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DETECTION OF AMPLIFIED NUCLEIC ACID USING SECONDARY CAPTURE OLIGONUCLEOTIDES AND TEST KIT

This invention relates to a method for amplifying and detecting nucleic acids of interest. It also relates to a test kit comprising a capture probe and secondary oligonucleotides useful for improved capture hybridization efficiency.

Nucleic acid probe technology has developed rapidly in recent years as researchers have discovered its value for detection of various diseases, organisms or genetic features which are present in small quantities in a human or animal test sample. The use of probes is based upon the concept of complementarity such that complementary strands of nucleotides can and will, under proper conditions, hybridize to form a double stranded product. DNA inherently has two strands bound together by hydrogen bonds between complementary nucleotides (which are also known as nucleotide pairs). RNA, while being single stranded, also can hybridize with a complementary strand of nucleotides.

Hybridization of complementary strands is a central feature of what are known as hybridization assays (also known as genetic probe assays). Thus, if at least a sequence of a nucleic acid of interest (identified as a target nucleic acid) is known, it can be hybridized and detected using appropriate oligonucleotides (identified as probes) which are designed to be complementary to that known sequence. The probe usually is labeled in some fashion so that its detection also signals the presence of the hybridized product of probe and target nucleic acid. If the target nucleic acid is then unique to a particular organism, viral infection or genetic

feature, the presence of the organism, virus or genetic feature can then readily be determined.

In some instances, the target nucleic acid (single strand form) is insolubilized on a solid surface (such as a nitrocellulose membrane) to prevent undesirable hybridization with oligonucleotides other than probes. In what are known as "immunometric" or "sandwich" assays, the target nucleic acid may be captured using another oligonucleotide which is immobilized in some manner, for example on a membrane as described in US-A-4,727,019. In other instances, the oligonucleotide is immobilized on polymeric particles which are embedded within a porous matrix (for example as described in EP-A-0 200 381).

EP-A-0 318 245 describes the need to improve the kinetics of hybridization between a water-soluble probe (such as a detection probe) and a long target nucleic acid in solution hybridization assays. This need is allegedly met using "helper" oligonucleotides which, it is believed, reorder the secondary and tertiary structure of the target nucleic acid in solution. These oligonucleotides hybridize with the target nucleic acid in regions other than that where the detection probe hybridizes.

Where a capture probe is used in a hybridization assay, the oligonucleotide attached to a water-insoluble support (such as a small polymeric particle) is usually very small in relation to the size of the support. The length of the oligonucleotide is so short that it extends only a very short distance from the surface of the support. Thus, steric hindrance is believed responsible for slow hybridization rates between the capture probe and the target nucleic acid.

Thus, there is a continuing need to improve the hybridization efficiency between target nucleic acids

and insolubilized capture probes having very short oligonucleotides.

The present invention provides a way to improve hybridization of relatively short target nucleic acids with relatively short capture probes which are covalently bound to water-insoluble supports.

In one aspect, the present invention comprises a method for the amplification and detection of a double-stranded nucleic acid comprising:

A. after denaturation of a target double-stranded nucleic acid, and under hybridizing conditions, amplifying the target nucleic acid using a thermostable DNA polymerase, complementary primers and dNTPs,

B. forming a water-insoluble hybridization product of the amplified target nucleic acid with a water-insoluble capture probe which is not detectably labeled, the capture probe comprising a water-insoluble polymeric particle to which is covalently attached an oligonucleotide complementary to a first sequence of the target nucleic acid, the oligonucleotide being from 15 to 20 nucleotides in length, and

simultaneously or prior to such product formation, contacting the amplified target nucleic acid with one or more water-soluble, distinct secondary oligonucleotides, each of the secondary oligonucleotides being complementary to a sequence of the target nucleic acid other than the first sequence, and each of the secondary oligonucleotides having a length which is equal to or greater than the length of the capture probe oligonucleotide,

to hybridize the secondary oligonucleotides with the amplified target nucleic acid, and

C. detecting the resulting hybridized product of the target nucleic acid with the capture probe.

The invention also provides a kit for the amplification and detection of a target nucleic acid comprising a probe comprising an oligonucleotide complementary to a first sequence of the target nucleic acid, and one or more water-soluble, distinct secondary oligonucleotides, each of the secondary oligonucleotides being complementary to a sequence of the target nucleic acid other than the first sequence, the kit characterized wherein the probe is a water-insoluble capture probe which is not detectably labeled, and comprises a water-insoluble polymeric particle to which the probe oligonucleotide is attached, the oligonucleotide being from 15 to 20 nucleotides in length, and

each of the secondary oligonucleotides has a length which is equal to or greater than the length of the capture probe oligonucleotide.

