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<b>(21) International Application Number:</b> PCT/US97/16423 <b>(22) International Filing Date:</b> 15 September 1997 (15.09.97)  <b>(30) Priority Data:</b> 60/026,387                      16 September 1996 (16.09.96)      US  <b>(71) Applicant (for all designated States except US):</b> THE GOVERNMENT OF THE UNITED STATES OF AMERICA, represented by THE SECRETARY, DEPARTMENT OF HEALTH AND HUMAN SERVICES, Centers for Disease Control and Prevention, Technology Transfer Office [US/US]; Mailstop E-67, Executive Park Bldg. 4, Suite 1103, Atlanta, GA 30329 (US).  <b>(72) Inventors; and</b> <b>(75) Inventors/Applicants (for US only):</b> MORRISON, Christine, J. [US/US]; 3110 Tolbert Drive, Decatur, GA 30033 (US). REISS, Errol [US/US]; 3642 Castaway Court, Chamblee, GA 30341 (US). HOLLOWAY, Brian [US/US]; 1517 Hartsmill Road, Atlanta, GA 30319 (US). SHIN, Jong, Hee [KR/KR]; 85-62 Gyerim 3-dong, Dongku, Kwangju (KR).  <b>(74) Agents:</b> WARREN, William, L. et al.; Jones & Askew, 37th floor, 191 Peachtree Street, N.E., Atlanta, GA 30303 (US).		<b>(81) Designated States:</b> AU, CA, JP, US, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>
<b>(54) Title:</b> METHODS AND COMPOSITIONS FOR THE DETECTION OF <i>CANDIDA</i> SPP.		
<b>(57) Abstract</b> <p>This invention provides for compositions and assays to detect <i>Candida</i> spp. as well as individual species members including <i>C. parapsilosis</i>, <i>C. tropicalis</i>, <i>C. glabrata</i> and <i>C. krusei</i>. Kits for the performance of such assays are further provided.</p>		

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5                   METHODS AND COMPOSITIONS FOR THE DETECTION OF  
                    *CANDIDA SPP.*

                    FIELD OF THE INVENTION

                    This invention relates to diagnostic assays for the  
10     detection and differentiation of the genus *Candida* and  
       different species of *Candida* as well as other microorganisms,  
       and compositions and kits for performing the assays.

                    BACKGROUND OF THE INVENTION

15                   *Candida albicans* is a commensal of the  
       gastrointestinal tract. *C. albicans*, and to a lesser extent  
       several other related species, are of increasing importance as  
       opportunistic pathogens in immunocompromised hosts. A  
       dimorphic, diploid yeast with no known sexual cycle, *C.*  
20     *albicans* is an endogenous organism that can be isolated from  
       skin and mucosal tissues of persons whose immune systems are  
       intact. However, perturbations of the immune or endocrine  
       systems can create opportunities for *Candida* species to  
       convert from a commensal state to invade tissues either  
25     locally or systemically. An example of this opportunism is  
       the oral-esophageal or vaginal candidiasis that is encountered  
       in association with HIV infection.

                    In *C. albicans*, the nuclear rDNA genes encoding the  
       5S, 18S, 5.8S, and 28S rRNAs are found as 50-100 copy tandem  
30     repeats of approximately 10 kb unit length on chromosome seven  
       (Magee et al., 1987, Thrash-Bingham and Gorman, 1992). The 5S  
       rDNA gene (121 bp) is flanked by two nontranscribed regions  
       located between the small and large subunits, and collectively  
       termed the intergenic spacer (IGS). Ribosomal 5.8S sequences  
35     have been compiled from a variety of eukaryotes (Dams et al.,  
       1988). In addition, sequence analysis of the 5.8/28S  
       internally transcribed spacer (ITS) region has shown strain  
       variation within at least one fungal species (O'Donnell,

1992), while other species have demonstrated complete conservation (Mitchell et al., 1992). Strain-specific restriction polymorphisms (RFLPs) have previously been observed in the IGS region for *C. albicans* (Magee et al., 1987).

An opportunistic fungus, *C. albicans* also causes systemic disease in severely immunocompromised hosts. It is the most causative species of disseminated candidiasis followed by *C. tropicalis*, *C. parapsilosis*, and *C. glabrata* (Odds, 1988). Dissemination occurs when *Candida* is spread via the bloodstream or by invasion of mucosal surfaces to internal organs (Odds, 1988). High-risk patient populations include individuals with malignancy or neutropenia, those receiving chemotherapy and/or multiple antibiotics, and those with indwelling catheters or low birth weight infants (Armstrong, 1989).

Diagnosis of systemic candidiasis is complicated by the absence of clinically distinguishing signs, frequently negative blood cultures, and the absence of a reliable serological test to detect infection. Currently, disseminated candidiasis is often diagnosed by a minimum of at least two positive blood cultures (Odds, 1988). However, blood culture alone is clearly not sufficient for the diagnosis of disseminated candidiasis since as many as 50% of disseminated candidiasis cases are diagnosed at autopsy (Telenti, et al. 1989). The nephrotoxicity of amphotericin B, the drug of choice for immunocompromised patients with disseminated disease, precludes its use for prophylaxis.

The incidence of disseminated candidiasis has increased in recent years due to the rising number of immunosuppressed and post-operative patients. The advent of new anti-fungal drugs has improved the prospects for management of this disease; however, diagnosis remains difficult. In addition, although fluconazole prophylaxis of bone marrow transplant patients has reduced the incidence of disseminated disease caused by *Candida albicans*, other *Candida* species which are innately resistant to fluconazole, most notably *C. krusei* and *C. glabrata*, have increased as the

primary causative agent. Early detection and identification of *Candida* species is therefore essential for the proper targeting of antifungal therapy.

