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(54) Title: GENOMIC MARKERS OF HEPATITIS B VIRUS ASSOCIATED WITH HEPATOCELLULAR CARCINOMA

(57) Abstract: The present invention provides methods of predicting a pre-disposition of HBV-infected individuals to develop hepatocellular carcinoma (HCC).

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GENOMIC MARKERS OF HEPATITIS B VIRUS ASSOCIATED WITH HEPATOCELLULAR CARCINOMA

BACKGROUND OF THE INVENTION

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[01] Hepatitis B virus (HBV) infects over 300 million people worldwide. For those individuals with high levels of viral replication, chronic active hepatitis with progression to cirrhosis, liver failure and hepatocellular carcinoma (HCC) is common.

[02] The natural progression of chronic HBV infection over a 10 to 20 year
10 period leads to cirrhosis in 20-to-50% of patients and progression of HBV infection to hepatocellular carcinoma has been well documented. There have been no studies that have determined sub-populations of hepatitis B virus that are most likely to cause hepatocellular carcinoma, thus to date all hepatitis B virus have been considered of equal risk of hepatocarcinogenesis.

[03] It is important to note that the survival for patients diagnosed with
15 hepatocellular carcinoma is only 0.9 to 12.8 months from initial diagnosis (Takahashi *et al.*, *American Journal of Gastroenterology* 88:240-243 (1993)). Treatment of hepatocellular carcinoma with chemotherapeutic agents has not proven effective and only 10% of patients will benefit from surgery due to extensive tumor invasion of the liver (Trinchet *et al.*, *Presse*
20 *Medicine* 23:831-833 (1994)). Given the aggressive nature of primary hepatocellular carcinoma, the only viable treatment alternative to surgery is liver transplantation (Pichlmayr *et al.*, *Hepatology* 20:33S-40S (1994)).

BRIEF SUMMARY OF THE INVENTION

25

[04] The present invention provides for methods of determining a pre-disposition of an individual infected with hepatitis B virus (HBV) to develop hepatocellular carcinoma (HCC). In some embodiments, the methods comprise:

(a) determining nucleotides in the genome of HBV isolated from the
30 individual at positions corresponding to nucleotides 31, 53, 312, 799, 961, 1165, 1499, 1613, 1762, 1764, 1899, 2170, 2441, 2525, and/or 2712 of SEQ ID NO:1; and

(b) comparing the determined nucleotides to nucleotides associated with a pre-disposition to cause HCC, wherein the nucleotides associated with a pre-disposition to

cause HCC comprise: 31C, 53C, 312C, 799G, 961G, 1165T, 1499G, 1613A, 1762T, 1764A, 1899A, 2170C, 2170G, 2441C, 2525C, 2712C, 2712A, and/or 2712G.

[05] In some embodiments, the methods comprise:

(a) determining nucleotides in the genome of a genotype B HBV isolated from the individual at positions corresponding to nucleotides 1165, 1762, 1764, 2525 or 2712 of SEQ ID NO:1; and

(b) comparing the determined nucleotides to nucleotides associated with a pre-disposition to cause HCC, wherein the nucleotides associated with a pre-disposition to cause HCC comprise: 1165T, 1762T, 1764A, 2525C, 2712C, 2712A, or 2712G.

[06] In some embodiments, the methods comprise:

(a) determining nucleotides in the genome of a genotype B HBV isolated from the individual at positions corresponding to nucleotides 1165, 1762, 1764, 2525 and 2712 of SEQ ID NO:1; and

(b) comparing the determined nucleotides to nucleotides associated with a pre-disposition to cause HCC, wherein the nucleotides associated with a pre-disposition to cause HCC in genotype B comprise:

1762T and 1764A and 2712A; or

1762T and 1764A and 2712C; or

1762T and 1764A and 2712G; or

1762T and 1764A and 2712T and 2525C; or

1762A and 1764G and 1165T.

[07] In some embodiments, the method comprises determining the genotype of the HBV from the individual.

[08] In some embodiments, the determining step comprises nucleotide sequencing the HBV genome flanking the nucleotides at positions corresponding to nucleotides 1165, 1762, 1764, 2525 and 2712 of SEQ ID NO:1.

[09] In some embodiments, the determining step comprises amplifying at least a portion of the HBV genome to produce one or more amplification products comprising the nucleotides at the positions corresponding to nucleotides 1165, 1762, 1764, 2525 and 2712 of SEQ ID NO:1. In some embodiments, the method comprises contacting the one or more amplification products with one or more probes that hybridize to HCC-associated nucleotides:

1762T and 1764A and 2712A; or

1762T and 1764A and 2712C or;

1762T and 1764A and 2712G; or
1762T and 1764A and 2712T and 2525C; or
1762A and 1764G and 1165T;

under conditions to allow for hybridization of a probe to an amplification product only if the
5 amplification product comprises a complementary nucleotide at the position of the HCC-
associated nucleotide. In some embodiments, the hybridization is performed as a line probe
assay.

[10] In some embodiments, the method comprises:

(a) determining nucleotides in the genome of a genotype C HBV isolated
10 from the individual at positions corresponding to nucleotides 31, 53, 312, 799, 961, 1499,
1613, 1899, 2170, or 2441 of SEQ ID NO: 1; and

(b) comparing the determined nucleotides to nucleotides associated with a
pre-disposition to cause HCC, wherein the nucleotides associated with a pre-disposition to
cause HCC comprise: 31C, 53C, 312C, 799G, 961G, 1499G, 1613A, 1899A, 2170C, 2170G,
15 or 2441C.

[11] In some embodiments, the method comprises

a) determining the subtype of a genotype C HBV from the individual,
wherein:

subtype C1 comprises nucleotides 2733A, 1856C, 1009T and 2892T,
20 subtype C2 comprises nucleotides 2733C, 1856T, 1009T and 2892T, and
subtype C3 comprises nucleotides 2733C, 1856C, 1009C and 2892T;

b1) if the HBV is genotype C1, determining the nucleotides at positions
corresponding to nucleotides 31, 53 and 1499 of SEQ ID NO:1; or

b2) if the HBV is genotype C2, determining the nucleotides at positions
25 corresponding to nucleotides 799, 2441 and 2170 of SEQ ID NO:1; and

b3) if the HBV is genotype C3, determining the nucleotides at positions
corresponding to nucleotides 312, 961, 1613, 1899 of SEQ ID NO:1; and

c) comparing the determined nucleotides to nucleotides at the positions
associated with a pre-disposition to cause HCC, wherein the nucleotides associated with a
30 pre-disposition to cause HCC in subtype C1 comprise:

31C; and/or
53C; and/or
1499G; and

the nucleotides associated with a pre-disposition to cause HCC in subtype C2
comprise:

2170C; and/or

2170G; and/or

5 2441C; and/or

799G; and

the nucleotides associated with a pre-disposition to cause HCC in subtype C3
comprise:

312C; and/or

10 961G; and/or

1613A; and/or

1899A.

[12] In some embodiments, the determining step comprises nucleotide
sequencing the HBV genome flanking the nucleotides at positions corresponding to
15 nucleotides 31, 53, and 1499 of SEQ ID NO:1. In some embodiments, the determining step
comprises nucleotide sequencing the HBV genome flanking the nucleotides at positions
corresponding to nucleotides 799, 2441, and 2170 of SEQ ID NO:1. In some embodiments,
the determining step comprises amplifying at least a portion of the HBV genome to produce
one or more amplification products comprising the nucleotides at the positions corresponding
20 to nucleotides 31, 53, and 1499 of SEQ ID NO:1. In some embodiments, the determining
step comprises nucleotide sequencing the HBV genome flanking the nucleotides at positions
corresponding to nucleotides 312, 961, 1613, and 1899 of SEQ ID NO:1.

[13] In some embodiments, the determining step comprises amplifying at
least a portion of the HBV genome to produce one or more amplification products comprising
25 the nucleotides at the positions corresponding to nucleotides 799, 2441, and 2170 of SEQ ID
NO:1. In some embodiments, the determining step comprises amplifying at least a portion of
the HBV genome to produce one or more amplification products comprising the nucleotides
at the positions corresponding to nucleotides 312, 961, 1613, and 1899 of SEQ ID NO:1.

[14] In some embodiments, the method comprises contacting the one or
30 more amplification products with one or more probes that hybridize to HCC-associated
nucleotides:

31C; and/or

53C; and/or

1499G;

under conditions to allow for hybridization of a probe to an amplification product only if the amplification product comprises a complementary nucleotide at the position of the HCC-associated nucleotide.

5 [15] In some embodiments, the hybridization is performed as a line probe assay.

 [16] In some embodiments, the method comprises contacting the one or more amplification products with probes that hybridize to HCC-associated nucleotides:

 2170G; and/or

10 2441C; and/or

 799G;

under conditions to allow for hybridization of the probes to the amplification product only if the amplification product comprises a complementary nucleotide at the position of the HCC-associated nucleotide. In some embodiments, the hybridization is performed as a line assay.

15 [17] In some embodiments, the method comprises contacting the one or more amplification products with probes that hybridize to HCC-associated nucleotides:

 312C; and/or

 961G; and/or

 1613A; and/or

20 1899A.

 [18] under conditions to allow for hybridization of the probes to the amplification product only if the amplification product comprises a complementary nucleotide at the position of the HCC-associated nucleotide. In some embodiments, the hybridization is performed as a line assay.

25 [19] In some embodiments, the method further comprises determining the genotype of the HBV from the individual.

 [20] In some embodiments, the method comprises:

 determining the genotype of the HBV, wherein genotype B comprises 2733C, 1856C, 1009T and 2892T, genotype C1 comprises 2733A, 1856C, T1099T and 2892T,
30 genotype C2 comprises 2733C, 1856T, 1009T and 2892T and genotype C3 comprises 2733C, 1856C, 1009C and 2892T;

determining nucleotides at positions corresponding to nucleotides 1165, 1762, 1764, 2525 and 2712 of SEQ ID NO: 1 of the HBV genome if the HBV is genotype B; and/or

determining nucleotides at positions corresponding to nucleotides 31 and/or 53 and/or 1499 of SEQ ID NO: 1 of the HBV genome if the HBV is C1; and/or

5 determining nucleotides at positions corresponding to nucleotides 2170 and/or 2441 and/or 799 of SEQ ID NO: 1 of the HBV genome if the HBV is C2; and/or

determining nucleotides at positions corresponding to nucleotides 312 and/or 961 and/or 1613 and/or 1899 of SEQ ID NO: 1 of the HBV genome if the HBV is C3; and

10 comparing the determined nucleotides to nucleotides associated with a pre-disposition to cause HCC,

wherein nucleotides associated with a pre-disposition to cause HCC in genotype B comprise:

1762T and 1764A and 2712A; or

1762T and 1764A and 2712C or;

15 1762T and 1764A and 2712G; or

1762T and 1764A and 2712T and 2525C; or

1762A and 1764G and 1165T;

wherein nucleotides associated with a pre-disposition to cause HCC in genotype C1 comprise:

20 31C; and/or

53C; and/or

1499G; and

wherein nucleotides associated with a pre-disposition to cause HCC in genotype C2 comprise:

25 2170C; and/or

2170G; and/or

2441C; and/or

799G;

30 wherein nucleotides associated with a pre-disposition to cause HCC in genotype C3 comprise:

312C; and/or

961G; and/or

1613A; and/or

1899A;

thereby determining the pre-disposition of the individual to develop HCC.

[21] The present invention also provides kits for detecting HBV isolates that are associated with the development hepatocellular carcinoma (HCC).

[22] In some embodiments, the kits comprise:

5 one or more probe which, when contacted to an HBV genome, selectively hybridizes to the genome if the genome comprises at least one of the following nucleotides at the positions corresponding to nucleotides of SEQ ID NO:1: 31C, 53C, 312C, 799G, 961G, 1165T, 1499G, 1613A, 1762T, 1762A, 1764A, 1764G, 1899A, 2441C, 2170C, 2170G, 2712A, 2712C, 2712G; or 2525C.

10 [23] In some embodiments, the probe is linked to a solid support.

[24] In some embodiments, the probe selectively hybridizes to:

1762T and 1764A and 2712A; and/or

1762T and 1764A and 2712C; and/or;

1762T and 1764A and 2712G; and/or

15 1762T and 1764A and 2712T and 2525C; and/or

1762A and 1764G and 1165T.

[25] In some embodiments, the probe selectively hybridizes to:

31C; and/or

53C; and/or

20 1499G.

[26] In some embodiments, the probe selectively hybridizes to:

2170C; and/or

2170G; and/or

2441C; and/or

25 799G.