As used herein the term dNTP's is a generic term for the various nucleotide triphosphate units that make up a nucleic acid, and which can be incorporated onto the end of a nucleic acid by a polymerase. Typically they include dATP, dCTP, dGTP and dTTP, together with dUTP for RNA molecules.

The method and kit of this invention provides a means for rapid and sensitive detection of nucleic acids using known PCR procedures which are hereby improved in the detection step. The improvement is achieved by using secondary oligonucleotides with the capture probe, all of which hybridize with the amplified target nucleic acid. In addition, the assay provides advantages so that the capture probe is readily separated from unwanted materials because of the polymeric particles to which the capture

oligonucleotide is covalently and directly attached. Separation can be readily achieved using filtration membranes, porous matrices, centrifugation and other separation techniques. In addition, the capture probe can be attached in a suitable fashion to a nonporous particle which is readily contacted with an amplified target.

It is also important in this invention that the secondary oligonucleotides be of a certain length, namely equal to or greater than the length of the capture oligonucleotide. The capture oligonucleotide is from 15 to 20 nucleotides in length. This invention provides improved hybridization rates between target nucleic acid and capture probe.

The general principles and conditions for amplification and detection of nucleic acids using polymerase chain reaction are quite well known, the details of which are provided in numerous references including US-A-4,683,195, US-A-4,683,202 and US-A-4,965,188.

The present invention is directed to the amplification and detection of one or more specific nucleic acid sequences present in one or more targeted nucleic acids in a test specimen. Such specimens can include cellular or viral material, hair, body fluids or other materials containing genetic DNA or RNA which can be detected.

The present invention is especially useful for producing, in exponential quantities relative to the number of reaction steps involved, at least one specific nucleic acid sequence. The product will be a discrete nucleic acid duplex with termini corresponding to the ends of the specific primers employed. Any source of nucleic acid, purified or not, can be utilized as the starting material. A

mixture of nucleic acids can be employed if desired. The sequence to be duplicated can be a fragment of the entire nucleic acid.

Nucleic acids to be detected can be obtained from various sources including plasmids, naturally occurring DNA or RNA from any source (such as bacteria, yeast, viruses, plants and higher animals, humans). It may be extracted from various tissues including blood, peripheral blood mononuclear cells (PBMC), tissue material or other sources known in the art using known procedures. The present invention is particularly useful for the amplification and detection of nucleic acid sequences found in genomic DNA, bacterial DNA, fungal DNA, viral RNA, or DNA or RNA found in bacterial or viral infected cells.

The method described herein can be used to provide the detection or characterization of specific nucleic acid sequences associated with infectious diseases, genetic disorders or cellular disorders such as cancers. It may also be used in forensic investigations and DNA typing. For purposes of this invention, genetic diseases include specific deletions or mutations in genomic DNA from any organism, such as sickle cell anemia, cystic fibrosis, a-thalessemia, b-thalessemia and others readily apparent to one skilled in the art. Human Leukocyte Antigen (HLA) can be categorized with the present invention. Various infectious diseases can be diagnosed by the presence in a clinical sample of small quantities of specific DNA sequences characteristic of the organism, whether it be a yeast, bacterium or virus. Such bacteria which can be detected include, but are not limited to, Salmonella, Streptococcal organisms, Chlamydial organisms, Gonococcal organisms, Mycobacterium tuberculosis, Mycobacterium avium complex, Mycoplasma

15 APR 2002

Haemophilus influenzae, Shigella and Listeria. Viruses which are detectable include, but are not limited to, herpes, Epstein Barr virus, cytomegalovirus, human papilloma virus, hepatitis and retroviruses such as HTLV-I, HIV-I and HIV-II. Other detectable species would be readily apparent to one skilled in the art. The amount of b-globin DNA can also be detected. The invention is particularly useful for the detection of the presence of viral DNA.

Preferably, the target nucleic acid is less than 250-mer in length. The term "mer" is used to refer to a single nucleotide.

The primer is preferably single stranded for maximum efficiency in amplification. Preferably, the primer is an oligodeoxyribonucleotide. The exact size of each primer will vary depending upon the use contemplated, the complexity of the targeted sequence, reaction temperature and the source of the primer. Generally, the primers used in this invention will have from 12 to 60 nucleotides, and preferably, they have from 18 to 45 nucleotides.

Primers, probe oligonucleotides and secondary oligonucleotides useful herein can be obtained from a number of sources or prepared using known techniques and equipment, including for example, an ABI DNA Synthesizer (available from Applied Biosystems) or a Biosearch 8600 Series or 8800 Series Synthesizer (available from Milligen-Biosearch, Inc.) and known methods for their use (for example as described in US-A-4,965,188. Naturally occurring primers isolated from biological sources are also useful (such as restriction endonuclease digests).