5 These facts, in conjunction with the difficulty of reliably culturing *Candida* from the blood and the lack of a sensitive and specific serological test to detect disease, underscore the need to develop alternative diagnostic approaches.

10 Technology has been developed for the detection of bacterial and viral DNA from the bloodstream of infected patients through the use of the polymerase chain reaction (PCR). The PCR amplifies genomic DNA geometrically so that it may be detected by agarose gel electrophoresis, Southern blotting, or dot blot hybridization (Miyakawa et al. 1992, 15 Kafatos et al. 1979, Lasker et al. 1992).

PCR-based diagnostic methods may provide increased sensitivity relative to blood culture techniques since viable organisms are not required for amplification or detection. There has only been one report to date describing the 20 detection of *C. albicans* cells in infected patient blood through the use of PCR-amplified DNA (Buckman et al. 1990). Buchman et al. lysed *C. albicans* cells with ZYMOLYASE and proteinase K and extracted the DNA with phenol and chloroform. The limit of sensitivity by this method was 120 cells per ml 25 of whole blood. As described, this method was time consuming, labor-intensive, repeatedly used toxic chemicals (phenol and chloroform), and has not been shown to be readily reproducible. In addition, a single copy gene, the cytochrome P-450 gene, was the target for DNA amplification, thus making 30 the method much less sensitive. Miyakawa et al. described improved sensitivity by use of Southern blot hybridization for the detection of PCR products from *Candida* DNA (Miyakawa et al. 1991). The limit of sensitivity by Southern blot in their study was 10 cells per ml of urine and did not address 35 detection in blood.

Use of polymerase chain reaction (PCR)-based tests to detect *C. albicans* DNA in body fluids has produced some encouraging results. However, routine application of these

tests for the detection of candidemia remains difficult. Current methods require labor-intensive sample preparation, costly enzymes for liberation of *Candida* DNA, and phenol-chloroform extraction to purify DNA before PCR amplification. After amplification, detection of PCR products by gel electrophoresis or Southern blotting is often not practical in a clinical laboratory setting. Sensitivity has been variable and false positive as well as false negative results have been reported. Also, most studies have concentrated on the detection of *C. albicans* DNA but not on DNA from non-*albicans* *Candida* species.

On the other hand, routine, culture-based identification of *Candida* species requires at least one day following initial positive results to obtain a pure culture, another day to identify *C. albicans* isolates by germ tube formation, and two or more additional days to identify non-*albicans* *Candida* isolates by API-20C sugar assimilation strip tests and cornmeal agar morphology. Therefore, a test to rapidly and accurately identify *Candida* isolates to the species level would be both clinically and epidemiologically useful.

The ability to detect *Candida* in blood is crucial for the rapid and accurate diagnosis of systemic candidiasis, because detection from urine or mucosal secretions can be confused with the normal commensal status of the organism or a localized non-disseminated infection.

#### SUMMARY OF THE INVENTION

The invention provides a rapid approach to species identification through the use of non-conserved regions of the ITS2 flanked by highly conserved, functional domains. Genus and other related organism identification is also enhanced by detection of "genus"-specific regions of the 5.8S rRNA gene. It was surprising to find a region of this gene which enabled us to selectively retrieve the organisms described here.

The present invention provides an isolated double-stranded nucleic acid consisting essentially of the nucleotide sequence defined in the Sequence Listing by SEQ ID NO:5. This

is the *C. albicans* ITS2 sequence and includes a nucleic acid comprising a nucleotide sequence that is specific for *C. albicans*. Further examples of an isolated double stranded nucleic acid of the present invention consist essentially of the nucleotide sequences defined in the Sequence Listing by SEQ ID NOs:6-9. These are the ITS2 sequences for *C. parapsilosis*, *C. tropicalis*, *C. glabrata* and *C. krusei*. These nucleic acids can include a nucleotide sequence that is specific for the respective organism.

The present invention further provides an isolated double stranded nucleic acid consisting essentially of the sequence set out in Table 1 and referred to as "ALL-CAN-TET" and its complement. Nucleic acid sequences which specifically hybridize with this sequence, particularly the first four base pairs (AGGC) or their complement, is indicative of a number of *Candida spp.*, if not all, and *Saccharomyces cerevisiae* and at least two *Aspergillus* species all as indicated on Table 4. These organisms are opportunistic pathogens and knowledge of their presence can provide useful treatment information. Detection for both *Aspergillus* and *Candida* is important because they tend to appear under the same circumstances such as in bone marrow transplant patients. Treatment is similar whether one or the other or both genera are detected.

An isolated nucleic acid that specifically hybridizes with or selectively amplifies a nucleic acid of the invention or fragments thereof is also contemplated. An isolated nucleic acid complementary to the above nucleic acid is also provided.

A method of diagnosing systemic candidiasis in a subject is also provided. The method comprises the steps of: (a) collecting blood from the subject into tubes containing detergent, polypropylene glycol, sodium polyanetholesulfonate, and sodium ethylene diamine tetraacetic acid; (b) lysing *Candida* cells using ZYMOLASE-100T with agitation; (c) extracting and precipitating the DNA from the lysed cells; (d) amplifying the precipitated DNA using universal fungal primer pairs derived from the internal transcribed spacer regions of the *Candida* ribosomal DNA; and (e) detecting amplified DNA

from *Candida* by hybridizing the amplified DNA with a probe that selectively hybridizes with *Candida* DNA, the presence of amplified DNA indicating systemic candidiasis.

