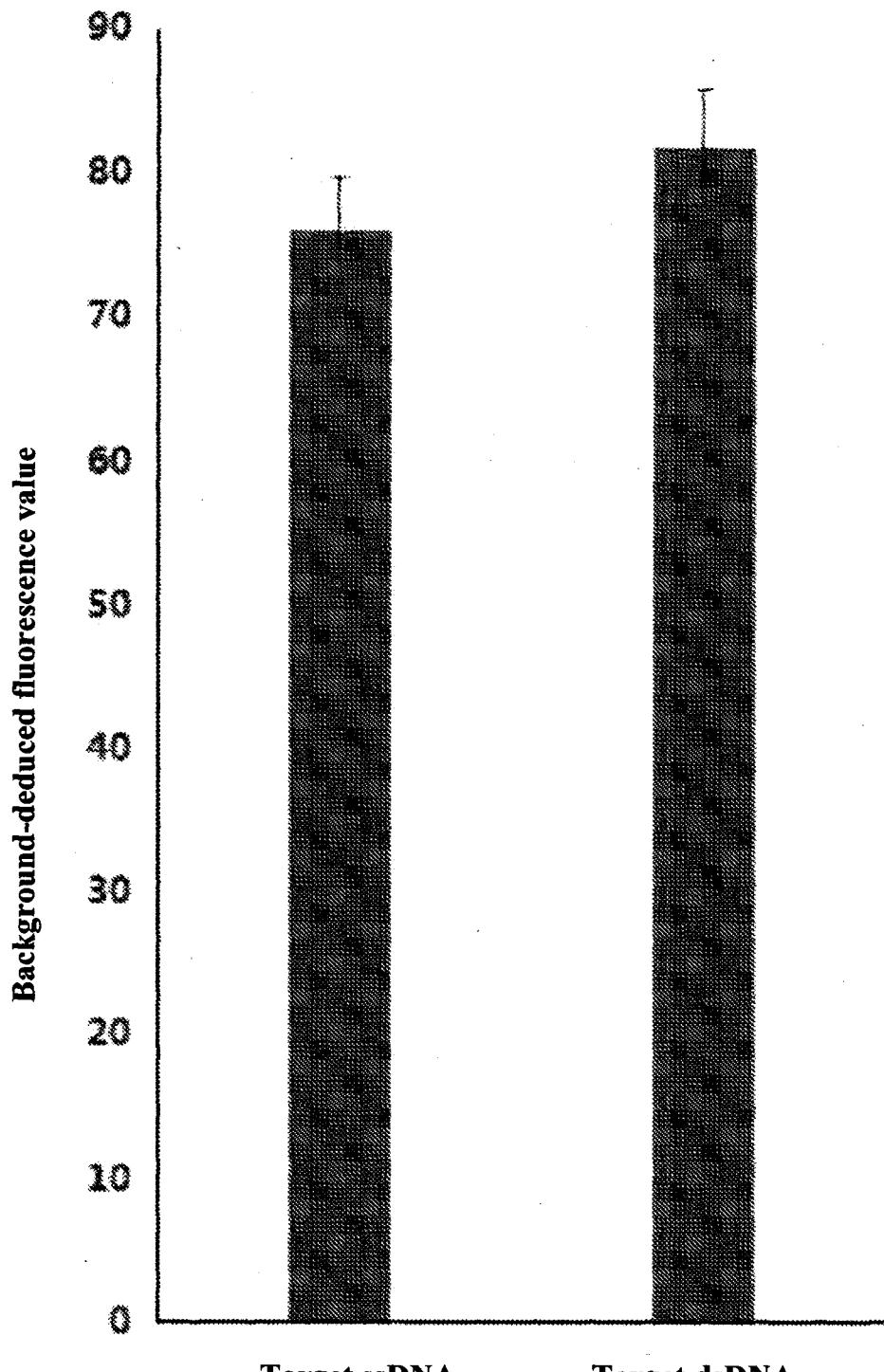
Escherichia coli (MG1655)

FIG. 21

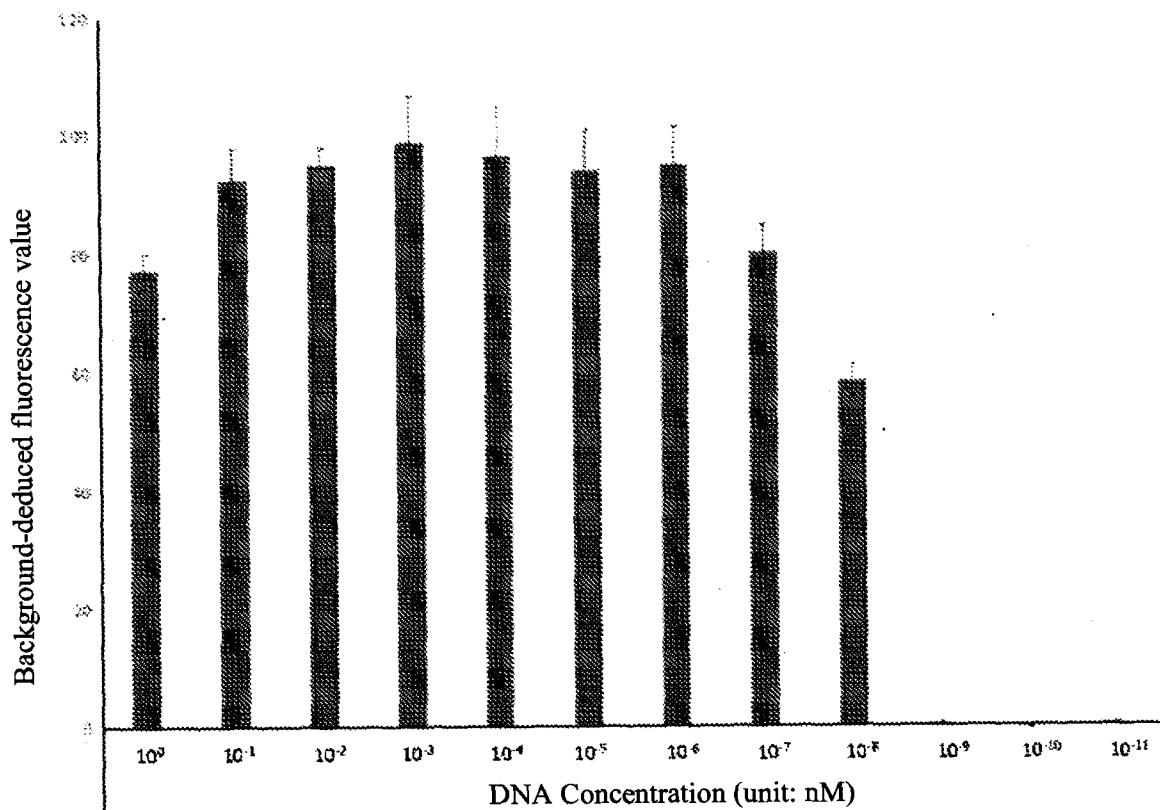
Lane	M	1	2	3	4	5	6
Cas12b		+(100)	+(250)	+(500)	+(500)	+(500)	-
sgRNA		+(100)	+(250)	+(500)	+(500)	-	-
target DNA(ssDNA:T1)		+	+	+	-	-	-
ssDNA probe (ssDNA:DNMT1-3'-5'FAM)		+	+	+	+	+	+

**FIG. 22**

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**FIG. 23**

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**FIG. 24**