As used herein, a "capture probe" is a water-insoluble material comprised of a solid polymeric particle (described below) to which is covalently

15 APR 2002

attached an oligonucleotide which is substantially complementary to a "first" nucleic acid sequence of the targeted nucleic acid.

The oligonucleotide of the probes is of a critical length, that is from 15 to 20 nucleotides, in order to best detect single base mutations or deletions in a target nucleic acid.

A number of thermostable DNA polymerases have been reported in the art, including those mentioned in US-A-4,965,188 and US-A-4,889,818. Particularly useful polymerases are those obtained from various Thermus bacterial species, such as Thermus aquaticus, Thermus thermophilus or Thermus flavus. Other useful thermostable polymerases are described in WO-A-89/06691.

The secondary oligonucleotides used in the practice of this invention generally have a length equal to or greater than that of the probe oligonucleotide. More specifically, the length is from 15 to 35 nucleotides. At least one secondary oligonucleotide is used in the invention, each of which is complementary to a distinct sequence of the target nucleic acid, and those distinct sequences are different from the "first" sequence to which the probe oligonucleotide is complementary.

A targeted nucleic acid can be obtained from any of a variety of sources. Generally, it is extracted in some manner to make it available for contact with the primers and other reaction materials. This usually means removing unwanted proteins and cellular matter from the specimen in a suitable manner. Various procedures are known in the art.

Since the nucleic acid to be amplified or detected is usually in double stranded form, the two strands must be separated (that is, denatured) before

priming can take place. Denaturing is accomplished using a heat treatment alone or in combination with any suitable other physical, chemical or enzymatic means as described in the art.

The denatured strands are then cooled to a second temperature which is generally in the range of from 55 to 70°C where priming and primer extension are carried out in the presence of the DNA polymerization reagents identified below. The resulting double-stranded primer extension products are heated to denature the strands. Once the strands are separated, they are available as templates for forming additional primer extension products therewith.

The specimen is mixed with the thermostable DNA polymerase, suitable deoxyribonucleotide-5'-triphosphates (for example, dATP, dCTP, dGTP and dTTP) and a suitable set of primers at the beginning of the first cycle. The amount of thermostable DNA polymerase to be used is known in the art.

The dNTP's and primers are present in amounts effective for DNA polymerization to occur, such amounts being known in the art. Other reagents are also preferably present, including salts such as magnesium chloride, extenders such as gelatin or other water soluble or water dispersible colloids. The reaction mixture is generally buffered to a pH of from 7 to 9 with pH of 8 being preferred using any of a number of suitable buffers known in the art. The volume of the reaction mixture including the targeted nucleic acid is not critical, but with smaller volumes, heat can be transferred to and away more rapidly.

The reagents for polymerization can be added to the specimen containing targeted nucleic acid at any suitable time, as is known in the art. The reagents

can be added at several and various times during an amplification cycle. Workers skilled in the art would be able to design an acceptable protocol for reagent addition.

The newly synthesized hybridized product of the template and its complementary nucleic acid formed from the primer are used in subsequent steps of the method. They are then denatured by heating, and used as templates for further cycles of priming, extension and denaturation as is known in the art. The time for each cycle can vary widely depending upon the equipment and reagents used. In a preferred embodiment, each cycle is 120 seconds or less. The cycle can be completed as often as needed to produce the desired quantity of the targeted nucleic acid.

After the last cycle, the final primer extension products can be detected as described below. Preferably, the products are denatured a last time providing multiple copies of the strands of the targeted nucleic acid.

The amplification method of this invention is preferably conducted in a continuous, automated manner so that the reaction mixture is temperature cycled in a controlled manner for desired preset times. A number of instruments have been developed for this purpose, as one of ordinary skill in the art would know.

One such instrument for this purpose is described in some detail in US-A-4,965,188 and EP-A-0 236 069, and involves moving liquids from one temperature environment to another under controlled conditions.

Another instrument utilizes temperature cycling without a liquid handling system, and is also described in some detail in US-A-4,965,188 and EP-A-0 236 069. Generally, this instrument includes a heat

15 APR 2002

conducting container for holding a number of reaction tubes containing reaction mixture, a means for heating, cooling and temperature maintenance, and a computing means to generate signals to control the amplification sequence, changes in temperature and timing.