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## DEFINITIONS

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Singleton et al. (1994) *Dictionary of Microbiology and Molecular Biology*, second edition, John Wiley and Sons (New York); Walker (ed) (1988) *The Cambridge Dictionary of Science and Technology*, The press syndicate of the University of Cambridge (New York); and Hale and Marham (1991) *The Harper Collins Dictionary of Biology* Harper Perennial (New York) all provide one of skill with a general dictionary of many of the terms used in this invention. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, certain preferred methods and materials are described. For purposes of the present invention, the following terms are defined below.

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The terms "isolated" or "biologically pure" refer to material which is substantially or essentially free from components which normally accompany it as found in its native state.

30

The term "nucleic acid" refers to a deoxyribonucleotide or ribonucleotide polymer in either single- or double-stranded form, and unless otherwise limited, encompasses known analogues of natural nucleotides that hybridize to nucleic acids in a manner similar to naturally occurring nucleotides. Unless otherwise indicated, a particular nucleic acid sequence optionally includes the complementary sequence thereof.

35

Two single-stranded nucleic acids "hybridize" when they form a double-stranded duplex. The region of double-strandedness can include the full-length of one or both of the single-stranded nucleic acids, or all of one single stranded nucleic acid and a subsequence of the other single stranded



nucleic acid, or the region of double-strandedness can include a subsequence of each nucleic acid. An overview to the hybridization of nucleic acids is found in Tijssen (1993) *Laboratory Techniques in Biochemistry and Molecular Biology-- Hybridization with Nucleic Acid Probes* Part I Chapter 2 "Overview of principles of hybridization and the strategy of nucleic acid probe assays", Elsevier (New York).

"Stringent hybridization wash conditions" in the context of nucleic acid hybridization experiments such as Southern and northern hybridizations are sequence dependent, and are different under different environmental parameters. An extensive guide to the hybridization of nucleic acids is found in Tijssen, *supra*. Generally, highly stringent wash conditions are selected to be about 5°C lower than the thermal melting point ( $T_m$ ) for the specific sequence at a defined ionic strength and pH. The  $T_m$  is the temperature (under defined ionic strength and pH) at which 50% of the target sequence hybridizes to a perfectly matched probe. Very stringent conditions are selected to be equal to the  $T_m$  point for a particular probe. Nucleic acids which do not hybridize to each other under stringent conditions are still substantially identical if the polypeptides which they encode are substantially identical. This occurs, e.g., when a copy of a nucleic acid is created using the maximum codon degeneracy permitted by the genetic code.

The term "identical" in the context of two nucleic acid sequences refers to the residues in the two sequences which are the same when aligned for maximum correspondence. A nucleic acid is "substantially identical to a reference nucleic acid when it is at least about 70% identical, preferably at least about 80% identical, and optionally about 90% identical or more.

The term "primer" as used herein refers to an oligonucleotide, whether occurring naturally as in a purified restriction digest, or produced synthetically, and is capable of hybridizing to a strand of the target sequence. When the terminal 3' nucleotide has hybridized it acts as a point of initiation of synthesis under conditions in which synthesis of

an extension of the primer is induced. These conditions typically include the presence of four different nucleotide triphosphates (a nucleotide reagent) and thermostable enzyme in an appropriate buffer and at a suitable temperature. When primer pairs are referred to herein, the pair is meant to include one primer which is capable of hybridizing to the sense strand of a double-stranded target nucleic acid (the "sense primer") and one primer which is capable of hybridizing to the antisense strand of a double-stranded target nucleic acid (the "antisense primer"). The primer pair will be designed such that they flank the region of the target nucleic acid to be amplified and will cause the target region to be amplified when placed in an amplification protocol such as polymerase chain reaction.

What is meant by a primer "substantially homologous" or "substantially complementary" to a nucleotide sequence is a polynucleotide or oligonucleotide containing naturally occurring nucleotides or their analogs, such as 7-deazaguanosine or inosine, sufficiently complementary to hybridize with the target sequence such that stable and specific binding occurs between the primer and the target sequence. The degree of homology required for formation of a stable hybridization complex (duplex) varies with the stringency of the amplification medium. The primer should be substantially homologous to the target strands of each specific sequence to be amplified. This means that the primer must be sufficiently complementary to hybridize with the appropriate strand under standard amplification conditions. Therefore, the primer sequence need not reflect the exact sequence of the template. For example, a noncomplementary nucleotide fragment may be attached to the 5' end of the primer, with the remainder of the primer sequence complementary to the strand. Alternatively, noncomplementary bases or longer sequences can be interspersed into the primer provided that the primer sequence has sufficient complementarity with the sequence of the target sequence to hybridize with it and thereby form a template for synthesis of the extension product.

## DETAILED DESCRIPTION OF THE INVENTION

The present invention provides an isolated double-stranded nucleic acid consisting essentially of the nucleotide sequence defined in the Sequence Listing by SEQ ID NO:5. This includes the *C. albicans* ITS2 sequence. By "isolated" is meant separated from other nucleic acids found in the naturally occurring organism. The nucleic acid comprises a nucleotide sequence that is specific for *C. albicans*. By "specific" is meant a sequence which does not hybridize with other nucleic acids to prevent determination of an adequate positive hybridization with nucleic acids from *C. albicans*. Probes which "specifically hybridize" with the double-stranded nucleic acid are hybridizing with one of the two strands when in single stranded form.