[27] In some embodiments, the probe selectively hybridizes to:

312C; and/or

961G; and/or

1613A; and/or

30 1899A.

[28] In some embodiments, the kits further comprise primers for amplification of at least a portion of the HBV genome.

[29] The present invention also provides a computer readable medium for determining whether an HBV sequence is likely to result in the development of HCC. In some embodiments, the computer readable form comprises:

- a) code for receiving information describing: nucleotides at positions corresponding to nucleotides 31, 53, 312, 799, 961, 1165, 1499, 1613, 1762, 1764, 1899, 2170, 2441, 2525, or 2712 of SEQ ID NO:1;
- b) code for comparing the nucleotides received in a) to nucleotides associated with a pre-disposition to cause HCC; and
- c) code for providing a determination of the pre-disposition of the HBV to cause HCC,

wherein nucleotides associated with a pre-disposition to cause HCC comprise: 31C, 53C, 312C, 799G, 961G, 1165T, 1499G, 1613A, 1762T, 1764A, 1899A, 2170C, 2170G, 2441C, 2525C, 2712C, 2712A, or 2712G.

DEFINITIONS

[30] A probe "selectively hybridizes" to a viral genome comprising a particular nucleotide when the probe hybridizes to the genome when the particular nucleotide (at the specified position) is present, but does not hybridize if the nucleotide at the specified position is different or absent. Conditions to allow for hybridization of a probe to a particular DNA molecule only if a complementary nucleotide is present in a particular target DNA are generally "stringent hybridization conditions."

[31] The phrase "stringent hybridization conditions" refers to conditions under which a probe will hybridize to its target subsequence, typically in a complex mixture of nucleic acid, but to no other sequences, or at least to no other sequences at which a particular position is anything but one particular nucleotide. Stringent conditions are sequence-dependent and will be different in different circumstances. Longer sequences hybridize specifically at higher temperatures. An extensive guide to the hybridization of nucleic acids is found in Tijssen, *Techniques in Biochemistry and Molecular Biology--Hybridization with Nucleic Probes*, "Overview of principles of hybridization and the strategy of nucleic acid assays" (1993). Generally, stringent conditions are selected to be about 5-10° C lower than the thermal melting point (T_m) for the specific sequence at a defined ionic

strength pH. The T_m is the temperature (under defined ionic strength, pH, and nucleic concentration) at which 50% of the probes complementary to the target hybridize to the target sequence at equilibrium (as the target sequences are present in excess, at T_m , 50% of the probes are occupied at equilibrium). Stringent conditions for Southern hybridization are generally those in which the salt concentration is less than about 1.0 M sodium ion, typically about 0.01 to 1.0 M sodium ion concentration (or other salts) at pH 7.0 to 8.3 and the temperature is at least about 30°C for short probes (*e.g.*, 10 to 50 nucleotides) and at least about 60°C for long probes (*e.g.*, greater than 50 nucleotides). Stringent conditions may also be achieved with the addition of destabilizing agents such as formamide. For selective hybridization, a positive signal is at least two times background, optionally 10 times background hybridization, *i.e.*, hybridization to another nucleotide sequence with a different nucleotide at the position of interest. Exemplary stringent hybridization conditions can be as follows: 50% formamide, 5X SSC, and 1% SDS, incubating at 42°C, or 5X SSC, 1% SDS, incubating at 65°C, with wash in 0.2X SSC, and 0.1% SDS at 65°C. Such washes can be performed for 5, 15, 30, 60, 120, or more minutes.

[32] "Determining nucleotides in the genome of HBV at positions corresponding to" particular nucleotides of a reference sequence (*e.g.*, SEQ ID NO:1) refers to identifying a position in an isolated HBV genome that occurs in a position that is the equivalent of the particular position in the reference sequence. The variants identified in the present invention are not limited to predicting sequence pre-disposition of variants of SEQ ID NO:1, but instead apply to any HBV strain carrying particular corresponding nucleotides. Thus, when the genome of an HBV isolate differs from SEQ ID NO:1 (*e.g.*, by changes in nucleotides or addition or deletion of nucleotides), it may be that a particular nucleotide associated with the development of HCC will not be in exactly the same position as it is in SEQ ID NO:1. For example, the nucleotide corresponding to nucleotide 31C of SEQ ID NO:1 may occur at position 32 of a particular HBV strain due to a one nucleotide insertion at an earlier position in the strain's genome. Nevertheless, position 32 of the HBV strain would correspond to position 31 of SEQ ID NO:1, which can be readily illustrated in an alignment of the two sequences. As described herein, the corresponding nucleotide in the genome of an HBV isolate can be determined using an alignment algorithm such as BLAST.

BRIEF DESCRIPTION OF THE DRAWINGS

[33] Figure 1 illustrates the locations of various primers used for amplification of HBV and the resulting amplified fragments relative to the HBV genome, represented as a line at the bottom of the figure.

5 [34] Figures 2A and 2B illustrate the genome (SEQ ID NO:1) of an exemplary HBV genotype B isolate comprising highlighted nucleotides associated with the development of HCC.

[35] Figures 3A and 3B illustrate the genome (SEQ ID NO:2) of an exemplary HBV genotype C1 isolate comprising highlighted nucleotides associated with the
10 development of HCC.

[36] Figures 4A and 4B illustrate the genome (SEQ ID NO:3) of an exemplary HBV genotype C2 isolate comprising highlighted nucleotides associated with the development of HCC.

15 DETAILED DESCRIPTION OF THE INVENTION

I. Introduction

[37] The present invention is based on the discovery that certain sequence variants of HBV are associated with the development of hepatocellular carcinoma (HCC) in
20 individuals infected with HBV. Specifically, the presence of the following nucleotides in an HBV genome is associated with the development of HCC: 31C, 53C, 312C, 799G, 961G, 1165T, 1499G, 1613A, 1762T, 1764A, 1899A, 2170C, 2170G, 2441C, 2525C, 2712C, 2712A, or 2712G. Accordingly, the invention provides for methods of determining whether an individual infected with HBV has a predisposition for HCC by detecting the nucleotide
25 sequence of the HBV variant infecting the individual. The method also provides for kits comprising reagents to detect any of the specific variants associated with HCC and computer readable forms for applying the methods of the invention.

II. Detecting HBV variants associated with HCC

30 [38] Any number of methods may be used to determine the nucleotides at the positions corresponding to nucleotides at positions 31, 53, 312, 799, 961, 1165, 1499, 1613, 1762, 1764, 1899, 2170, 2441, 2525, and/or 2712 of SEQ ID NO:1 and/or other positions as described herein.

[39] In some embodiments, nucleotide sequencing is used to determine the nucleotides at particular positions of the HBV genome. Without intending to limit the invention, examples of nucleotide sequencing include chain termination sequencing. *See, e.g., Sanger et al. Proc. Nat. Acad. Sci. USA* 74:5463-5467 (1977); Sambrook *et al., Molecular Cloning, A Laboratory Manual* (2nd ed. 1989); Kriegler, *Gene Transfer and Expression: A Laboratory Manual* (1990); and *Current Protocols in Molecular Biology* (Ausubel *et al., eds.,* 1994)). Sequencing may be performed following amplification of the HBV genome or a fragment thereof. Direct sequencing of PCR generated amplicons by selectively incorporating boronated nuclease resistant nucleotides into the amplicons during PCR and digestion of the amplicons with a nuclease to produce sized template fragments may also be performed (Porter *et al., Nucleic Acids Research* 25(8):1611-1617 (1997)). Alternatively, microfluidic techniques such as those described in U.S. Patent Publication No. 2003/0215862 may be used. *See also* U.S. Patent Publication No. 2003/0152996 describing alternate sequencing methods.

[40] Specific probes that bind to nucleotides at particular positions in the HBV genome may also be used to detect nucleotides in the HBV genome. Probes that detect the particular nucleotides associated with HCC may be used in a reverse hybridization assay format using immobilized oligonucleotide probes present at distinct locations on a solid support. More particularly, the Line Probe Assay (LiPA) may be used. The LiPA is a reverse hybridization assay using oligonucleotide probes immobilized as parallel lines on a solid support strip. *See, e.g., PCT Publication No. WO 94/12670.* In this assay, specific oligonucleotides may be immobilized at known locations on membrane strips and hybridized under strictly controlled conditions with the labeled PCR product. Different probes may be designed such that each probe on the strip comprises an HBV nucleotide sequence, or complement thereof, but contains a different nucleotide at a particular position. Amplifying an HBV genome, or fragment thereof, and hybridizing the amplification product to one or more probes specific for a particular variant will result in complete or at least preferential hybridization of one of the probes to the product, thereby indicating which nucleotide at the particular position is contained in the amplified genome. Hybridization conditions using this assay are generally set at a high stringency such that only one probe binds to the amplification product. Exemplary conditions may include, *e.g.,* standard hybridization and washing conditions (*e.g.,* 1x SSC buffer containing 0.1% sodium dodecyl sulfate at 62°C).

Amplification of HBV

[41] The HBV genome or a portion thereof may be amplified before the nucleotides at positions associated with HCC are determined. An “amplification” refers to any chemical, including enzymatic, reaction that results in increased copies of a template nucleic acid sequence. Amplification reactions include polymerase chain reaction (PCR) and ligase chain reaction (LCR) (see U.S. Patents 4,683,195 and 4,683,202; *PCR Protocols: A Guide to Methods and Applications* (Innis *et al.*, eds, 1990)), strand displacement amplification (SDA) (Walker, *et al. Nucleic Acids Res.* 20(7):1691-6 (1992); Walker *PCR Methods Appl* 3(1):1-6 (1993)), transcription-mediated amplification (Phyffer, *et al., J. Clin. Microbiol.* 34:834-841 (1996); Vuorinen, *et al., J. Clin. Microbiol.* 33:1856-1859 (1995)), nucleic acid sequence-based amplification (NASBA) (Compton, *Nature* 350(6313):91-2 (1991), rolling circle amplification (RCA) (Lisby, *Mol. Biotechnol.* 12(1):75-99 (1999)); Hatch *et al., Genet. Anal.* 15(2):35-40 (1999)) and branched DNA signal amplification (bDNA) (see, e.g., Iqbal *et al., Mol. Cell Probes* 13(4):315-320 (1999)).

[42] Amplified portions of the HBV genome (optionally labeled) may be hybridized to DNA comprising one or more HCC-associated nucleotides, or a complement thereof, thereby allowing for determination of the identity of nucleotides at a nucleotide position of interest. Alternatively, the probes may detect non-HCC-associated nucleotides, thereby allowing for detection of HCC-associated HBV variants by detecting a lack of hybridization.

[43] In some embodiments, the amplified fragment of the genome will comprise more than one HCC-associated nucleotide. Thus, in some embodiments, the fragment will comprise any combination of positions corresponding to nucleotides at positions 31, 53, 312, 799, 961, 1165, 1499, 1613, 1762, 1764, 1899, 2170, 2441, 2525, and/or 2712 of SEQ ID NO:1. In some embodiments, the fragment will comprise positions corresponding to nucleotides 1165, 1762, 1764, 2525 and 2712 of SEQ ID NO:1. In some embodiments, the fragment will comprise positions corresponding to nucleotides 31, 53, 312, 799, 961, 1499, 1613, 1899, 2170, and 2441 of SEQ ID NO:1.

[44] In some cases, more than one fragment of HBV is amplified. In these cases, the sum of all fragments amplified may comprise any combination of positions corresponding to nucleotides at positions 31, 53, 312, 799, 961, 1165, 1499, 1613, 1762, 1764, 1899, 2170, 2441, 2525, and/or 2712 of SEQ ID NO:1. For example, one fragment may comprise positions 31, 53, 312, 799, 961, 1165, 1499, 1613, 1762, 1764 and a second fragment may comprise positions 1899, 2170, 2441, 2525, or 2712. In some embodiments,

the sum of all amplified fragments will comprise positions corresponding to nucleotides 1165, 1762, 1764, 2525 and 2712 an SEQ ID NO:1. In some embodiments, the sum of all amplified fragments will comprise positions corresponding to nucleotides 31, 53, 312, 799, 961, 1499, 1613, 1899, 2170, and 2441.

5 [45] In some embodiments, amplification and detection methods are used in combination, and sometimes in the same reaction vessel, to detect HBV polynucleotides using detectably-labeled probes that distinguish between HCC-associated nucleotides and nucleotides not associated with HCC. Binding of a probe to its complementary hybridization sequence allows the user to quantify the accumulation of a particular sequence without
10 necessarily removing the contents from the reaction vessel. In general, any type of label that allows for the detection and differentiation of different probes can be used according to the methods of the invention.