A preferred instrument for processing amplification reactions in a disposable chemical test pack is described in some detail in EP-402 994. In general, this instrument comprises a support surface for supporting a chemical test pack, pressure applicators supported above the surface for acting on the reaction pack to transfer fluids between adjacent chambers in the test pack, and means for operating the pressure applicators through a range of movement extending across the test pack.

EP-402 995 provides details of useful chemical test packs which can be processed using the instrument described in EP-402 994. Also described therein are means for heating and cooling the test pack at repeated intervals (that is, through cycles) appropriate for the method of the present invention.

The method of this invention can be used to advantage to rapidly detect a target nucleic acid which is present, for example, in an infectious agent. Once a desired amount of the target nucleic acid has been generated, it is detected by forming a water-insoluble, hybridization product of it with a capture probe which is not labeled.

The capture probe comprises a water-insoluble polymeric particle to which is covalently attached an oligonucleotide (15-20 nucleotides) which is complementary to a first sequence of the target nucleic acid.

The oligonucleotide can be directly attached through covalent bonds resulting from chemical reaction of the oligonucleotide and reactive groups on the particles. Alternatively, a spacer group of some type can be attached to the particle or oligonucleotide prior to attachment. One such useful spacer group and procedures for its use are described in US-A-4,914,210.

A wide variety of polymeric particles can be used in practicing this invention, including those prepared from naturally occurring or synthetically prepared polymers. Preferably the particles are spherical in shape and have an average size (largest dimension) of from 0.01 to 10 mmeters, although the size, structural and spatial configurations are not critical. Preferred particles have an average diameter of from 0.01 to 5 mmeters. Many such particles are commercially available from a number of sources. Alternatively, reagents and procedures for preparing such particles are well known, for example as described in EP-A-0 323 692.

The oligonucleotide is covalently attached to the surface of the particles using any of a number of reactive groups and reactions known in the art. Reactive groups on the surface of the particles can be provided as part of the structure of the polymer, or added by coating or chemical treatment of an inert material. One skilled in the art would readily understand how to prepare such materials to have suitable reactive groups including, but not limited to: carboxy, 2-substituted ethylsulfonyl, 2-substituted ethylcarbonyl, vinylsulfonyl, amino, sulfhydryl, vinylcarbonyl, epoxy, aldehyde, active halogen groups, hydrazide and active esters such as succinimidoxycarbonyl.

15 APR 2002

Particularly useful particulate carrier materials are polymeric beads described, for example, in EP-A-0 323 692 which are prepared from one or more ethylenically unsaturated polymerizable monomers having an active halogen group, activated 2-substituted ethylsulfonyl or vinylsulfonyl groups. Other particularly useful particles having reactive carboxy groups are described in EP-A-0 466 220.

Useful homo- and copolymers include, but are not limited to: poly(styrene-co-acrylic acid) (70:30 molar ratio), poly(m & p-chloromethylstyrene), poly(styrene-co-m & p-chloromethylstyrene-co-2-hydroxyethyl acrylate) (67:30:3 molar ratio), poly[styrene-co-m & p-(2-chloroethylsulfonyl-methyl)styrene] (96:4 molar ratio), poly{styrene-co-N-[m & p-(2-chloroethylsulfonylmethyl)phenyl]acrylamide} (99.3:0.7 molar ratio), poly(m & p-chloromethylstyrene-co-metharylic acid) (95:5 molar ratio), poly[styrene-co-m & p-(2-chloroethylsulfonylmethyl)styrene-co-methacrylic acid] (93.5:4.5:2 molar ratio) and poly[styrene-co-4-(2-chloroethylsulfonylmethyl)styrene] (95.5:4.5 molar ratio).

Forming a hybridization product of the amplified target nucleic acid and the capture probe can be accomplished by mixing the two materials under conventional conditions, such as a temperature in the range of from 40 to 45°C for a time of at least 5 minutes. Representative specific conditions are described in the example below.

Simultaneously with or prior to the hybridization of the capture probe and target nucleic acid, the target nucleic acid is also hybridized with two or more distinct secondary oligonucleotides. Each of these oligonucleotides is complementary to a distinct

sequence of the target nucleic acid which is different from the first sequence noted above, and different from each other. The length of these oligonucleotides is described above. They are generally unlabeled and water-soluble. Preferably two secondary oligonucleotides are used in the assay, but more can be used if desired. It is also preferred that the amplified target nucleic acid be contacted with the capture probe and secondary oligonucleotides substantially simultaneously. The amount of secondary oligonucleotide can be widely varied, but preferably it is present at about the same concentration as the capture probe oligonucleotide.

The resulting hybridized product of amplified target nucleic acid, capture probe and secondary oligonucleotides can be detected in any suitable fashion which would be apparent to a skilled worker in the art.