A further example of an isolated double stranded nucleic acid of the present invention consists essentially of the nucleotide sequence defined in the Sequence Listing by SEQ ID NO:6. This includes the ITS2 sequence for *C. parapsilosis*. This nucleic acid comprises a nucleotide sequence that is specific for *C. parapsilosis*.

Another example of the isolated double stranded nucleic acid of the invention consists essentially of the nucleotide sequence defined in the Sequence Listing by SEQ ID NO:7. This includes the *C. tropicalis* ITS2 sequence. This nucleic acid comprises a nucleotide sequence that is specific for *C. tropicalis*.

A still further example of the isolated double stranded nucleic acid of the invention consists essentially of the nucleotide sequence defined in the Sequence Listing by SEQ ID NO:8. This includes the *C. glabrata* ITS2 sequence. This nucleic acid comprises a nucleotide sequence that is specific for *C. glabrata*.

Another example of the isolated double stranded nucleic acid of the invention consists essentially of the nucleotide sequence defined in the Sequence Listing by SEQ ID NO:9. This includes the *C. krusei* ITS2 sequence. This nucleic acid comprises a nucleotide sequence that is specific for *C. krusei*.

Another example of an isolated double stranded nucleic acid of the invention consists essentially of the nucleotide sequence referred to herein as All-CAN-TET and defined in the Sequence Listing by SEQ ID NO:\_\_. This nucleic acid comprises a nucleotide sequence that is specific for all *Candida spp.*, *Saccharomyces cerevisiae*, *Aspergillus fumigatus*, and *Aspergillus flavus*, but not other fungal, bacterial or human DNA tested as described below in Table 4. If *Aspergillus sp.* are to be detected for, it is desired that the sample be subjected to mechanical disruption to release *Aspergillus* nucleic acid.

An isolated nucleic acid that specifically hybridizes with or selectively amplifies a nucleic acid of the invention or fragments thereof is also contemplated. An isolated nucleic acid complementary to the above nucleic acid is also provided. The sequences can be selected based on the nucleotide sequence and the utility of the particular sequence. More specifically the invention provides isolated nucleic acids that specifically hybridize with the nucleic acids consisting essentially of the nucleotide sequences defined in the Sequence Listing by SEQ ID NOS:5-9.

Oligonucleotides for use as primers or probes are typically synthesized chemically according to the solid phase phosphoramidite triester method described by Beaucage and Caruthers (1981), *Tetrahedron Letts.*, 22(20):1859-1862, e.g., using an automated synthesizer, e.g., as described in Needham-VanDevanter et al. (1984) *Nucleic Acids Res.*, 12:6159-6168. Oligonucleotides can also be custom made and ordered from a variety of commercial sources known to persons of skill. Purification of oligonucleotides, where necessary, is typically performed by either native acrylamide gel electrophoresis or by anion-exchange HPLC as described in Pearson and Regnier (1983) *J. Chrom.* 255:137-149. The sequence of the synthetic oligonucleotides can be verified using the chemical degradation method of Maxam and Gilbert (1980) in Grossman and Moldave (eds.) Academic Press, New York, *Methods in Enzymology* 65:499-560.

One of skill will also recognize many ways of generating alterations in a given nucleic acid sequence. Such well-known methods include site-directed mutagenesis, PCR amplification using degenerate oligonucleotides, exposure of  
 5 cells containing the nucleic acid to mutagenic agents or radiation, chemical synthesis of a desired oligonucleotide (e.g., in conjunction with ligation and/or cloning to generate large nucleic acids) and other well-known techniques. See, Gilman and Smith (1979) *Gene* 8:81-97; Roberts et al. (1987)  
 10 *Nature* 328:731-734 and Sambrook et al. (1989) *Molecular Cloning - A Laboratory Manual* (2nd Ed) Vol. 1-3; Innis, Ausbel, Berger, Needham VanDevanter and Mullis (*all supra*).

The primers of use in the assay methods described here are preferably single stranded for maximum efficiency and  
 15 amplification, but may alternatively be double stranded. If double stranded, the primer is first treated to separate its strands before being used to prepare extension products. Preferably, the primer is an oligodeoxyribonucleotide. The primer must be sufficiently long to prime the synthesis of  
 20 extension products in the presence of an enzyme. The exact lengths of the primers will depend on many factors, including temperature, source of primer and use of the method. Most typically, amplification primers are between 8 and 100 nucleotides in length, and preferably between about 10 and 30  
 25 nucleotides in length. More typically, the primers are between about 18 and 28 nucleic acids in length.

Probes of the invention to detect for individual species or genus will be of a length sufficient to specifically hybridize with and result in the specific  
 30 isolation of the targeted sequence. These probes will be about 4 to about 234 base pairs in length, preferably about 8 to about 35 base pairs in length, and most preferably about 15 to about 22 base pairs in length. Examples of probes for individual *Candida* spp. which are five base pairs in length  
 35 are as follows:

<i>C. albicans</i> :	CAAAC or TTCAA or CTTCA
<i>C. parapsilosis</i> :	AAATT or CAAAT or CAAAA
<i>C. tropicalis</i> :	ATAAC or TTCAT or TCATA
<i>C. glabrata</i> :	TAACT or TTAAG or AAGTT
40 <i>C. krusei</i> :	ATTAC or TCATA or CATAA

The term "consisting essentially of", as used herein includes modifications to the nucleic acids of the invention as long as the specificity (genus or species) of the nucleic acids is maintained. Likewise, fragments used as primers or probes can have substitutions so long as enough complementary bases exist for specific hybridization (Kunkel et al. *Methods Enzymol.* 1987:154:367, 1987).