 [46] Accumulation of amplified product can be quantified by any method known to those in the art. For instance, fluorescence from a probe can be detected by
15 measurement of light at a particular frequency. Similarly, the accumulation of various chemical products created via an enzymatic reaction linked to the probe can be measured, for instance, by measuring absorbance of light at a particular wavelength. In other embodiments, amplification reactions can be quantified directly by blotting them onto a solid support and hybridizing with a detectably-labeled nucleic acid probe. Once unbound probe is washed
20 away, the amount of probe can be quantified by measuring radioactivity as is known to those of skill in the art. Other variations of this technique employ the use of chemiluminescence to detect hybridization events.

 [47] Measurement of amplification products can be performed after the reaction has been completed or can be measured in "real time" (i.e., as the reaction occurs).
25 If measurement of accumulated amplified product is performed after amplification is complete, then detection reagents (e.g. probes) can be added after the amplification reaction. Alternatively, probes can be added to the reaction prior or during the amplification reaction, thus allowing for measurement of the amplified products either after completion of amplification or in real time. Real time measurements can be particularly useful because they
30 allow for measurement at any given cycle of the reaction and thus provide more information about accumulation of products throughout the reaction. For measurement of amplification product in real time, fluorescent probes are often used.

 [48] One amplification assay utilizing a FRET pair to detect an amplification product is the "TaqMan®" assay described in Gelfand *et al.* U.S. Patent No.

5,210,015, and Livak *et al.* U.S. Patent No. 5,538,848. The probe is a single-stranded oligonucleotide labeled with a FRET pair. In a TaqMan® assay, a DNA polymerase releases single or multiple nucleotides by cleavage of the oligonucleotide probe when it is hybridized to a target strand. That release provides a way to separate the quencher label and the fluorophore label of the FRET pair.

[49] Another type of nucleic acid hybridization probe assay utilizing FRET pairs is described in Tyagi *et al.* U.S. Pat. No. 5,925,517, which utilizes labeled oligonucleotide probes, which are referred to as "molecular beacons." See Tyagi, S. and Kramer, F. R., *Nature Biotechnology* 14: 303-308 (1996). A molecular beacon probe is an oligonucleotide whose end regions hybridize with one another in the absence of target but are separated if the central portion of the probe hybridizes to its target sequence. The rigidity of the probe-target hybrid precludes the simultaneous existence of both the probe-target hybrid and the intramolecular hybrid formed by the end regions. Consequently, the probe undergoes a conformational change in which the smaller hybrid formed by the end regions disassociates, and the end regions are separated from each other by the rigid probe-target hybrid. For molecular beacon probes, a central target-recognition sequence is flanked by arms that hybridize to one another when the probe is not hybridized to a target strand, forming a "hairpin" structure, in which the target-recognition sequence (which is commonly referred to as the "probe sequence") is in the single-stranded loop of the hairpin structure, and the arm sequences form a double-stranded stem hybrid. When the probe hybridizes to a target, that is, when the target-recognition sequence hybridizes to a complementary target sequence, a relatively rigid helix is formed, causing the stem hybrid to unwind and forcing the arms apart.

[50] One of skill will recognize that a large number of different fluorophores can be used to label probes useful in the invention. Some fluorophores useful in the methods and composition of the invention include: fluorescein, fluorescein isothiocyanate (FITC), carboxy tetrachloro fluorescein (TET), NHS-fluorescein, 5 and/or 6-carboxy fluorescein (FAM), 5- (or 6-) iodoacetamidofluorescein, 5- {[2(and 3)-5-(Acetylmercapto)-succinyl]amino} fluorescein (SAMSA-fluorescein), and other fluorescein derivatives, rhodamine, Lissamine rhodamine B sulfonyl chloride, Texas red sulfonyl chloride, 5 and/or 6 carboxy rhodamine (ROX) and other rhodamine derivatives, coumarin, 7-amino-methyl-coumarin, 7-Amino-4-methylcoumarin-3-acetic acid (AMCA), and other coumarin derivatives, BODIPY™ fluorophores, Cascade Blue™ fluorophores such as 8-methoxypyrene-1,3,6-trisulfonic acid trisodium salt, Lucifer yellow fluorophores such as 3,6-Disulfonate-4-amino-naphthalimide, phycobiliproteins derivatives, Alexa fluor dyes

(available from Molecular Probes, Eugene, OR) and other fluorophores known to those of skill in the art. For a general listing of useful fluorophores, *see* Hermanson, G.T., BIOCONJUGATE TECHNIQUES (Academic Press, San Diego, 1996). Thus, each probe used in a reaction may fluoresce at a different wavelength and can be individually detected without interference from the other probes. This is useful, for example, if probes that detect different nucleotides at a particular position are used in a reaction. Thus, for example, one wavelength may indicate binding of a probe that detects 31T while a probe comprising a label with a different wavelength will detect 31C.

Preparing HBV from a test sample

[51] The presence or amount of HBV nucleic acids in a test sample can be determined by amplifying the target regions within the HBV gene. Thus, any liquid or solid material believed to comprise HBV nucleic acids can be an appropriate sample. Preferred sample tissues include plasma, serum, whole blood, blood cells, lymphatic fluid, cerebral spinal fluid, synovial fluid and others.

[52] As used herein, the term "test sample" refers to any liquid or solid material believed to comprise HBV nucleic acids. A test sample may be obtained from a biological source, such as cells in culture or a tissue sample from an animal, e.g., a human. Sample tissues of the instant invention may include, but are not limited to, plasma, serum, whole blood, blood cells, lymphatic fluid, cerebrospinal fluid, synovial fluid, urine, saliva, and skin or other organs (e.g. liver biopsy material).

[53] Such sample will often be taken from patients suspected of having HBV infection, or having any of the wide spectrum of liver diseases related to HBV infection.

[54] Nucleic acids representing the HBV gene of interest may be extracted from tissue samples. Various commercial nucleic acid purification kits, such as QIAmp 96 Virus BioRobot Kit and Qiagen's BioRobot 9604 are known to the skilled artisan, and used to isolate HBV nucleic acids from samples.

III. Determination of HBV genotype

[55] The present methods may also involve a determination of the genotype of HBV in an individual. For example, particular nucleotide variants identified herein may have a stronger predisposition to cause HCC if the variants are found in one genotype than in another. In this context, "genotype" refers to the at least 8 genotypes of HBV (genotypes A, B, C, D, E, F, G, and H) deduced from genome comparisons and designated genotypes A to

H. See, e.g., Westland C. *Hepatology* 36: 2-8 (2002); Borchani-Chabchoub I, *et al.*, *Microbes Infect* 2: 607-12 (2000); Grandjacques C, *et al.*, *J Hepatol* 33: 430-9 (2000); Kato H, *et al.*, *J Virol Methods* 98: 153-9 (2001); Ashton-Rickardt PG, *et al.*, *J Med Virol* 29: 204-14 (1989). Thus, by detecting nucleotides at particular positions identified to occur only in a specific genotype, one may determine the genotype of HBV. Of course, other methods such as serological methods may also be used.

[56] In some embodiments, the presence or absence of the B or C genotype of HBV will be determined. In some embodiments, genotype B comprises 2733C, 1856C, 1009T and 2892T. Further, the subtype of genotype may also be determined. For example, in some embodiments, subtype C1 is characterized by 2733A, 1856C, T1099T and 2892T. In some embodiments, subtype C2 is identified by 2733C, 1856T, 1009T and 2892T. In some embodiments, subtype C3 is identified by 2733C, 1856C, 1009C and 2892T. The details are showed in the table below:

	2733	1856	1009	2892
B	C	C	T	T
C1	A	C	T	T
C2	C	T	T	T
C3	C	C	C	T

[57] Detection of the nucleotides associated with a particular genotype may be detected by any method useful for detecting nucleotide sequences, including all of those described herein (e.g., amplification, nucleotide sequencing and/or probes, etc.).

IV. Comparing nucleotides of HBV with nucleotides associated with HCC

[58] Nucleotide sequence information regarding an isolate from an individual may be compared to nucleotides associated with HCC by any method.

[59] Where a nucleotide sequence of the isolate is determined, the sequence may be aligned with SEQ ID NO:1 or another HBV genomic sequence to determine the position of the specific nucleotides of interest. Methods of alignment of sequences for comparison are well-known in the art. Optimal alignment of sequences for comparison can be conducted, e.g., by the local homology algorithm of Smith & Waterman, *Adv. Appl. Math.* 2:482 (1981), by the homology alignment algorithm of Needleman & Wunsch, *J. Mol. Biol.* 48:443 (1970), by the search for similarity method of Pearson & Lipman, *Proc. Nat'l. Acad. Sci. USA* 85:2444 (1988), by computerized implementations of these algorithms (GAP, BESTFIT, FASTA, and TFASTA in the Wisconsin Genetics Software Package, Genetics

Computer Group, 575 Science Dr., Madison, WI), or by manual alignment and visual inspection (*see, e.g., Current Protocols in Molecular Biology* (Ausubel *et al.*, eds. 1995 supplement)).

[60] An example of algorithm that is suitable for aligning sequences and determining percent sequence identity and sequence similarity are the BLAST and BLAST 2.0 algorithms, which are described in Altschul *et al.*, *Nuc. Acids Res.* 25:3389-3402 (1977) and Altschul *et al.*, *J. Mol. Biol.* 215:403-410 (1990), respectively. BLAST and BLAST 2.0 may be used, with the parameters described herein, to determine an optimal alignment. Software for performing BLAST analyses is publicly available through the National Center for Biotechnology Information (<http://www.ncbi.nlm.nih.gov/>). This algorithm involves first identifying high scoring sequence pairs (HSPs) by identifying short words of length W in the query sequence, which either match or satisfy some positive-valued threshold score T when aligned with a word of the same length in a database sequence. T is referred to as the neighborhood word score threshold (Altschul *et al.*, *supra*). These initial neighborhood word hits act as seeds for initiating searches to find longer HSPs containing them. The word hits are extended in both directions along each sequence for as far as the cumulative alignment score can be increased. Cumulative scores are calculated using, for nucleotide sequences, the parameters M (reward score for a pair of matching residues; always > 0) and N (penalty score for mismatching residues; always < 0). For amino acid sequences, a scoring matrix is used to calculate the cumulative score. Extension of the word hits in each direction are halted when: the cumulative alignment score falls off by the quantity X from its maximum achieved value; the cumulative score goes to zero or below, due to the accumulation of one or more negative-scoring residue alignments; or the end of either sequence is reached. The BLAST algorithm parameters W, T, and X determine the sensitivity and speed of the alignment. The BLASTN program (for nucleotide sequences) uses as defaults a wordlength (W) of 11, an expectation (E) of 10, M=5, N=-4 and a comparison of both strands and it is generally useful to turn off the complexity filter.

[61] Positions of nucleotides of interest are provided throughout this application with reference to the first C of the first EcoR1 cleavage site (GAACTCC) that generally occur in the HBV genome. The first "C" is position 1 of SEQ ID NO:1. Thus, following alignment of a sequence of interest with SEQ ID NO:1, a particular nucleotide of the sequence of interest may be assigned a position relative to the corresponding position in the alignment with SEQ ID NO:1.

[62] The presence of any of the following nucleotides is indicative of a pre-disposition for HCC: 31C, 53C, 312C, 799G, 961G, 1165T, 1499G, 1613A, 1762T, 1764A, 1899A, 2170C, 2170G, 2441C, 2525C, 2712C, 2712A, or 2712G. While those of skill in the art will recognize that any number of algorithms may be useful for predicting a predisposition for developing HCC, as described in the Example, particularly good sensitivity and specificity may be obtained using the following algorithm:

[63] For genotype B HBV, the presence of:

1762T and 1764A and 2712A; or

1762T and 1764A and 2712C or;

1762T and 1764A and 2712G; or

1762T and 1764A and 2712T and 2525C; or

1762A and 1764G and 1165T, indicates a pre-disposition for HCC.

[64] For genotype C1 HBV, the presence of:

31C; and/or

53C; and/or

1499G, indicates a pre-disposition for HCC.

[65] For genotype C2 HBV, the presence of:

2170C; and/or

2170G; and/or

2441C; and/or

799G, indicates a pre-disposition for HCC.

[66] For genotype C3 HBV, the presence of:

312C; and/or

961G; and/or

1613A; and/or

1899A, indicates a pre-disposition for HCC.

[67] In some embodiments of the invention, it is useful to apply the above-listed algorithms in a computer readable form. The code for performing any of the functions described herein can be executed by the digital computers and may be stored on any suitable computer readable media. Examples of computer readable media include magnetic, electronic, or optical disks, tapes, sticks, chips, etc. The code for performing any of the functions described herein may also be written in any suitable computer programming language including, for example, Fortran, C, C++, etc. The graphical user interfaces and

functions underlying the graphical user interfaces can be created using an object oriented programming language such as Java.