Generally, detection requires that the hybridized product be separated from the other materials in the reaction medium. This can be done by any of a number of ways, including filtration, centrifugation or other suitable separation techniques.

Particularly useful separation means include microporous filtration membranes such as the polyamide membranes marketed by Pall Corp. They can be used uncoated or precoated with surfactants or other materials which facilitate fluid flow. Other types of filters can be used also.

The membrane or filter can be used as a separate article with suitable containers for collecting fluid and water-soluble materials. Preferably, however, the membranes are mounted as part of a test device. Various test devices are known in the art including those described in US-A-3,825,410, US-A-3,888,629, US-

A-3,970,429 and US-A-4,446,232. Particularly useful devices are described in US-A-4,921,677

Alternatively to separation as described above, the target nucleic acid can be detected using the capture probe which has been immobilized on a flat substrate, such as the microporous filtration membranes described above, or on thin polymeric films, uncoated papers or polymer coated papers, a number of which are known in the art, glass slides and other nonporous substrates readily apparent to one skilled in the art.

In one embodiment, detection of the hybridized product can be accomplished using a detection probe which is complementary either to the capture probe or to still another sequence of the target nucleic acid (that is, a sequence other than those complementary to the capture probe and secondary oligonucleotides).

In another embodiment, detection can be achieved using a detection probe complementary to at least one of the secondary oligonucleotides.

Procedures for attaching labels for detection and preparing such probes are well known in the art, for example, as described by Agrawal and others, Nucleic Acid Res., 14, pp. 6227-45 (1986), US-A-4,914,210 relating to biotin labels, US-A-4,962,029 relating to enzyme labels, and the references noted therein. Useful labels include radioisotopes, electron-dense reagents, chromogens, fluorogens, phosphorescent moieties, ferritin and other magnetic particles (see US-A-4,795,698 and US-A-4,920,061), chemiluminescent moieties and enzymes (which are preferred). Useful enzymes include, glucose oxidase, peroxidases, uricase, alkaline phosphatase and others known in the art and can be attached to oligonucleotides using known procedures. Substrates and reagents for

15 APR 2002

providing a detectable colorimetric, fluorometric or chemiluminescent signal in the presence of a given enzyme label are well known, for example as described in US-A-4,994,373.

Where the label is a preferred enzyme such as a peroxidase, at some point in the assay, hydrogen peroxide and suitable dye-forming compositions are added to provide a detectable dye. For example, useful dye-providing reagents include tetramethylbenzidine and derivatives thereof, and leuco dyes, such as triarylimidazole leuco dyes (as described in US-A-4,089,747), or other compounds which react to provide a dye in the presence of peroxidase and hydrogen peroxide. Particularly useful dye-providing compositions are described in EP-A-0 308 236.

Detection of the resulting signal can be achieved using suitable detection equipment and procedures which are well known. Certain probes may provide signals which are visible to the eye without the use of detection equipment.

In a preferred embodiment, one of the primers is labeled with a specific binding ligand such as biotin, an antibody or lectin. The labeled primer provides (through amplification) an amplified target nucleic acid which has the specific binding ligand attached. This amplified nucleic acid is detected using a detectably labeled receptor for specific binding ligand. For example, if the specific binding moiety is biotin, the receptor is avidin or an equivalent thereof. The receptor, for example avidin, can be conjugated with an enzyme, or have a radioactive moiety which provides a detectable signal as noted above.

In still another embodiment, the amplified target nucleic acid can be detected by incorporating a radioisotope into the amplified product by using dNTPs in the primer extension which are labeled with a radioisotope.

It is also useful for the method of this invention to be carried out in a suitable container. The most crude container would be a test tube, cuvette, flask or beaker, but more sophisticated containers have been fashioned in order to facilitate automated procedures for performing the method. For example, a cuvette constructed to provide certain temperature characteristics during the practice of the method is described in US-A-4,902,624.

The following examples are included to illustrate the practice of this invention, and are not meant to be limiting in any way. All percentages are by weight unless otherwise noted.

Examples 1-3: Assay for HLA DNA

These examples illustrate the practice of this invention for the amplification and detection of a representative nucleic acid, namely a fragment of HLA DNA.