The nucleic acid can have homology with nucleotide sequences present in more than one *Candida* species. Such a nucleic acid sequence shared with other *Candida* species can be used, for example, as a primer to simultaneously amplify nucleic acids from more than one *Candida* species. The amplified nucleic acids can then be detected using the specific nucleic acids described herein to permit either genus specific or species specific diagnosis. Thus, the specific nucleic acid can be specific for the genus *Candida* and can be used to detect any candidiasis in methods such as polymerase chain reaction, ligase chain reaction and hybridization.

A method of diagnosing systemic candidiasis in a subject is also provided. The method comprises the steps of:

- (a) collecting blood from the subject into tubes containing detergent, polypropylene glycol, sodium polyanetholesulfonate, and disodium ethylene diamine tetraacetic acid ((Na)<sub>2</sub>EDTA);
- (b) lysing *Candida* cells using ZYMOLASE-100T with agitation;
- (c) extracting and precipitating the DNA from the lysed cells;
- (d) amplifying the precipitated DNA using universal fungal primer pairs derived from the internal transcribed spacer regions of the *Candida* ribosomal DNA; and (e) detecting amplified DNA from *Candida* by hybridizing the amplified DNA with a probe that selectively hybridizes with *Candida* DNA, the presence of amplified DNA indicating systemic candidiasis.

In the method, the lysis step can use the lysis buffer from the ISOQUICK® kit in addition to ZYMOLASE-100T. The agitation step can be by rocking at about 16 cycles per minute. The extracting step can use the extraction matrix in the ISOQUICK® kit. In the amplification step of the above method, one of the primers of the primer pair is derived from the internal transcribed spacer 1 (ITS1) and the other primer

of the primer pair is derived from the internal transcribed spacer 2 (ITS2). Alternatively, one of the primers of the primer pair is derived from the internal transcribed spacer 3 (ITS3) and the other primer of the primer pair is derived from the internal transcribed spacer 4 (ITS4). The detecting step hybridization can be by dot blot hybridization using a genus or species specific *Candida* probe.

In the method of detecting systemic candidiasis, the DNA that is amplified can be from *C. albicans* and the probe can specifically hybridize with a specific nucleotide sequence of the nucleic acid of SEQ ID NO:5 as described in Example 2. By using the other specific nucleic acids as provided herein, the method of Example 2 can be used to detect any of the other *Candida* species as taught herein. If the DNA that is amplified is from *C. parapsilosis*, the probe specifically hybridizes with a specific nucleotide sequence of the nucleic acid of SEQ ID NO:6. If the DNA that is amplified is from *C. tropicalis*, the probe specifically hybridizes with a specific nucleotide sequence of the nucleic acid of SEQ ID NO:7. If the DNA that is amplified is from *C. glabrata*, the probe specifically hybridizes with a specific nucleotide sequence of the nucleic acid of SEQ ID NO:8. If the DNA that is amplified is from *C. krusei*, the probe specifically hybridizes with a specific nucleotide sequence of the nucleic acid of SEQ ID NO:9. A nucleic acid having homology with more than one *Candida* species can also be used as a probe that specifically hybridizes with *Candida* DNA to detect systemic candidiasis.

Additionally, it is contemplated that the nucleic acids (e.g., probes and primers) can be attached to or labeled with (covalently or non-covalently) a detectable moiety. The probes may be suitably labeled using, for example, a radio label, enzyme label, fluorescent label, biotin-avidin label and the like for subsequent visualization in the example of the dot blot hybridization procedure taught in Example 2. An example of such a labeled nucleic acid is the digoxigenin-UTP labelled probe provided in Example 2, although others can be readily generated using standard methods (See, e.g., Sambrook et al., 1989). The nucleic acids specific for a given *Candida*

species can each be labeled with a distinct detectable moiety, such that species specific probes for several species can be used with the same sample of amplified DNA to permit species specific diagnosis. The distinct label for each species specific probe can be detected in the sample if DNA from the particular species is present in the subject.

The detection of fungal DNA as described herein can also be performed using a ligase chain reaction (LCR). Essentially, this reaction, known to those of skill in the art, involves the use of, for each region to be detected, two primers that hybridize to the same strand of the target DNA, either abutting each other or with one or two nucleotides between the two primer sequences (i.e., "immediately 5'" or "immediately 3'" to the junction). The ligase reaction is performed, and the products are electrophoresed through a gel that can detect very small fragments, such as an SDS-polyacrylamide gel. A positive result is one in which a product equal in size to the sum of the two primers is produced, as this indicates the presence of all of the target DNA region. It is preferable that three reactions be run in three separate tubes, targeted at detecting (1) the first junction, (2) the second junction and (3) an internal sequence as a positive LCR control. If one wants to electrophorese all LCR products together through the gel, primers must be carefully chosen such that their individual sizes can be distinguished from the predicted size of any LCR products. Alternatively, the product of each reaction can be electrophoresed separately. Primers are preferably exactly homologous to the target region and of a size between approximately 20 - 40 nucleotides.