V. Benefits of identifying individuals pre-disposed for HCC

5 [68] The conventional methods of surveillance for HCC are testing an infected person's serum alfa-fetoprotein levels (*see, e.g., Liaw Y F et al., Gastroenterology*, 30:263-267 (1986); Colombo M. *et al., N. Engl. J. Med.*, 325:675-680 (1991); Oka H. *et al., Hepatology* 12:680-687 (1990) or by subjecting the person to abdominal ultrasound scanning. Another method for diagnosis of HCC is detecting des-gamma-carboxy prothrombin (Chan C
10 Y *et al. J Hepatol.* 13:21-24 (1991); Weitz I C *et al., Hepatology* 18:990-997 (1993)). Another marker for HCC is TGF-1 β . *See, e.g., US Patent Publication No. 2004/0121414.*

[69] However, without information regarding which patients may be pre-disposed for HCC, it is necessary to screen every person infected with HBV on a regular basis to catch HCC as early as possible. Unfortunately, given the large number of people
15 infected with HBV, as well as the finite resources available to screen individuals, it is impossible to perform all of the necessary screens. The present invention addresses this problem, by indicating which individuals should have intense surveillance for the initial signs of HCC and which individuals do not require such intense surveillance. Thus, the present invention provides for detecting those individuals carrying HBV that is pre-disposed to cause
20 HCC and then further testing those individuals on a regular basis for the presence of HCC and optionally, only rarely or never testing those individuals lacking HCC-associated HBV variants.

VI. Kits

25 [70] Kits comprising the components needed in the methods (typically in an unmixed form) and kit components (packaging materials, instructions for using the components and/or the methods, one or more containers (reaction tubes, columns, etc.)) for holding the components are a feature of the present invention. Kits of the present invention may contain reagents for detecting any one or more of the following nucleotide variants in an
30 HBV genome: 31C, 53C, 312C, 799G, 961G, 1165T, 1499G, 1613A, 1762T, 1764A, 1899A, 2170C, 2170G, 2441C, 2525C, 2712C, 2712A, and/or 2712G. For example, the kits of the invention may comprise combinations of primers and/or probes as described herein for the detection of nucleotide variants associated with HCC. Optionally, the kits may contain

reagents for amplification, including but not limited to, thermostable polymerases such as *Taq* polymerase, nucleotides, buffers, etc.

EXAMPLE

5 [71] Our goal was to discover genetic markers of HCC cases from HBV DNA sequences. In other words, we built up a classification model based on HBV DNA to predict cancer. Several classification models including Naive Bayes, Decision Tree, Neural Networks, and Rule Learning Using Evolutionary Algorithm, have been applied to classify the DNA datasets. The experimental results showed that the Rule Learning Using
10 Evolutionary Algorithm has the best performance. In this section, we present the results of applying the Rule Learning Using Evolutionary Algorithm to classify the HBV DNA data in liver cancer (HCC) and normal cases.

Experimental Methodology

15 [72] For each experiment, 90% of samples are selected randomly as the training set and the remains 10% samples form the testing set. For each dataset, the experiment is repeated for 10 times.

 [73] In medical diagnosis and disease predication problems, the algorithm or model performance is not only judged by accuracy, but also sensitivity and specificity.
20 Sensitivity is generally more important than specificity and accuracy in medical diagnoses because doctors and patients prefer not to miss any patients with diseases. Extra diagnosis and tests can be performed to confirm their prediction and remove initial false positives.

 [74] We evaluated our model in all these three measurements.

$$\begin{aligned} \text{Accuracy} &= \frac{\text{True Positive} + \text{True Negative}}{\text{True Positive} + \text{True Negative}} \\ \text{Sensitivity} &= \frac{\text{True Positive}}{\text{True Positive} + \text{False Negative}} \\ \text{Specificity} &= \frac{\text{True Negative}}{\text{True Negative} + \text{False Positive}} \end{aligned}$$

25

 [75] The true positive is the number of all the patients with the disease and a positive test result, whereas the true negative is the number of all the patients without the disease and a negative test result. The false positive is the number of all the patients without
30 the disease but a positive test result, whereas the false negative is the number of all the

patients with the disease but a negative test result. In medical diagnosis, a false negative is the most undesirable case.

Results

Data Description

[76] Genotype B and genotype C data were separated for analysis. The proportion of patients in each genotype or C subtypes is shown in Table 2. "CON" refers to "control," i.e., no HCC.

Table 2

Datasets	CON	HCC	Total	%
B	49	37	86	43.8776
C1	10	16	26	13.2653
C2	18	22	40	20.4082
C3	19	25	44	22.4490
Total	96	100	196	100

Genotype B

[77] Table 3 shows the details of the markers for HBV genotype B.

Table 3

HBV markers for HCC of genotype B

Markers	Normal value	HCC-related value
1762, 1764	AG	TA
1165	C	T
2712	T	C (A, G)
2525	A, T	C

[78] The classification rules based on the applied data cleansing process for genotype B are as follows:

If 1762A and 1764G and 1165T are present in genotype B, then HCC is likely to occur.

If 1762T and 1764A and 2712A, 2712C or 2712G are present in genotype B, then HCC is likely to occur.

If 1762T and 1764A and 2712T and 2525C are present in genotype B, then HCC is likely to occur.

[79] The experimental results for the genotype B dataset are shown in Table

4.

Table 4

Results of genotype B HBV dataset to predict HCC

Results	Training set (STD)	Testing set (STD)
Sensitivity	0.75029(0.05361)	0.75 (0.16667)
Specificity	0.68 (0.06215)	0.66 (0.13499)
Accuracy	0.7093 (0.02615)	0.70 (0.07499)

C1 subgroup

[80] Table 5 shows the details of the markers for C1 subgroup.

Table 5

HCC related markers for C1 subgroup

Markers	Normal value	HCC-related value
31	T	C
53	T	C
1499	A	G

5

[81] The classification rules based on the applied data cleansing process for C1 subgroup are as follows:

If 31C or 53C or 1499G are present in genotype C1, then HCC is likely to occur.

10

[82] The Experimental results for the C1 subgroup are showed in Table 6.

Table 6

Results of genotype C1 HBV dataset to predict HCC

Results	Training set (STD)	Testing set (STD)
Sensitivity	0.80769(0.04054)	0.75 (0.26252)
Specificity	0.7875 (0.06038)	0.7 (0.48305)
Accuracy	0.8 (0.03012)	0.7333 (0.21082)

15

C2 subgroup

[83] Table 7 shows the details of the markers for C2 subgroup.

Table 7

HCC related markers for C2 subgroup

Markers	Normal value	HCC-related value
2170	T	C, G
2441	T	C
799	A	G

20

[84] The classification rules based on the applied data cleansing process for C2 subgroup are as follows:

If 2170C or 2170G or 2441C or 799G are present in genotype C2, then HCC is likely to occur.

25

[85] The Experimental results on the C2 subgroup are showed in Table 8.

Table 8

Results of C2 genotype dataset to predict HCC

Results	Training set (STD)	Testing set (STD)
Sensitivity	0.84706 (0.06323)	0.85 (0.24152)
Specificity	0.97857 (0.0345)	1 (0.00000)
Accuracy	0.90645 (0.0355)	0.925 (0.12076)

[86] The classification rules based on the applied data cleansing process for C3 subgroup are as follows:

If C312 or G961 or A1613 or A1899 are present in genotype C3, then HCC is likely to occur.

[87] The Experimental results on the C3 subgroup are showed in Table 9.

Table 9

Results of C3 genotype dataset to predict HCC

Results	Training set (STD)	Testing set (STD)
Sensitivity	0.75 (0.0044)	0.77 (0.22)
Specificity	0.81 (0.0040)	0.80 (0.26)
Accuracy	0.77 (0.0024)	0.78 (0.18)

Patients and Methods

Patients

[88] Residual serum samples of one hundred chronic hepatitis B patients suffering from hepatocellular carcinoma (HCC) and one hundred age-matched control patients who had chronic hepatitis B but without hepatocellular carcinoma were studied. Consecutive patients with confirmed diagnosis of HCC who had positive HBsAg attending the Joint Hepatoma Clinic, Prince of Wales Hospital from July 1999 to 2001 were included. Confirmed diagnosis of HCC is defined by either histology or radiological evidence of a hepatic mass with a serum alpha-fetoprotein (AFP) of 500 µg/l or more. Patients who had positive anti-HCV or history of alcoholism were excluded. Informed consent to provide serum sample for experimental study were routinely obtained from patients in Joint Hepatoma Clinic. Relevant clinical information of enrolled patients was collected retrospectively.

[89] Age-matched control patients were identified from the cohort of chronic hepatitis B patients prospectively follow-up in the Hepatitis Clinic since December 1997. Patients who had other possible causes of hepatitis or liver cirrhosis including autoimmune liver disease, primary biliary cirrhosis, Wilson's disease and hemochromatosis were also excluded. At initial presentation, abdomen ultrasounds were performed to exclude any pre-existing HCC. Patients were prospectively followed up every 6 monthly, or more frequently if clinically indicated, with monitoring of liver biochemistry, HBeAg and anti-HBe status as well as alfa-fetoprotein levels. Abdomenal ultrasounds, computerized tomography, hepatic angiogram and/or liver biopsy were performed whenever alfa-

fetoprotein level was higher than 50 µg/l or on a rising trend over 20 µg/l to confirm the diagnosis of HCC. For patients with normal alfa-fetoprotein levels, ultrasound abdomen was performed every 1-2 yearly.

5 *Laboratory Method*

Extraction Of DNA

[90] Serum viral DNA was extracted using QIAamp DNA Blood Mini Kit (Qiagen, CA, USA) according to the manufacturer's instructions.

Amplification of HBV DNA

[91] To obtain the full-length HBV DNA sequence, a long distance semi-nested PCR was performed to amplify three overlapping fragments (A, B and C). Relative positions of these PCR fragments to the map of HBV genome are shown in Figure 1 and the nucleotide sequences of the PCR primers can be found in Table 1.

Table 1

The sequences of primers used for amplifying and sequencing the HBV DNA

	Name	Nucleotide sequence (5'→3')	Nt positions	Direction
Primers used for PCR				
	P1	TTTTTCACCTCTGCCTAATCA	1821-1841	sense
	P2	CCCTAGAAAATTGAGAGAAGTC	262-283	antisense
25	P3 ^a	CCACTGCATGGCCTGAGGATG	3193-3213	antisense
	P4	GCCTCATTTTGTGGGTCACCATA	2801-2824	sense
	P5	TTCTTTGACATACTTTCCA	979-997	antisense
	P6 ^a	TTGGGGTGGAGCCCTCAGGCT	3070-3090	sense
	P7 ^a	TTGGCCAAAATTCGCAGTC	300-318	sense
30	P8 ^a	CCCCACTGTTTGGCTTTCAG	714-734	sense
	P9 ^a	GTTGATAAGATAGGGGCATTTGGTGG	2299-2325	antisense
Primers used for sequencing				
	S1	CTCCGGAACATTGTTACCT	2031-2050	sense
35	S2	AAGGTGGGAACTTTACTGGGC	2469-2490	sense
	S3	GCTGACGCAACCCCCACTGG	1186-1205	sense
	S4	TCGCATGGAGACCACCGTGA	1604-1623	sense
	S5	GGCAAAAACGAGAGTAACTC	1940-1959	antisense
	S6	GGGTCGTCCGCGGGATTGAG	1441-1460	antisense
40	S7	GACATACTTTCCAATCAATAGG	970-991	antisense
	S8	GAAGATGAGGCATAGCAGCAGG	411-433	antisense
	S9	CATGCTGTAGCTCTTGTTCC	2831-2850	antisense

^aThese primers were also used for sequencing

Fragment A

[92] When amplifying fragment A, 5 μ l of the extracted DNA was subjected to PCR in the presence of 50mM KCl, 1.5mM MgCl₂, 10mM Tris-HCl, 200 μ M of each dNTP, 1.25 units *Taq* DNA polymerase (Amersham Biosciences), 1.5 units pfu DNA polymerase (Promega), and 10pmol of each P1 primer and P2 primer in a final volume of 50 μ l. PCR was carried out under a 5-min initial denaturation at 95°C, followed by 10 cycles of amplification (94°C, 36 sec; 60°C, 36 sec; 72°C, 2.5 min) and then 30 cycles of amplification (94°C, 36 sec; 50°C, 36 sec; 72°C, 2.5 min) and 7-min final extension at 72°C.