Materials and Methods:

A capture probe was composed of particles of poly(styrene-co-acrylic acid) (70:30 molar ratio, 2.1 mmeter average diameter) having covalently attached thereto an oligonucleotide having the following sequence which is complementary to a first sequence of the target nucleic acid:

SEQ ID NO:1:

5'-X-GCCTGATGCC GAGTACT-3'

The oligonucleotide was attached to the particles through "X", an aminotetraethylene glycol linker having 16 ethylene glycol units using the

15 APR 2002

procedure described in US-A-4,914,210. More specifically, an aqueous suspension of the particles (1 ml, 30 mg solids) was centrifuged and the supernatant discarded. The particles were then resuspended in glass-distilled water (1 ml) by vigorous vortexing, followed by centrifugation and removal of the supernatant. The particles were then resuspended again in a solution (1 ml) of sodium chloride (3 normal) in methylimidazole buffer (0.2 molar, pH 7).

To this suspension was added the noted oligonucleotide (2.5 nmoles) followed by thorough mixing. The activating compound, 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (5 mg) was added, and after thorough mixing by vortex, the reaction mixture was incubated at room temperature with occasional stirring for at least two hours.

The reaction mixture was centrifuged and the supernatant removed. The resulting particulate reagent was washed with the following fluids by centrifugation and pipetting off the supernatant between washings: a) three washings with glass-distilled water (1 ml each time), and b) three washings with a buffer solution (1 ml each time, pH 7.4) comprising sodium chloride (0.018 molar), sodium phosphate (1 mmolar) ethylenediaminetetraacetic acid (0.1 mmolar) and dodecyl sulfate (0.5%) and which had been prewarmed to 70°C.

After the last wash, the reagents were resuspended in glass-distilled water to a final volume of 1 ml to make a 3% dispersion. It was stored at 4°C until its use.

A leuco dye composition was prepared containing 2-(4-hydroxy-3,5-dimethoxyphenyl)-4,5-bis(4-methoxyphenyl)imidazole as follows:

Solid leuco dye (to make a 0.1% solution) was dissolved in a solution of poly(vinylpyrrolidone) (20%) in sodium phosphate buffer (5 mmolar). This solution was then added to a solution of hydrogen peroxide (10 mmolar), 4'-hydroxyacetanilide electron transfer agent (5 mmolar) and diethylenetriaminepentaacetic acid chelating agent (10 mmolar) in sodium phosphate buffer to produce a final concentration of 1% polymer and 0.005% leuco dye.

A DNA polymerase was used during amplification which was isolated from Thermus aquaticus using standard procedures, and which had an activity of 4 units/ml). A "unit" is defined as the amount of enzyme activity required to incorporate 10 nmoles of total nucleotides (dNTP's) into an extending nucleic acid chain in 30 minutes at 74° C.

The target nucleic acid was a HLA DNA fragment generated by amplifying a 231-base pair segment of HLA DQb gene using primers flanking a hyperviable region located in Exon 1. The HLA DNA fragment was isolated from the cell line FPF (Human Genetic Mutant Cell Deposit, Camden, New Jersey) as described by Maniatis and others, Molecular Cloning, A Laboratory Manual, page 458, Cold Spring Harbor Laboratory, New York, 1982.

The primers used in amplification in the assay had the following sequences:

SEQ ID NO:2:

5'-Y-CTCGGATCCG CATGTGCTAC TTCACCAACG-3'

and

SEQ ID NO:3:

5'-GAGCTGCAGG TAGTTGTGTC TGCACAC-3'

wherein Y represents a biotintetraethylene glycol linker moiety attached to the oligonucleotide using the procedure described in US-A-4,914,210.

The secondary oligonucleotides used in the practice of this invention had the following sequences:

SEQ ID NO:4:

5'-ACGTGGGGGT GTATCGGGCG GTGACGC-3'

SEQ ID NO:5:

5'-GGAACAGCCA GAAGCAAGTC CTGGAG-3'

All of the oligonucleotides used in these examples were prepared and purified using a conventional automated SAM-1 DNA synthesizer (Biosearch) and known procedures (for example, as described by Beaucage and others, Tetrahedron Letters, 22, 1859-1862, 1981).

15 APR 2002

Assay Protocol:

An amplified target nucleic acid was provided by amplifying the noted HLA DNA fragment using tritiated dNTP's in the following manner:

The HLA DNA fragment (1 mg) was added to a buffer solution (100 ml) containing tris(hydroxymethyl)aminomethane hydrochloride buffer (67 mmolar, pH 8.8), ammonium sulfate (16.6 mmolar), magnesium chloride (2.5 mmolar) and gelatin (10 mg). The primers described above were added (20 pmoles of each) followed by the tritiated dNTP's (0.17 mmolar of each), and the DNA polymerase (12 units).

Amplification was carried out for 35 of the following cycles using a conventional Perkin-Elmer Thermal Cycler:

denaturation at 95°C for 30 seconds,

cooling to and hybridization at 65°C for 30 seconds, and

heating to and primer extension at 70°C for 1 minute.