#### Kits

Further contemplated are kits for the assays and detection of organisms described here. Combinations of reagents useful in the methods set out above, particularly any of the probes or primers, can be packaged either singly or together with instructions for using them in the described assays. A preferred kit would contain the probes set out in



Table 1 and instructions for performing the assay with a single test aliquot.

The following examples are intended to illustrate, but not limit, the invention. While they are typical of those that might be used, other procedures known to those skilled in the art may be alternatively employed.

## EXAMPLES

### Example 1

#### Nucleotide Sequence Analysis of the ITS2 Region of *Candida albicans* and Related Species.

##### Yeast strains and maintenance

All *Candida* isolates have been previously characterized by assimilation (API) profiles and morphology (Van der Walt and Yarrow, 1984). In addition, all *C. albicans* and *C. parapsilosis* isolates have previously been electrophoretically karyotyped and are known to represent distinct, non-related strains (Lasker et al., 1989). All isolates were grown and maintained on yeast-peptone-dextrose (YPD) medium (Guthrie and Fink, 1991). For DNA extractions, 10 ml of overnight cultures grown on YPD at 37°C were washed twice in 1 x TE buffer and the DNA extracted by standard procedures (Sambrook et al., 1989). Prior to PCR amplifications, DNA was digested with EcoRI restriction endonuclease (New England Biolabs), electrophoresed on 1.0% agarose gels, and stained with ethidium bromide (EtBr) to verify concentration and purity.

##### PCR amplification and DNA sequencing

Taq polymerase, buffers, and conditions for PCR were those supplied by the vendor (Perkin-Elmer/Cetus), using 100 ng genomic DNA per reaction. For primary amplifications, 35 cycles of 95°C, 55°C, and 72°C at one min. intervals were followed by a five min. final extension at 72°C. The following "universal" ITS primers were used, for which calculated T<sub>m</sub>'s have previously been reported (White et al., 1990):

ITS1 5' TCC GTA GGT GAA CCT GCG G 3' (SEQ ID NO:1)  
ITS3 5' GCA TCG ATG AAG AAC GCA GC 3' (SEQ ID NO:2)  
ITS4 5' TCC TCC GCT TAT TGA TAT GC 3' (SEQ ID NO:3)

5 Primer ITS1 is to a conserved 3' domain in the 18S nuclear subunit. Primer ITS3 is approximately 25 bp from the end of the 5.8S subunit, and ITS4 is a reverse primer to a conserved region of the nuclear large rDNA. In addition, a -21M13 forward primer sequence (Messing et al. 1981) was added at the  
10 5' end to primers ITS1 and ITS4 for sequencing in the forward and reverse directions, respectively, and consisted of the sequence:

5' GTA AAA CGA CGG CCA G 3' (SEQ ID NO:10) where the terminal 5' T of ITS1 and ITS4 made 17 bp of the 18 bp  
15 annealing sequence. From preliminary experiments it was determined that the addition of this sequence did not alter the nature of the derived PCR product. The aqueous phase of the primary PCR reaction was ethanol-precipitated, dried, and resuspended in 8  $\mu$ l TE buffer. The entire amount was loaded  
20 into single wells of a 1.5% agarose, 1.0% NuSieve agarose gel (Lehmann et al. 1992), electrophoresed at 110 V., and stained with EtBr. Single, intensely staining bands of the appropriate size were excised and the DNA was extracted in Spin-X cellulose acetate columns (Costar, Inc.) for 30 min. at  
25 40°C, 13000 x g. The DNA was then ethanol-precipitated, washed twice in 70% EtOH, dried briefly, and resuspended in H<sub>2</sub>O for sequencing. Automated DNA sequencing (Smith et al. 1986), was performed using the Applied Biosystems Catalyst 800 workstation, with the "Prism" dye-primer dideoxy-sequencing  
30 reactions (Sanger et al. 1977), using conditions supplied by the vendor (Applied Biosystems). The precipitated DNA was dried and resuspended in 6  $\mu$ l of formamide/50 mM EDTA (5:1), denatured for 2 min. at 90°C, and loaded on an Applied Biosystems model 373A DNA sequencer. All DNAs were sequenced  
35 in both forward and reverse orientations, and multiple runs were performed for all species and most strains within a given species.

### 5.8s rDNA

5.8S sequence alignments were performed both manually and with the "pileup" program from the University of Wisconsin Genetics Computer Group (GCG) package (Devereux et al., 1984). ITS alignments were performed in all possible pairwise combinations using the Needleman and Wunsch algorithm as implemented by GCG (Needleman and Wunsch 1970). DNA parsimony and bootstrap analysis was performed using the "Phylip" programs of Felsenstein (Felsenstein 1982), implemented on a micro-vax (Digital Equip. Corp.) cluster. Dendrograms were constructed using the global option and using a variety of different species as the outgroup (Felsenstein 1985). Other 5.8S sequences were: *Neurospora crassa*, *Schizosaccharomyces pombe*, *Saccharomyces cerevisiae*, *Pneumocystis carinii*, *Fusarium sambucium*, *Epichloe typhina*, *Cephalosporium acremonium*, *Lentinula edodes*.

For *C. albicans* and *C. parapsilosis*, where multiple strains were analyzed, there was complete nucleotide conservation within the entire 159 bp 5.8S region. The greatest degree of diversity for the species used in this study was found in the two relatively unconserved regions between bp 79-85 and bp 118-136. The overall average degree of diversity between the *Candida* species was approximately three percent. The minimum degree of diversity was found between *C. tropicalis* and *C. parapsilosis*, with a single C-A transversion at bp 62. Interestingly, both *C. albicans* and *C. krusei* contained A-G transitions in the termination consensus TCATT.