[93] The PCR product was further amplified in a semi-nested PCR. One microliter of the product was subjected to PCR in the presence of 50mM KCl, 1.5mM MgCl₂, 10mM Tris-HCl, 200 μ M of each dNTP, 2.5 units *Taq* DNA polymerase (Amersham Biosciences) and 10pmol of each P1 primer and P3 primer in a final volume of 50 μ l. PCR was carried out under a 5-min initial denaturation at 95°C, followed by 10 cycles of amplification (94°C, 36 sec; 60°C, 36 sec; 72°C, 2 min) and then 30 cycles of amplification (94°C, 36 sec; 52°C, 36 sec; 72°C, 2 min) and a 7-min final extension at 72°C. Finally, quality and quantity of the PCR product was examined on a 1.0% agarose/EtBr gel run in 1X TBE buffer.

Fragment B

[94] When amplifying fragment B, 5 μ l of the extracted DNA was subjected to PCR in the presence of 50mM KCl, 1.5mM MgCl₂, 10mM Tris-HCl, 200 μ M of each dNTP, 1.25 units *Taq* DNA polymerase (Amersham Biosciences), 1.5 units pfu DNA polymerase (Promega), and 10pmol of each P4 primer and P5 primer in a final volume of 50 μ l. PCR was carried out under a 5-min initial denaturation at 95°C, followed by 10 cycles of amplification (94°C, 36 sec; 60°C, 36 sec; 72°C, 90 sec) and then 30 cycles of amplification (94°C, 36 sec; 50°C, 36 sec; 72°C, 90 sec) and a 7-min final extension at 72°C.

[95] The PCR product was further amplified in a semi-nested PCR. One microliter of the product was subjected to PCR in the presence of 50mM KCl, 1.5mM MgCl₂, 10mM Tris-HCl, 200 μ M of each dNTP, 2.5 units *Taq* DNA polymerase (Amersham Biosciences) and 10pmol of each P5 primer and P6 primer in a final volume of 50 μ l. PCR was carried out under a 5-min initial denaturation at 95°C, followed by 10 cycles of amplification (94°C, 36 sec; 60°C, 36 sec; 72°C, 90 sec) and then 30 cycles of amplification (94°C, 36 sec; 52°C, 36 sec; 72°C, 90 sec) and a 7-min final extension at 72°C. Finally,

quality and quantity of the PCR product was examined on a 1.0% agarose/EtBr gel run in 1X TBE buffer.

Fragment C

5 [96] When amplifying fragment C, 5 μ l of the extracted DNA was subjected to PCR in the presence of 50mM KCl, 1.5mM MgCl₂, 10mM Tris-HCl, 200 μ M of each dNTP, 1.25 units *Taq* DNA polymerase (Amersham Biosciences), 1.5 units pfu DNA polymerase (Promega), and 10pmol of each P7 primer and P9 primer in a final volume of 50 μ l. PCR was carried out under a 5-min initial denaturation at 95°C, followed by 10 cycles
10 of amplification (94°C, 36 sec; 60°C, 36 sec; 72°C, 2 min and 15 sec) and then 30 cycles of amplification (94°C, 36 sec; 50°C, 36 sec; 72°C, 2 min and 15 sec) and a 7-min final extension at 72°C.

[97] The PCR product was further amplified in a semi-nested PCR. One microliter of the product was subjected to PCR in the presence of 50mM KCl, 1.5mM MgCl₂,
15 10mM Tris-HCl, 200 μ M of each dNTP, 2.5 units *Taq* DNA polymerase (Amersham Biosciences) and 10pmol of each P8 primer and P9 primer in a final volume of 50 μ l. PCR was carried out under a 5-min initial denaturation at 95°C, followed by 10 cycles of amplification (94°C, 36 sec; 60°C, 36 sec; 72°C, 1 min and 50 sec) and then 30 cycles of amplification (94°C, 36 sec; 52°C, 36 sec; 72°C, 1 min and 50 sec) and a 7-min final
20 extension at 72°C. Finally, quality and quantity of the PCR product was examined on a 1.0% agarose/EtBr gel run in 1X TBE buffer.

DNA Sequencing

[98] All semi-nested PCR products (plus and minus strands) were directly
25 sequenced with the Cycling Sequencing Kit DYEnamic ET Dye terminator for MegaBACE (Amersham Biosciences).

[99] Primers for the sequencing of three HBV DNA fragments (primers sequences are listed in Table 1):

30

Fragment A: S1, S2, P3, S9

Fragment B: P6, P7, S7, S8

35

Fragment C: P8, S3, S4, P9, S5, S6

[100] One microliter of unpurified PCR product was used as the DNA template for cycle sequencing. It was subjected to sequencing reaction in the presence of 8μl of DYEnamic ET reagent premix and 10pmol primer in a final volume of 20μl. Sequencing reaction mix was subjected to a 2 min initial denaturation at 95°C, followed by 30 cycles at 95°C, 25 sec; 52°C, 30 sec; 60°C, 60 sec.

[101] The sequencing products were purified by post reaction clean up using ethanol precipitation. In each reaction tube, 2μl of 7.5M ammonium acetate and 2.5 volumes (55μl) of 100% ethanol were added so that the final concentration of ethanol was 70%. Then it was subjected to centrifugation at 4,000 rpm for 30 min at 14°C. Afterwards, the supernatant was drawn off by performing a brief inverted spin (1 min at 500 rpm). The DNA pellet was washed by 100μl of 70% ethanol. Then, it was subjected to centrifugation at 4,000 rpm for 15 min at 14°C and the supernatant was drawn off by performing a brief inverted spin (1 min at 500 rpm). Then the DNA pellet was allowed to air dry and was resuspended in 10μl of loading buffer (70% formamide and 1mM EDTA). The samples were stored at 4°C before gel electrophoresis analysis using the MegaBACE 1000 DNA sequencer.

[102] It is understood that the examples and embodiments described herein are for illustrative purposes only and that various modifications or changes in light thereof will be suggested to persons skilled in the art and are to be included within the spirit and purview of this application and scope of the appended claims. All publications, patents, and patent applications cited herein are hereby incorporated by reference in their entirety for all purposes.

WHAT IS CLAIMED IS:

1. A method of determining a pre-disposition of an individual infected with hepatitis B virus (HBV) to develop hepatocellular carcinoma (HCC), the method comprising:

5 determining nucleotides in the genome of HBV isolated from the individual at positions corresponding to nucleotides 31, 53, 312, 799, 961, 1165, 1499, 1613, 1762, 1764, 1899, 2170, 2441, 2525, and/or 2712 of SEQ ID NO:1; and

comparing the determined nucleotides to nucleotides associated with a pre-disposition to cause HCC, wherein the nucleotides associated with a pre-disposition to cause
10 HCC comprise: 31C, 53C, 312C, 799G, 961G, 1165T, 1499G, 1613A, 1762T, 1764A, 1899A, 2170C, 2170G, 2441C, 2525C, 2712C, 2712A, and/or 2712G.

2. The method of claim 1, the method comprising

determining nucleotides in the genome of a genotype B HBV isolated from the
15 individual at positions corresponding to nucleotides 1165, 1762, 1764, 2525 or 2712 of SEQ ID NO:1; and

comparing the determined nucleotides to nucleotides associated with a pre-disposition to cause HCC, wherein the nucleotides associated with a pre-disposition to cause
HCC comprise: 1165T, 1762T, 1764A, 2525C, 2712C, 2712A, or 2712G.

20 3. The method of claim 1, the method comprising

determining nucleotides in the genome of a genotype B HBV isolated from the individual at positions corresponding to nucleotides 1165, 1762, 1764, 2525 and 2712 of SEQ
ID NO:1; and

comparing the determined nucleotides to nucleotides associated with a pre-
25 disposition to cause HCC, wherein the nucleotides associated with a pre-disposition to cause HCC in genotype B comprise:

1762T and 1764A and 2712A; or

1762T and 1764A and 2712C; or

1762T and 1764A and 2712G; or

30 1762T and 1764A and 2712T and 2525C; or

1762A and 1764G and 1165T.

4. The method of claim 3, wherein the determining step comprises nucleotide sequencing the HBV genome flanking the nucleotides at positions corresponding to nucleotides 1165, 1762, 1764, 2525 and 2712 of SEQ ID NO:1.

5. The method of claim 3, wherein the determining step comprises
5 amplifying at least a portion of the HBV genome to produce one or more amplification products comprising the nucleotides at the positions corresponding to nucleotides 1165, 1762, 1764, 2525 and 2712 of SEQ ID NO:1.

6. The method of claim 5, comprising contacting the one or more amplification products with one or more probes that hybridize to HCC-associated nucleotides:
10 1762T and 1764A and 2712A; or
1762T and 1764A and 2712C or;
1762T and 1764A and 2712G; or
1762T and 1764A and 2712T and 2525C; or
1762A and 1764G and 1165T;
15 under conditions to allow for hybridization of the probe to the amplification product only if the amplification product comprises a complementary nucleotide at the position of the HCC-associated nucleotide.

7. The method of claim 6, wherein the hybridization is performed as a line probe assay.

20 8. The method of claim 3, further comprising determining the genotype of the HBV from the individual.

9. The method of claim 1, the method comprising
determining nucleotides in the genome of a genotype C HBV isolated from the individual at positions corresponding to nucleotides 31, 53, 312, 799, 961, 1499, 1613, 1899,
25 2170, or 2441 of SEQ ID NO: 1; and

comparing the determined nucleotides to nucleotides associated with a pre-disposition to cause HCC, wherein the nucleotides associated with a pre-disposition to cause HCC comprise: 31C, 53C, 312C, 799G, 961G, 1499G, 1613A, 1899A, 2170C, 2170G, or 2441C.

30 10. The method of claim 9, the method comprising
a) determining the subtype of a genotype C HBV from the individual,
wherein:

subtype C1 comprises nucleotides 2733A, 1856C, 1009T and 2892T,

subtype C2 comprises nucleotides 2733C, 1856T, 1009T and 2892T, and

subtype C3 comprises nucleotides 2733C, 1856C, 1009C and 2892T;

b1) if the HBV is genotype C1, determining the nucleotides at positions corresponding to nucleotides 31, 53 and 1499 of SEQ ID NO:1; or

5 b2) if the HBV is genotype C2, determining the nucleotides at positions corresponding to nucleotides 799, 2441 and 2170 of SEQ ID NO:1; and

b3) if the HBV is genotype C3, determining the nucleotides at positions corresponding to nucleotides 312, 961, 1613, 1899 of SEQ ID NO:1; and

10 c) comparing the determined nucleotides to nucleotides at the positions associated with a pre-disposition to cause HCC, wherein the nucleotides associated with a pre-disposition to cause HCC in subtype C1 comprise:

31C; and/or

53C; and/or

1499G; and

15 the nucleotides associated with a pre-disposition to cause HCC in subtype C2 comprise:

2170C; and/or

2170G; and/or

2441C; and/or

20 799G; and

the nucleotides associated with a pre-disposition to cause HCC in subtype C3 comprise:

312C; and/or

961G; and/or

25 1613A; and/or

1899A.

11. The method of claim 10, wherein the determining step comprises nucleotide sequencing the HBV genome flanking the nucleotides at positions corresponding to nucleotides 31, 53, and 1499 of SEQ ID NO:1.

30 12. The method of claim 10, wherein the determining step comprises nucleotide sequencing the HBV genome flanking the nucleotides at positions corresponding to nucleotides 799, 2441, and 2170 of SEQ ID NO:1.

13. The method of claim 10, wherein the determining step comprises nucleotide sequencing the HBV genome flanking the nucleotides at positions corresponding to nucleotides 312, 961, 1613, and 1899 of SEQ ID NO:1.

14. The method of claim 10, wherein the determining step comprises
5 amplifying at least a portion of the HBV genome to produce one or more amplification products comprising the nucleotides at the positions corresponding to nucleotides 31, 53, and 1499 of SEQ ID NO:1.

15. The method of claim 10, wherein the determining step comprises
10 amplifying at least a portion of the HBV genome to produce one or more amplification products comprising the nucleotides at the positions corresponding to nucleotides 799, 2441, and 2170 of SEQ ID NO:1.

16. The method of claim 10, wherein the determining step comprises
15 amplifying at least a portion of the HBV genome to produce one or more amplification products comprising the nucleotides at the positions corresponding to nucleotides 312, 961, 1613, and 1899 of SEQ ID NO:1.

17. The method of claim 14, comprising contacting the one or more
amplification products with one or more probes that hybridize to HCC-associated nucleotides:
31C; and/or
53C; and/or
20 1499G;
under conditions to allow for hybridization of the probe to the amplification product only if the amplification product comprises a complementary nucleotide at the position of the HCC-associated nucleotide.