A solution (10 ml) of the resulting amplified target nucleic acid was heated to 95°C for five minutes to denature the strands of nucleic acid, then mixed separately with the following components:

the capture probe (150 mg) alone in a Control assay,

the capture probe (150 mg) and secondary oligonucleotide SEQ ID NO: 4 (identified above, 50 mmolar) in Example 1,

the capture probe (150 mg) and secondary oligonucleotide SEQ ID NO: 5 (identified above, 50 mmolar) in Example 2, and

the capture probe (150 mg) and both secondary oligonucleotides SEQ ID NO: 4 and SEQ ID NO: 5 (identified above, 50 mmolar) in Example 3.

Each of the resulting suspensions were in a buffered solution containing sodium phosphate (0.125 molar, pH 6.8), sodium chloride (2.5 molar) and ethylenediaminetetraacetic acid (1 mmolar). They were incubated at 42°C for 10 minutes to allow the capture and secondary oligonucleotides to hybridize to the amplified target nucleic acid.

The hybridized products were washed with a solution (300 ml) containing sodium phosphate (0.85 mmolar), sodium chloride (15 mmolar) and sodium dodecyl sulfate (0.5%) which had been prewarmed to 50°C. The resulting suspensions were centrifuged, and the supernatants decanted. The amount of tritium label remaining in the water-insoluble product was measured for all assays. The results are shown in Table I below.

A separate set of suspensions containing the hybridized products of capture probe, secondary oligonucleotides and amplified target nucleic acid were detected using colorimetric signals in SURECELL™ disposable test devices (Eastman Kodak Company). These devices contained three test wells having a LOPRODYNE™ microporous membrane (1.2 mmeter average pore size, Pall Corp.) in each test well. The suspensions were added to the test devices and fluid was allowed to flow through the membranes while retaining the hybridized products on the membranes.

The products were washed with a solution (300 ml) containing sodium phosphate (0.85 mmolar), sodium chloride (15 mmolar) and sodium dodecyl sulfate (0.5%) which had been prewarmed to 50°C.

The avidin-horseradish peroxidase conjugate (30 ml of solution containing 2.3 ng of conjugate) was added to the test wells, and the SURECELL™ test devices were incubated at room temperature for 2

minutes. The products were then washed with a solution (200 ml) containing tris(hydroxymethyl)aminomethane (50 mmolar, pH 8.8), sodium dodecyl sulfate (2.4%), sodium chloride (0.5 molar) and 1-methyl-2-pyrrolidinone (0.25 mmolar). The leuco dye solution (50 ml) was added, followed by incubation for 5 minutes at room temperature. The dye signal on the membranes was visually evaluated and scored against a color chart (scores of 0 to 10 with 10 representing highest dye density). The results are shown in Table I below.

The results indicate that the presence of one or both of the secondary oligonucleotides improves the efficiency of detection of the amplified target nucleic acid.

Table 1

Assay	Tritium Label Signal (counts per minute)	Visual Dye Signal
Control	651	7.5
Example 1	3296	10
Example 2	2212	9
Example 3	3291	10

(1) INFORMATION FOR SEQ ID NO:1:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 17 nucleotides

(B) TYPE:

Nucleic acid
(C) STRANDEDNESS: Single
(D) TOPOLOGY: Linear
(ii) MOLECULE TYPE: Probe oligonucleotide
(iii) HYPOTHETICAL: No
(iv) ANTI-SENSE: No
(vi) ORIGINAL SOURCE: Synthetically prepared
(vii) IMMEDIATE SOURCE: Synthetically prepared
(x) PUBLICATION INFORMATION: None
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:
GCCTGATGCC GAGTACT

(2) INFORMATION FOR SEQ ID NO:2:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 30 nucleotides
(B) TYPE: Nucleic acid
(C) STRANDEDNESS: Single
(D) TOPOLOGY: Linear
(ii) MOLECULE TYPE: Primer
(iii) HYPOTHETICAL: No
(iv) ANTI-SENSE: No
(vi) ORIGINAL SOURCE: Synthetically prepared
(vii) IMMEDIATE SOURCE: Synthetically prepared
(x) PUBLICATION INFORMATION: None
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

CTCGGATCCG CATGTGCTAC TTCACCAACG

(3) INFORMATION FOR SEQ ID NO:3:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 27 nucleotides

(B) TYPE: Nucleic acid

(C) STRANDEDNESS: Single

(D) TOPOLOGY: Linear

(ii) MOLECULE TYPE: Primer

(iii) HYPOTHETICAL: No

(iv) ANTI-SENSE: No

(vi) ORIGINAL SOURCE: Synthetically prepared

(vii) IMMEDIATE SOURCE: Synthetically prepared

(x) PUBLICATION INFORMATION: None

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

GAGCTGCAGG TAGTTGTGTC TGCACAC

(4) INFORMATION FOR SEQ ID NO:4:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 27 nucleotides