A phylogenetic analysis was performed with all known fungal 5.8S sequences using strict parsimony as implemented by Felsenstein and statistical bootstrap analysis (Felsenstein 1982; 1985). *P. carinii* was used as the outgroup considering previous findings based on 18S analysis using a larger database of eukaryotic organisms (Edman et al. 1988). There were a total of 47 informative sites for the number of fungal sequences compiled, including 4 single base pair gaps. Re-analysis of the data set without gaps did not significantly alter the tree topology. The cumulative number of positive

selections out of 100 total iterations is given for each branch point. The derived tree does not differ significantly from previous research using a weighted difference algorithm for 18S sequences, and supports the view that these species are related such that *C. albicans*, *C. parapsilosis* and *C. tropicalis* are more closely aligned than *C. krusei* within a clade. Likewise, *C. glabrata* appears more distantly related and can equally be placed at a number of positions within the larger branch of yeast-like fungi. It is generally accepted that values of 70 or greater out of 100 randomly tested samples will represent similar trees to a significant degree of probability.

#### ITS2 rDNA

The sequences of the ITS2 regions for *C. albicans*, *C. parapsilosis*, *C. tropicalis*, *C. glabrata* and *C. krusei* are shown in the Sequence Listing as SEQ ID NOs:5-9.

A total of ten *C. albicans* isolates, representing typical and morphologically (or physiologically) atypical strains, were found to be identical at the nucleotide level within the ITS region. Similarly, five strains of *C. parapsilosis*, displaying a wide range of electrophoretic karyotypes and randomly amplified polymorphisms (RAPD), were also identical to the type strain for the species. The entire length of the ITS region was found to be species specific.

Similar to the results of the 5.8S alignments, we found that *C. albicans*, *C. parapsilosis*, and *C. tropicalis* were also most homologous in this ITS region. This homology extended for the first 57 bp 5' immediately adjacent to the termination of the 5.8S sequence. In contrast, the 3' region displayed little homology. For *C. krusei* and *C. glabrata* there was no apparent homology either to each other or to members of the *C. albicans* group over this entire ITS region. Sequences were aligned in all possible pairwise combinations (Needleman and Wunsch 1970), and the average degree of similarity was found to be approximately 40 percent.

Analysis of the ITS2 region has revealed that *C. albicans*, and possibly other closely related species, displays

no interstrain variation. In this respect this species resembles the opportunistic fungus *Cryptococcus neoformans*, and is unlike the plant pathogen *Fusarium sambucinum* which displays variation in this region.

5

## Example 2

### Detection of DNA from *Candida albicans* Cells in Blood by Use of the Polymerase Chain Reaction (PCR)

#### 10 Growth of C. albicans

C. albicans strain 36B was grown on Sabouraud's dextrose agar Emmons slants for 48 h at 25°C. Cells were harvested by washing each slant with 5 ml of 0.85% NaCl, centrifuged at 1500 x g for 10 min, and resuspended to the appropriate  
15 concentration in freshly collected rabbit's blood or 0.85% saline.

#### Yeast cell lysis and DNA purification

Blood from adult female rabbits (New Zealand White, Myrtle's Rabbit Farm) was collected from the central ear  
20 artery into ISOLATOR 10<sup>®</sup> microbial tubes (Wampole Laboratories, Cranbury, NJ) containing an aqueous solution of 1 unit of purified saponin, 8 ml/L polypropylene glycol, 9,6 g/L Na polyanetholesulfonate and 16 g/L (Na)<sub>2</sub>EDTA; EDTA-coated  
25 tubes (Becton Dickinson, Rutherford, NJ); or heparinized tubes (Becton Dickinson). *C. albicans* strain 36B (Quebec Gynecological Institute, Montreal, Quebec) cells were then introduced and samples were centrifuged at 3000 x g for 30 min. Supernatants were removed and an equal volume of  
30 deionized water was added to lyse residual blood cells. Remaining *C. albicans* cells were washed in 0.85% NaCl and pelleted by centrifugation at 1500 x g for 10 min. ISOLATOR 10<sup>®</sup> tubes have proven superior to other blood collection systems for the recovery of viable *C. albicans* cells from  
35 blood (Jones, 1990). The use of the ISOLATOR 10<sup>®</sup> tubes for blood collection resulted in PCR amplification of candidal DNA whereas the use of EDTA- or heparin-coated tubes did not.

*C. albicans* DNA was extracted and purified using the ISOQUICK® nucleic acid extraction kit according to the manufacturer's instructions with the addition ZYMOLASE-100T, to allow its use with fungi, since the ISOQUICK® kit was developed by MicroProbe Corporation for the isolation and purification of DNA from only mammalian cells and gram negative bacteria. Briefly, pelleted cells were suspended in 100 µl of sample buffer for 15 min after which 100 µl of lysis buffer was added. The mixture was incubated at 25°C for 1 h. Selected samples contained zymolyase (ZYMOLYASE-100T, Seikagaku Corp., Tokyo, Japan; 5 mg/ml in 1.0 M sorbitol, 0.1 M trisodium citrate, and 0.1% 2-mercaptoethanol) during the lysis step and were rocked at 16 cycles per min to optimize breakage of *C. albicans* cells. The addition of zymolyase to the lysis step allowed for successful adaptation of the ISOQUICK® kit for use with *C. albicans* cells. Alternatively, *C. albicans* cells were disrupted using a mini bead beater (Biospec Products, Bartlesville, OK) (Glee et al. 1987). Cells (1 ml) were delivered into Sarstedt microfuge tubes containing 1 ml of 0.5 mm diameter glass beads and beaten at maximum speed for 2 min. A third method released *C. albicans* DNA by boiling  $1 \times 10^7$  cells per ml in 2 mls of deionized water in an Eppendorf microcentrifuge tube for 30 min. Mechanical disruption of *C. albicans* cells by bead beating or boiling was less effective in producing PCR amplifiable DNA; these methods may be too harsh, resulting in shearing or fragmentation of DNA. For precipitation of the DNA sodium acetate and other components of the ISOQUICK® kit were used as directed.