18. The method of claim 17, wherein the hybridization is performed as a
25 line probe assay.

19. The method of claim 14, comprising contacting the one or more
amplification products with probes that hybridize to HCC-associated nucleotides:
2170C; and/or
2170G; and/or
30 2441C; and/or

799G;

under conditions to allow for hybridization of the probes to the amplification product only if the amplification product comprises a complementary nucleotide at the position of the HCC-associated nucleotide.

5 20. The method of claim 19, wherein the hybridization is performed as a line assay.

21. The method of claim 14, comprising contacting the one or more amplification products with probes that hybridize to HCC-associated nucleotides:

312C; and/or

10 961G; and/or

1613A; and/or

1899A;

under conditions to allow for hybridization of the probes to the amplification product only if the amplification product comprises a complementary nucleotide at the position of the HCC-associated nucleotide.

15 22. The method of claim 21, wherein the hybridization is performed as a line assay.

23. The method of claim 10, further comprising determining the genotype of the HBV from the individual.

20 24. The method of claim 1, the method comprising determining the genotype of the HBV, wherein genotype B comprises 2733C, 1856C, 1009T and 2892T, wherein genotype C1 comprises 2733A, 1856C, 1099T and 2892T, genotype C2 comprises 2733C, 1856T, 1009T and 2892T and genotype C3 comprises 2733C, 1856C, 1009C and 2892T;

25 determining nucleotides at positions corresponding to nucleotides 1165, 1762, 1764, 2525 and 2712 of the HBV genome of SEQ ID NO: 1 if the HBV is genotype B; and/or determining nucleotides at positions corresponding to nucleotides 31 and/or 53 and/or 1499 of the HBV genome of SEQ ID NO: 1 if the HBV is C1; and/or

determining nucleotides at positions corresponding to nucleotides 2170 and/or 30 2441 and/or 799 of the HBV genome of SEQ ID NO: 1 if the HBV is C2; and/or

determining nucleotides at positions corresponding to nucleotides 312 and/or 961 and/or 1613 and/or 1899 of SEQ ID NO: 1 of the HBV genome if the HBV is C3; and

comparing the determined nucleotides to nucleotides associated with a pre-disposition to cause HCC,

wherein nucleotides associated with a pre-disposition to cause HCC in genotype B comprise:

1762T and 1764A and 2712A; or

1762T and 1764A and 2712C or;

5 1762T and 1764A and 2712G; or

1762T and 1764A and 2712T and 2525C; or

1762A and 1764G and 1165T;

wherein nucleotides associated with a pre-disposition to cause HCC in genotype C1 comprise:

10 31C; and/or

53C; and/or

1499G; and

wherein nucleotides associated with a pre-disposition to cause HCC in genotype C2 comprise:

15 2170C; and/or

2170G; and/or

2441C; and/or

799G;

wherein nucleotides associated with a pre-disposition to cause HCC in genotype C3 comprise:

20 312C; and/or

961G; and/or

1613A; and/or

1899A;

25 thereby determining the pre-disposition of the individual to develop HCC.

25. A kit for detecting HBV isolates that are associated with the development hepatocellular carcinoma (HCC), comprising

one or more probe which, when contacted to an HBV genome, selectively hybridizes to the genome if the genome comprises at least one of the following nucleotides at positions corresponding to nucleotides of SEQ ID NO: 1:

30 31C, 53C, 312C, 799G, 961G, 1165T, 1499G, 1613A, 1762T, 1762A, 1764A, 1764G, 1899A, 2441C, 2170C, 2170G, 2712A, 2712C, 2712G; or 2525C.

26. The kit of claim 25, wherein the probe is linked to a solid support.

27. The kit of claim 25, wherein the probe selectively hybridizes to:

1762T and 1764A and 2712A; and/or
1762T and 1764A and 2712C; and/or;
1762T and 1764A and 2712G; and/or
1762T and 1764A and 2712T and 2525C; and/or
5 1762A and 1764G and 1165T.

28. The kit of claim 25, wherein the probe selectively hybridizes to:
31C; and
53C; and
1499G.

10 29. The kit of claim 25, wherein the probe selectively hybridizes to:
2170C; and/or
2170G; and/or
2441C; and/or
799G.

15 30. The kit of claim 25, wherein the probe selectively hybridizes to:
312C; and/or
961G; and/or
1613A; and/or
1899A.

20 31. The kit of claim 25, further comprising primers for amplification of at
least a portion of the HBV genome.

32. A computer readable medium comprising,

a) code for receiving information describing:

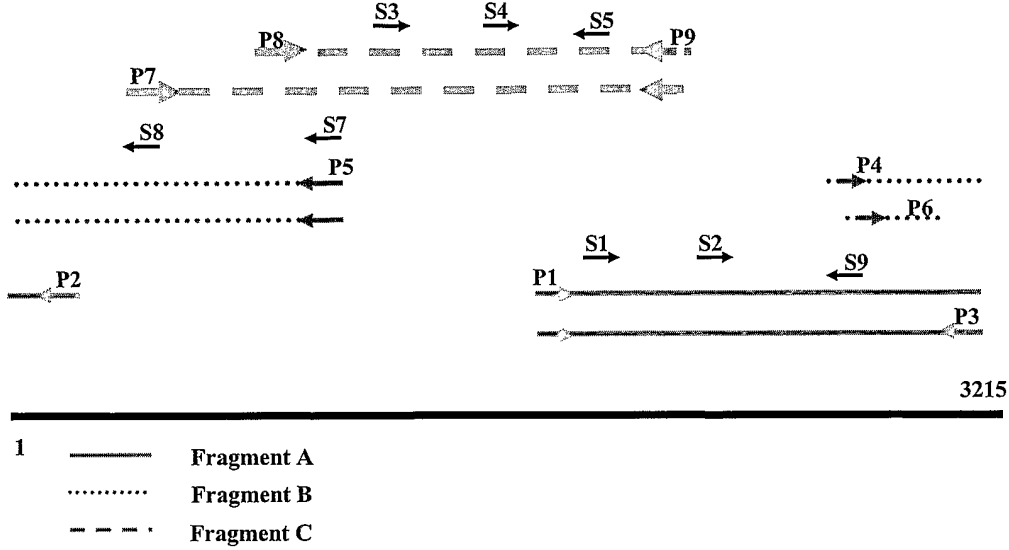
25 nucleotides at positions corresponding to nucleotides 31, 53, 312, 799,
961, 1165, 1499, 1613, 1762, 1764, 1899, 2170, 2441, 2525, or 2712
of SEQ ID NO:1;

b) code for comparing the nucleotides received in a) to nucleotides
associated with a pre-disposition to cause HCC; and

30 c) code for providing a determination of the pre-disposition of the HBV
to cause HCC,

wherein nucleotides associated with a pre-disposition to cause HCC comprise:
31C, 53C, 312C, 799G, 961G , 1165T, 1499G, 1613A, 1762T, 1762A, 1764A, 1764G,
1899A, 2441C, 2170C, 2170G, 2712A; 2712C, 2712G; or 2525C.

Figure 1: Locations of DNA fragments primer sequences used in the full genome sequencing of the HBV DNA



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Figure 2A

10	20	30	40	50	60
CTCCACCACT	TTCCACCAAA	CTCTTCAAGA	TCCCAGAGTC	AGGGCCCTGT	ACTTTTCCTGC
70	80	90	100	110	120
TGGTGGCTCC	AGTTCAGAAA	CAGTGAGCCC	TGCTCAGAAAT	ACTGTCTCTG	CCATATCGTC
130	140	150	160	170	180
AATCTTATCG	AAGACTGGGG	ACCCGTGTACC	GAACATGGAG	AACATCGCAT	CAGGACTCCT
190	200	210	220	230	240
AGGACCCCTG	CTCGTGTAC	AGGCGGGGT	TTTCTCGTTG	ACAAAAATCC	TCACAATACC
250	260	270	280	290	300
ACAGAGTCTA	GACTCGTGGT	GGACTTCTCT	CAATTTTCTA	GGGGAACAC	CCGTGTGTCT
310	320	330	340	350	360
TGGCCAAAAT	TCGCAGTCCC	AAATCTCCAG	TCACTCACCA	ACCTGTTGTC	CTCCAATTTG
370	380	390	400	410	420
TCCTGGTTAT	CGCTGGATGT	GTCTGCGGCG	TTTTATCATC	TTCTCTGCA	TCCTGCTGCT
430	440	450	460	470	480
ATGCCTCATC	TTCTTGTGG	TTCTTCTGGA	CTATCAAGGT	ATGTTGCCCG	TTTGTCCTCT
490	500	510	520	530	540
AATTCAGGA	TCATCAACGA	CCAGCACCGG	ACCATGCAAA	ACCTGCACAA	CTCCTGCTCA
550	560	570	580	590	600
AGGAACCTCT	ATGTTTCCCT	CATGTTGCTG	TACAAAACCT	ACGGACGGAA	ATTGCACCTG
610	620	630	640	650	660
TATFCCCATC	CCATCATCTT	GGGCTTTCGC	AAAATACCTA	TGGGAGTGGG	CCTCAGTCCG
670	680	690	700	710	720
TTTCTCTTGG	CTCAGTTTAC	TAGTGCCATT	TGTTCAAGTG	TTCTAGGGC	TTTCCCCAC
730	740	750	760	770	780
TGTCTGGCTT	TCAGTTATAT	GGATGATGTG	GTTTTGGGGG	CCAAGTCTGT	ACAACATCTT
790	800	810	820	830	840
GAGTCCCTTT	ATGCCGCTGT	TACCAATTTT	CTTTTGTCTT	TGGGTATACA	TTTAAACCTT
850	860	870	880	890	900
CACAAAACAA	AAAGATGGGG	ATATTCCTTT	AACTTCATGG	GATATGTAAT	TGGGAGTTGG
910	920	930	940	950	960
GGCACATTGC	CACAGGAACA	TATTGTACAA	AAAATCAAAA	TGTGTTTTCC	GAAACTTCCT
970	980	990	1000	1010	1020
GTAATAGAC	CTATTGATTG	GAAAGTATGT	CAACGAATTG	TGGGTCTTTT	GGGGTTTGCC
1030	1040	1050	1060	1070	1080
GCCCCTTTCA	CGCAATGTGG	ATATCCTGCT	TTAATGCCTT	TATATGCATG	TATTCAAGCA
1090	1100	1110	1120	1130	1140
AAACAGGCTT	TTACTTTCTC	GCCAACTTAC	AAGGCCTTTC	TAAGTAAACA	GTATCTGAAC
1150	1160	1170	1180	1190	1200
CTTTACCCCG	TTGCTCGGCA	ACGGCCTGGT	CTGTGCCAAG	TGTTTGCTGA	CGCAACCCCC
1210	1220	1230	1240	1250	1260
ACTGGTTGGG	GCTTGGCCAT	AGGCCATCAG	CGCATGCGTG	GAACCTTTGG	GTCTCCTCTG
1270	1280	1290	1300	1310	1320
CCGATCCATA	CTGCGGAAC	CCTAGCCGCT	TGTTTTGCTC	GCAGCAGGTC	TGGAGCAAGA
1330	1340	1350	1360	1370	1380
CTCATCGGGA	CTGACAATT	TGTCGTGCTC	TCCCGCAAGT	ATACATCAAT	TCCATGGCTG
1390	1400	1410	1420	1430	1440
CTAGGCTGTG	CTGCCAATG	GATCCTACGC	GGGACGTCC	TTGTTTACGT	CCCGTCGGCG
1450	1460	1470	1480	1490	1500
CTGAATCCCG	CGGACGACCC	CTCCCGGGC	CGCTTGGGGC	TCTACCGCCC	GCTTCTCCGC
1510	1520	1530	1540	1550	1560
CTATTGTACC	GACCGACCAC	GGGGCGCACC	TCTCTTTACG	CGGACTCCCC	GTCTGTGCCT
1570	1580	1590	1600	1610	1620
TCTCATCTGC	CGGACCGTGT	GCACCTTCGT	TCACCTCTGC	ACGTCGCATG	GAGACCACCG
1630	1640	1650	1660	1670	1680
TGAACGCCCA	CGGGAACCTG	CCCAAGGTCT	TGCATAAGAG	AACTCTTGGA	CTTTCAGCAA