(B) TYPE: Nucleic acid

(C) STRANDEDNESS: Single

(D) TOPOLOGY: Linear

(ii) MOLECULE TYPE: Oligonucleotide

(iii) HYPOTHETICAL: No

15 APR 2002

(iv) ANTI-SENSE: No

(vi) ORIGINAL SOURCE: Synthetically prepared

(vii) IMMEDIATE SOURCE: Synthetically prepared

(x) PUBLICATION INFORMATION: None

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:
ACGTGGGGGT GTATCGGGCG GTGACGC

(5) INFORMATION FOR SEQ ID NO:5:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 26 nucleotides

(B) TYPE: Nucleic acid

(C) STRANDEDNESS: Single

(D) TOPOLOGY: Linear

(ii) MOLECULE TYPE: Oligonucleotide

(iii) HYPOTHETICAL: No

(iv) ANTI-SENSE: No

(vi) ORIGINAL SOURCE: Synthetically prepared

(vii) IMMEDIATE SOURCE: Synthetically prepared

(x) PUBLICATION INFORMATION: None

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:
GGAACAGCCA GAAGCAAGTC CTGGAG

15 APR 2002

CLAIMS:

1. A method for the amplification and detection of a double-stranded nucleic acid comprising:

A. after denaturation of a target double-stranded nucleic acid, and under hybridizing conditions, amplifying the target nucleic acid using a thermostable DNA polymerase, complementary primers and dNTPs,

B. forming a water-insoluble hybridization product of the amplified target nucleic acid with a water-insoluble capture probe which is not detectably labeled, the capture probe comprising a water-insoluble polymeric particle to which is covalently attached an oligonucleotide complementary to a first sequence of the target nucleic acid, the oligonucleotide being from 15 to 20 nucleotides in length, and

simultaneously or prior to the product formation, contacting the amplified target nucleic acid with one or more water-soluble, distinct secondary oligonucleotides, each of the secondary oligonucleotides being complementary to a sequence of the target nucleic acid other than the first sequence, and each of the secondary oligonucleotides having a length which is equal to or greater than the length of the capture probe oligonucleotide,

to hybridize the secondary oligonucleotides with the amplified target nucleic acid, and

C. detecting the resulting hybridized product of the target nucleic acid with the capture probe.

2. The method as claimed in claim 1 for the detection of any of Human Leukocyte Antigen DNA, HIV-I DNA, HIV-II DNA, cytomegaloviral DNA, human papilloma viral DNA or b-globin DNA or a fragment thereof.

3. The method as claimed in either of claims 1 and 2 wherein the target nucleic acid is contacted with the capture probe and the secondary oligonucleotides simultaneously.

4. The method as claimed in any of claims 1 to 3 wherein the concentration of the secondary oligonucleotides is the same as that of the capture probe oligonucleotide.

5. The method as claimed in any of claims 1 to 4 wherein each hybridization is carried out at a temperature of from 40 to 45°C for at least 5 minutes.

6. The method as claimed in any of claims 1 to 5 wherein the target nucleic acid is less than 250-mer in length.

7. The method as claimed in any of claims 1 to 6 wherein amplification is achieved using a thermostable DNA polymerase isolated from a Thermus species, or a recombinant equivalent thereof, and at least 20 amplification cycles.

8. The method as claimed in any of claims 1 to 7 wherein the capture probe is immobilized on a substrate selected from the group consisting of a microporous filtration membrane, a polymeric film and a resin-coated paper, and detection of the hybridized product occurs on the substrate.

9. A kit for the amplification and detection of a target nucleic acid comprising a probe comprising an oligonucleotide complementary to a first sequence of the target nucleic acid, and one of more water-soluble, distinct secondary oligonucleotides, each of the secondary oligonuycleotides being complementary to a sequence of the target nucleic acid other than the first sequence,

the kit characterized wherein the probe is a water-insoluble capture probe which is not detectably

labeled, and comprises a water-insoluble polymeric particle to which the probe oligonucleotide is attached, the oligonucleotide being from 15 to 20 nucleotides in length, and

each of the secondary oligonucleotides has a length which is equal to or greater than the length of the capture probe oligonucleotide.

10. The kit as claimed in claim 9 wherein the capture probe oligonucleotide is from 15-mer to 20-mer, and each of the secondary oligonucleotides is independently from 15-mer to 35-mer.