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Figure 2B

1690	1700	1710	1720	1730	1740
TGTCAACGAC	CGACCTTGAG	GCATACTTCA	AAGACTGTGT	GTTTACTGAG	TGGGAGGAGT
1750	1760	1770	1780	1790	1800
TGGGGGAGGA	GATTAGGTTA	AAGGTCCTTG	TACTAGGAGG	CTGTAGGCAT	AAATTGGTGT
1810	1820	1830	1840	1850	1860
GTTCAACGAGC	ACCATGCAAC	TTTTTCACCT	CTGCCTAATC	ATCTCATGTT	CATGTCTTAC
1870	1880	1890	1900	1910	1920
TGTTCAAGCC	TCCAAGCTGT	GCCTTGGGTG	GCTTTGGGGC	ATGGACATTG	ACCCGTATAA
1930	1940	1950	1960	1970	1980
AGAAATTGGA	GCTTCTGTGG	AGTTACTCTC	TTTTTTGCCT	TCTGACTTCT	TTCTTCTTAT
1990	2000	2010	2020	2030	2040
TCGAGATCTC	CTCGACACCG	CCTCTGCTCT	GTATCGGGAG	GCCTTAGAGT	CTCCGGAACA
2050	2060	2070	2080	2090	2100
TTGTTACACCT	CACCATACGG	CACTCAGGCA	AGCTATTCTG	TGTTGGGGTG	AGTTAATGAA
2110	2120	2130	2140	2150	2160
TCTAGCCACC	TGGGTGGGAA	GTAATTGGA	AGATCCAGCA	TCCAGGGAAT	TAGTAGTCAG
2170	2180	2190	2200	2210	2220
CTATGTCAAC	GTTAATATGG	GCCTAAAAC	CAGACAAATA	TTGTGGTTTC	ACATTTCTTG
2230	2240	2250	2260	2270	2280
TCTTACTTTT	GGGAGAGAAA	CTGTTCTTGA	ATATTTGGTG	TCTTTTGGAG	TGTGGATTCTG
2290	2300	2310	2320	2330	2340
CACTCCTCCT	GCATATAGAC	CACAAAATGC	CCCTATCTTA	TCAACACTTC	CGGAAACTAC
2350	2360	2370	2380	2390	2400
TGTTGTTAGA	CGAAGATGCA	GGTCCCCTAG	AAGAAGAACT	CCCTCGCCTC	GCAGACGAAG
2410	2420	2430	2440	2450	2460
GTCTCAATCG	CCGCGTCGCA	GAAGATCTCA	ATCTCGGGAA	TCTCAATGTT	AGTATTCCTT
2470	2480	2490	2500	2510	2520
GGACACATAA	GGTGGGAAAC	TTTACGGGGC	TTTATTCTTC	TACGGTACCT	TGCTTTAATC
2530	2540	2550	2560	2570	2580
CTAAATGGCA	AACTCCTTCT	TTTCCTGACA	TTCATTGCA	GGAGGACATT	GTTGATAGAT
2590	2600	2610	2620	2630	2640
GCAAGCAATT	TGTGGGGCCC	CTTACAGTAA	ATGAAAACAG	GAGACTAAAA	TTAATTATGC
2650	2660	2670	2680	2690	2700
CTGCTAGGTT	TTATCCCAAT	GTTACTAAAT	ATTTGCCCTT	AGATAAAGGG	ATCAAAACCGT
2710	2720	2730	2740	2750	2760
ATTATCCAGA	GTATGTAGTT	AATCATTACT	TTCAGACGCG	ACATTATTTA	CACACTCTTT
2770	2780	2790	2800	2810	2820
GGAAGGCGGG	GATCTTATAT	AAAAGAGAGT	CCACACGTAG	CGCCTCATTT	TGCGGGTCAC
2830	2840	2850	2860	2870	2880
CATATTCTTG	GGAACAAGAT	CTACAGCATG	GGAGGTTGGT	CTTCCAAACC	TCGAAAAGGC
2890	2900	2910	2920	2930	2940
ATGGGGACAA	ATCTTTCTGT	CCCCAATCCC	CTGGGATTCT	TCCCCGATCA	TCAGTTGGAC
2950	2960	2970	2980	2990	3000
CCTGCATTCA	AAGCCAACTC	AGAAAATCCA	GATTGGGACC	TCAACCCGCA	CAAGGACAAC
3010	3020	3030	3040	3050	3060
TGGCCGGACG	CCAACAAGGT	GGGAGTGGGA	GCATTCGGGC	CAGGGTTCAC	CCCTCCCCAT
3070	3080	3090	3100	3110	3120
GGGGGACTGT	TGGGGTGGAG	CCCTCAAGCT	CAGGGCCTAC	TCACAACCTGT	GCCAGCAGCT
3130	3140	3150	3160	3170	3180
CCTCCTCCTG	CCTCCACCAA	TCGGCAGTCA	GGAAGGCAGC	CTACTCCCTT	ATCTCCACCT
3190	3200	3210	3220		
CTAAGGGACA	CTCATCCTCA	GGCCATGCAG	TGGAA		

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Figure 3A

10	20	30	40	50	60
CTCCAGCACA	TTCCACCAAG	CTCTGCTAGA	TCCCAGAGTG	AGGGGCCTAT	ACCTTCCTGC
70	80	90	100	110	120
TGGTGGCTCC	AGTTCCGGAA	CAGTAAACCC	TGTTCCGACT	ACTGCCTCTC	CCATATCGTC
130	140	150	160	170	180
AATCTTCTCG	AGGACTGGGG	ACCCTGCACC	GAATATGGAG	AGCACCACAT	CAGGATTCTT
190	200	210	220	230	240
AGGACCCCTG	CTCGTGTTAC	AGGCGGGGTT	TTTCTTGTTG	ACAAGAATCC	TCACAATACC
250	260	270	280	290	300
ACAGAGTCTA	GACTCGTGGT	GGACTTCTCT	CAATTTTCTA	GGGGGAGCAC	CCACGTGTCC
310	320	330	340	350	360
TGGCCAAAAT	TTGCAGTCCC	CAACCTCCAA	TCACTCACCA	ACCTCTTGTC	CTCCAATTTG
370	380	390	400	410	420
TCCTGGTTAT	CGCTGGATGT	GTCTGCGGCG	TTTTATCATC	TTCTCTTTCA	TCCTGCTGCT
430	440	450	460	470	480
ATGCCTCATC	TTCTTGTGGG	TTCTTCTGGA	CTACCAAGGT	ATGTTGCCCC	TTTGTCTCTT
490	500	510	520	530	540
ACTTCCAGGA	ACATCAACTA	CCAGCACGGG	ACCATGCAAG	ACCTGCACGA	TTCTTGCTCA
550	560	570	580	590	600
AGGAACCTCT	ATGTTTCCCT	CTTGTTGCTG	TACAAAACCT	TCGGACGGAA	ATTGCACTTG
610	620	630	640	650	660
TATTCCCATC	CCATCATCTT	GGGCTTTCGC	AAGATTCCCTA	TGGGAGTGGG	CCTCAGTCCG
670	680	690	700	710	720
TTTCTCCTGG	CTCAGTTTAC	TAGTGCCATT	TGTTTCAGTGG	TTCTAGGGGC	TTTCCCCCAC
730	740	750	760	770	780
TGTTTGGCTT	TCAGTTATAT	GGATGATGTG	GTATTGGGGG	CCAAGTCTGT	ACAACATCTT
790	800	810	820	830	840
GAATCCCTTT	ATACCGCTAT	TACCAATTTT	CTTGTGTCTT	TGGGTATACA	TTTAAACCTT
850	860	870	880	890	900
AATAAAACCA	AACGTTGGGG	CTACTCCCTT	AACTTCATGG	GATATGTAAT	TGGAAGTTGG
910	920	930	940	950	960
GGTACCTTGC	CACAGGAACA	TATTGTACAA	AAAATCAAAC	AATGTTTTTCG	AAAACCTTCT
970	980	990	1000	1010	1020
ATAAATAGAC	CTATTGATTG	GAAAGTATGT	CAAAGAATTG	TGGGTCTTTT	GGGTTTTTGC
1030	1040	1050	1060	1070	1080
GCTCCCTTTA	CACAATGTGG	TTACCCAGCA	TTAATGCCTT	TATATGCATG	TATACAAGCT
1090	1100	1110	1120	1130	1140
AAACAGGCTT	TCACTTTCTC	GCCAACTTAC	AAGGCCCTTC	TGTATAAACA	ATATCTGAAC
1150	1160	1170	1180	1190	1200
CTTTACCCCG	TTGCTCGGCA	ACGGTCAGGT	CTTTGCCAAG	TGTTTGCTGA	CGCAACCCCC
1210	1220	1230	1240	1250	1260
ACTGGTTGGG	GCTTGGCCAT	GGGCCATCAG	CGCATGCGTG	GAACCTTTGT	GGCTCCTCTG
1270	1280	1290	1300	1310	1320
CCGATCCATA	CTGCGGAAC	CCTAGCAGCT	TGTTTTGCTC	GCAGCCGGTC	TGGAGCAAAC
1330	1340	1350	1360	1370	1380
CTTATCGGCA	CCGACAACTC	TGTTGTCCCTC	TCTCGGAAAT	ACACCTCTTT	TCCATGGCTG
1390	1400	1410	1420	1430	1440
CTAGGCTGTG	CTGCCAACTG	GATCCTGCGC	GGGACGTCCT	TTGTCTACGT	CCCGTCGGCG
1450	1460	1470	1480	1490	1500
CTGAATCCCG	CGGACGACCC	GTCTCGGGGT	CGTTTGGGAC	TCTACCGTCC	CCTTCTCCGT
1510	1520	1530	1540	1550	1560
CTGCCGTTC	GGCCGACCAC	GGGGCGCACC	TCTCTTTACG	CGGACTCCCC	GTCTGTGCCT
1570	1580	1590	1600	1610	1620
TCTCATCTGC	CGGACCGTGT	GCACTTCGCT	TCACCTCTGC	ACGTCGCATG	GAGACCACCG
1630	1640	1650	1660	1670	1680
TGAACGCCCG	CCAGGTCTTG	CCTAAGGTCT	TACATAAGAG	GACTCTTGGA	CTCTCAGCAA

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Figure 3B

1690	1700	1710	1720	1730	1740
TGTCAACGAC	CGACCTTGAG	GCATACTTCA	AAGACTGTGT	ATTTAAGGAC	TGGGAGGAGT
1750	1760	1770	1780	1790	1800
TGGGGGAGGA	GATTAGGTTA	ATGATCTTTG	TACTGGGAGG	CTGTAGGCAT	AAATTGGTCT
1810	1820	1830	1840	1850	1860
GTTCAACCAGC	ACCATGCAAC	TTTTTCACCT	CTGCCTAATC	ATCTCATGTT	CATGTTCCAC
1870	1880	1890	1900	1910	1920
TGTTCAAGCC	TCCAAGCTGT	GCCTTGGGTG	GCTTTGGGGC	ATGGACATTG	ACCCGTATAA
1930	1940	1950	1960	1970	1980
AGAATTTGGA	GCTTCTGTGG	AGTTACTCTC	TTTTTTGCCT	TCTGACTTTT	TTCTTCTAT
1990	2000	2010	2020	2030	2040
TCGTGATCTC	CTCGACACCG	CCTCTGCTCT	GTATCGGGAG	GCCTTAGAGT	CTCCGGAACA
2050	2060	2070	2080	2090	2100
TTGTTACCT	CACCATACAG	CACTAAGGCA	AGCTATTCTG	TGTTGGGGTG	AGTTGATGAA
2110	2120	2130	2140	2150	2160
TCTGGCCACC	TGGGTGGGAA	GTAATTTGGA	AGACCCGGCA	TCCAGGGAAT	TAGTAGTAAG
2170	2180	2190	2200	2210	2220
CTATGTCAAT	GTTAATATGG	GCCTAAAAAT	CAGACAACTA	TTGTGGTTTC	ACATTTCTCTG
2230	2240	2250	2260	2270	2280
TCTTACTTTT	GGAAGAGAAA	CTGTTCTTGA	GTATTTGGTG	TCTTTTGGAG	TGTGGATTCTG
2290	2300	2310	2320	2330	2340
CACTCCTCCC	GCTTACAGAC	CACCAAATGC	CCCTATCTTA	TCAACACTTC	CGGAAACTAC
2350	2360	2370	2380	2390	2400
TGTTGTTAGA	CGACGAGGCA	GGTCCCCTAG	AAGAAGAACT	CCCTCGCCTC	GCAGACGAAG
2410	2420	2430	2440	2450	2460
GTCTCAATCG	CCGCGTCGCA	GAAGATCTCA	GTCTCGGGAA	TCTCAATGTT	AGTATCCCTT
2470	2480	2490	2500	2510	2520
GGACTCATAA	GGTGGGAAAC	TTTACTGGGC	TTTATTCTTC	TACTGTACCT	GTCTTTAATC
2530	2540	2550	2560	2570	2580
CTGAATGGCA	AAC'TCCCTCT	TTTCCTCACA	TTCATTTGAA	AGAGGATATT	ATCAATAGAT
2590	2600	2610	2620	2630	2640
GTCAACAATA	TGTGGGCCCT	CTTACAGTTA	ACGAAAAAAG	GAGATTAAAA	TTGATCATGC
2650	2660	2670	2680	2690	2700
CTGCTAGGTT	CTATCCTAAC	CTTACTAAAT	ATTTGCCCTT	AGATAAAGGC	ATCAAACCTT
2710	2720	2730	2740	2750	2760
ATTATCCTGA	ACATATAGTT	AATCATTACT	TCCAAACTAG	GCATTATTTA	CATACTCTGT
2770	2780	2790	2800	2810	2820
GGAAGGCTGG	TATTTTATAT	AAGAGAGAAA	CTACTCGCAG	CGCCTCATTT	TGTGGGTCAC
2830	2840	2850	2860	2870	2880
CATATTCTTG	GGAACAAGAG	CTACAGCATG	GGAGGTTGGT	CTTCCAAACC	TCGACAAGGC
2890	2900	2910	2920	2930	2940
ATGGGGACGA	ATCTTTCCGT	TCCCAATCCT	CTGGGATTCT	TTCCCGGTCA	CCAGTTGGAC
2950	2960	2970	2980	2990	3000
CCGACATTCTG	GAGCCAATTC	AAACAATCCA	GATTGGGACT	TCAACCCCAA	CAAGGATCAA
3010	3020	3030	3040	3050	3060
TGGCCAGCGG	CAAACCAGGT	AGGAGTGGGA	TCATTCTGGG	CGGGGTTTAC	TCCACCACAC
3070	3080	3090	3100	3110	3120
GGCAATCTTT	TGGGGTGGAG	CCCTCAGGCT	CAGGGCATAT	TGACAACAGT	ACCAGCAGCG
3130	3140	3150	3160	3170	3180
CCTCCTCCTG	CCTCCACCAA	TCGGCAGTCA	GGAAGAAAGC	CTACTCCCAT	CTCTCCACCT
3190	3200	3210	3220		
CTAAGAGACA	GTCATCCTCA	GGCCATGCAA	TGGAA		

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Figure 4A

10	20	30	40	50	60
CTCCAGCACA	TTCCACCAAG	CTCTGCTAGA	TCCCAGAGTG	AGGGGCCTAT	ACCTTCCTGC
70	80	90	100	110	120
TGGTGGCTCC	AGTTCCGGAA	CAGTAAACCC	TGTTCCGACT	ACTGCCTCTC	CCATATCGTC
130	140	150	160	170	180
AATCTTCTCG	AGGACTGGGG	ACCTTGCACC	GAATATGGAG	AGCACCACAT	CAGGATTCTT
190	200	210	220	230	240
AGGACCCCTG	CTCGTGTTAC	AGGCGGGGTT	TTTCTTGTTG	ACAAGAATCC	TCACAATACC
250	260	270	280	290	300
ACAGAGTCTA	GACTCGTGGT	GGACTTCTCT	CAATTTTCTA	GGGGGAGCAC	CCACGTGTCC
310	320	330	340	350	360
TGGCCAAAAT	TTGCAGTCCC	CAACCTCCAA	TCACTCACCA	ACCTCTTGTC	CTCCAATTTG
370	380	390	400	410	420
TCCTGGTTAT	CGCTGGATGT	GTCTGCGGCG	TTTTATCATC	TTCTCTTTCA	TCCTGCTGCT
430	440	450	460	470	480
ATGCCTCATC	TTCTTGTTGG	TTCTTCTGGA	CTACCAAGGT	ATGTTGCCCG	TTTGTCTCTT
490	500	510	520	530	540
ACTTCCAGGA	ACATCAACTA	CCAGCACGGG	ACCATGCAAG	ACCTGCACGA	TTCTTCTCTA
550	560	570	580	590	600
AGGAACCTCT	ATGTTTCCCT	CTTGTTGCTG	TACAAAACCT	TCGGACGGAA	ATTGCACTTG
610	620	630	640	650	660
TATTCCCATC	CCATCATCTT	GGGCTTTCGC	AAGATTTCCTA	TGGGAGTGGG	CCTCAGTCCG
670	680	690	700	710	720
TTTCTCCTGG	CTCAGTTTAC	TAGTGCCATT	TGTTTCAAGT	TTCTAGGGGC	TTTCCCCCAC
730	740	750	760	770	780
TGTTTGGCTT	TCAGTTATAT	GGATGATGTG	GTATTGGGGG	CCAAGTCTGT	ACAACATCTT
790	800	810	820	830	840
GAATCCCTTT	ATACCGCTAT	TACCAATTTT	CTTGTGTCTT	TGGGTATACA	TTTAAACCTT
850	860	870	880	890	900
AATAAAACCA	AACGTTGGGG	CTACTCCCTT	AACTTCATGG	GATATGTAAT	TGGAAGTTGG
910	920	930	940	950	960
GGTACCTTGC	CACAGGAACA	TATTGTACAA	AAAAATCAAAC	AATGTTTTCG	AAAACCTTCT
970	980	990	1000	1010	1020
ATAAATAGAC	CTATTGATTG	GAAAGTATGT	CAAAGAATTG	TGGGTCTTTT	GGGTTTTGCC
1030	1040	1050	1060	1070	1080
GCTCCCTTTA	CACAAATGTG	TTACCCAGCA	TTAATGCCTT	TATATGCATG	TATACAAGCT
1090	1100	1110	1120	1130	1140
AAACAGGCTT	TCACTTTCTC	GCCAACTTAC	AAGGCCTTTC	TGTATAAACA	ATATCTGAAC
1150	1160	1170	1180	1190	1200
CTTTTACCCCG	TTGCTCGGCA	ACGGTCAGGT	CTTTGCCAAG	TGTTTGCTGA	CGCAACCCCC
1210	1220	1230	1240	1250	1260
ACTGGTTGGG	GCTTGGCCAT	GGGCCATCAG	CGCATGCGTG	GAACCTTTGT	GGCTCCTCTG
1270	1280	1290	1300	1310	1320
CCGATCCATA	CTGCGGAAC	CCTAGCAGCT	TGTTTGTGCTC	GCAGCCGGTC	TGGAGCAAAC
1330	1340	1350	1360	1370	1380
CTTATCGGCA	CCGACAACTC	TGTTGTCTCT	TCTCGGAAAT	ACACCTCTTT	TCCATGGCTG
1390	1400	1410	1420	1430	1440
CTAGGCTGTG	CTGCCAACTG	GATCCTGCGC	GGGACGTCC	TTGTCTACGT	CCCGTCGGCG
1450	1460	1470	1480	1490	1500
CTGAATCCCG	CGGACGACCC	GTCTCGGGGT	CGTTTGGGAC	TCTACCGTCC	CCTTCTCCGT
1510	1520	1530	1540	1550	1560
CTGCCGTTCC	GGCCGACCAC	GGGGCGCACC	TCTCTTTACG	CGGACTCCCC	GTCTGTGCCT
1570	1580	1590	1600	1610	1620
TCTCATCTGC	CGGACCGTGT	GCACTTCGCT	TCACCTCTGC	ACGTGCGCATG	GAGACCACCG
1630	1640	1650	1660	1670	1680
TGAACGCCCG	CCAGGTCTTG	CCTAAGGTCT	TACATAAGAG	GACTCTTGGA	CTCTCAGCAA

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Figure 4B

1690	1700	1710	1720	1730	1740
TGTCAACGAC	CGACCTTGAG	GCATACTTCA	AAGACTGTGT	ATTTAAGGAC	TGGGAGGAGT
1750	1760	1770	1780	1790	1800
TGGGGGAGGA	GATTAGGTTA	ATGATCTTTG	TACTGGGAGG	CTGTAGGCAT	AAATTGGTCT
1810	1820	1830	1840	1850	1860
GTTCAACCAGC	ACCATGCAAC	TTTTTCACCT	CTGCCTAATC	ATCTCATGTT	CATGTTCCAC
1870	1880	1890	1900	1910	1920
TGTTCAAGCC	TCCAAGCTGT	GCCTTGGGTG	GCTTTGGGGC	ATGGACATTG	ACCCGTATAA
1930	1940	1950	1960	1970	1980
AGAAATTGGA	GCTTCTGTGG	AGTTACTCTC	TTTTTTGCCT	TCTGACTTTT	TTCTTCTTAT
1990	2000	2010	2020	2030	2040
TCGTGATCTC	CTCGACACCG	CCTCTGCTCT	GTATCGGGAG	GCCTTAGAGT	CTCCGGAACA
2050	2060	2070	2080	2090	2100
TTGTTACACCT	CACCATACAG	CACTAAGGCA	AGCTATTCTG	TGTTGGGGTG	AGTTGATGAA
2110	2120	2130	2140	2150	2160
TCTGGCCACC	TGGGTGGGAA	GTAATTGGA	AGACCCGGCA	TCCAGGGAAT	TAGTAGTAAG
2170	2180	2190	2200	2210	2220
CTATGTCAAT	GTTAATATGG	GCCTAAAAAT	CAGACAACCTA	TTGTGGTTTC	ACATTTCTCTG
2230	2240	2250	2260	2270	2280
TCTTACTTTT	GGAAGAGAAA	CTGTTCTTGA	GTATTTGGTG	TCTTTTGGAG	TGTGGATTCTG
2290	2300	2310	2320	2330	2340
CACTCCTCCC	GCTTACAGAC	CACCAAATGC	CCCTATCTTA	TCAACACTTC	CGGAAACTAC
2350	2360	2370	2380	2390	2400
TGTTGTTAGA	CGACGAGGCA	GGTCCCCTAG	AAGAAGAACT	CCCTCGCCTC	GCAGACGAAG
2410	2420	2430	2440	2450	2460
GTCTCAATCG	CCGCGTCGCA	GAAGATCTCA	GTCTCGGGAA	TCTCAATGTT	AGTATCCCTT
2470	2480	2490	2500	2510	2520
GGACTCATAA	GGTGGGAAAC	TTTACTGGGC	TTTATTCTTC	TACTGTACCT	GTCTTTAATC
2530	2540	2550	2560	2570	2580
CTGAATGGCA	AACTCCCTCT	TTTCCTCACA	TTCATTTGAA	AGAGGATATT	ATCAATAGAT
2590	2600	2610	2620	2630	2640
GTCAACAATA	TGTGGGCCCC	CTTACAGTTA	ACGAAAAAAG	GAGATTAAAA	TTGATCATGC
2650	2660	2670	2680	2690	2700
CTGCTAGGTT	CTATCCTAAC	CTTACTAAAT	ATTTGCCCTT	AGATAAAGGC	ATCAAACCTT
2710	2720	2730	2740	2750	2760
ATTATCCTGA	ACATATAGTT	AATCATTACT	TCCAAACTAG	GCATTATTTA	CATACTCTGT
2770	2780	2790	2800	2810	2820
GGAAGGCTGG	TATTTTATAT	AAGAGAGAAA	CTACTCGCAG	CGCCTCATTT	TGTGGGTCAC
2830	2840	2850	2860	2870	2880
CATATTCTTG	GGAACAAGAG	CTACAGCATG	GGAGGTTGGT	CTTCCAAACC	TCGACAAGGC
2890	2900	2910	2920	2930	2940
ATGGGGACGA	ATCTTTCCGT	TCCCAATCCT	CTGGGATTCT	TTCCCGGTCA	CCAGTTGGAC
2950	2960	2970	2980	2990	3000
CCGACATTTC	GAGCCAATTC	AAACAATCCA	GATTGGGACT	TCAACCCCAA	CAAGGATCAA
3010	3020	3030	3040	3050	3060
TGGCCAGCGG	CAAACCAGGT	AGGAGTGGGA	TCATTTCGGC	CGGGGTTTAC	TCCACCACAC
3070	3080	3090	3100	3110	3120
GGCAATCTTT	TGGGGTGGAG	CCCTCAGGCT	CAGGGCATAT	TGACAACAGT	ACCAGCAGCG
3130	3140	3150	3160	3170	3180
CCTCCTCCTG	CCTCCACCAA	TCGGCAGTCA	GGAAGAAAGC	CTACTCCCAT	CTCTCCACCT
3190	3200	3210	3220		
CTAAGAGACA	GTCATCCTCA	GGCCATGCAA	TGGAA		