After lysis, DNA was purified with the extraction matrix provided in the ISOQUICK® kit, precipitated with sodium acetate in the presence of isopropanol, and the precipitated DNA was dried by vacuum centrifugation for 15 min.

#### PCR amplification of genomic DNA

Universal fungal primer pairs, ITS1 and 2 or ITS3 and 4, synthesized by the CDC core facility., and the GeneAmpR DNA amplification reagent kit using native Taq DNA polymerase

(250 U, Perkin Elmer Cetus, Alameda, CA) were used for PCR amplification of genomic DNA (Saiki et al. 1988). These primers amplify DNA from all fungi and some parasites. Examples of the ITS1, ITS2, ITS3 and ITS4 primers are shown in the Sequence Listing as SEQ ID NOs:1, 4, 2 and 3, respectively. The reaction consisted of the following: 53.5  $\mu$ l of double distilled, sterile water, 10  $\mu$ l of 10X reaction buffer, 16  $\mu$ l of a mixture of equimolar (1.25 mM) quantities of dATP, dCTP, dGTP, and dTTP, 5  $\mu$ l of 20  $\mu$ M ITS1 or 3, 5  $\mu$ l of 20  $\mu$ M ITS2 or 4, 10  $\mu$ l of target DNA, 0.5  $\mu$ l of Taq polymerase, and 6  $\mu$ l of 25 mM  $MgCl_2$ . Samples were overlaid with mineral oil prior to placement in the thermal cycler (Perkin Elmer Cetus) to minimize evaporation during DNA amplification. Samples were initially denatured in the thermal cycler at 95°C for 5 min. This was followed by 30 cycles of: denaturation at 95°C for 1 min, annealing at 50°C for 2 min, and extension at 72°C for 1.5 min. Final extension occurred at 72°C for 5 min.

After amplification, mineral oil was discarded. An equal volume of chloroform was added to the samples which were then centrifuged for 5 min at 4100 x g to extract residual mineral oil. The aqueous layer was removed and the DNA precipitated from it by adding 2 volumes of ice-cold 100% ethanol followed by incubation for 30 min at -70°C. Samples were then centrifuged for 1 min at 4100 x g, the ethanol removed, the samples dried under vacuum, and resuspended in 20  $\mu$ l of TE buffer (20mM Tris plus 1 mM EDTA, pH 8.0). Amplified DNA was visualized after agarose (1% agarose plus 1% Nu-Sieve in TE buffer) gel electrophoresis by ethidium bromide staining or by dot blot hybridization analysis.

#### Dot blot hybridization

*C. albicans* strain 3307 DNA was used as a probe for the dot blot. To make the probe, 20 ng of *C. albicans* 3307 genomic DNA was PCR-amplified using ITS1 and ITS2 or ITS3 and ITS4 as primer pairs. The PCR product was then electrophoresed on an agarose gel and the resultant DNA band

cut out of the gel. The product was extracted from the gel by the freeze-squeeze method of Thuring et al (Thuring et al., 1975). The DNA probe was labeled by incubating overnight with digoxigenin-dUTP from a nonradioactive-DNA labeling and  
5 detection kit according to the manufacturers instructions ("Genius" kit, Boehringer Mannheim, Indianapolis, IN). Other genus or species specific probes derived from the nucleic acids of SEQ ID NOs:5-9 can also be used in this method.

Samples were prepared for the dot blot (Kafatos et  
10 al., 1979, Lasker et al., 1992) by diluting 10  $\mu$ l of *C. albicans* DNA to 25  $\mu$ l with TE buffer, adding NaOH to a final concentration of 0.3 M, and incubating for 10 min at 25°C. An equal volume of 2.0 M ammonium acetate was then added to each sample on ice. Each sample was then dotted under vacuum onto  
15 a nitrocellulose filter using a dot blot apparatus (BioRad, Richmond, CA) according to the manufacturer's instructions. The filter was then removed from the apparatus and dried at 80°C under vacuum for 2 h. The dried filter was placed in a plastic bag, sealed, and prehybridized with single-stranded  
20 salmon sperm DNA (10  $\mu$ g/ml) overnight in a 65°C water bath.

The digoxigenin-labeled probe was denatured by boiling for 5 min, added to the filter in the plastic bag, and placed in a 65°C water bath overnight. The filter was then washed twice for 30 min each in citrated saline (0.3 M NaCl  
25 with 0.03 M sodium citrate, pH 7.0) and 0.1% SDS at 60°C (Lasker et al., 1992). Washed filters were incubated for 30 min at 25°C with an anti-digoxigenin antibody (1:5000) labeled with alkaline phosphatase. Chromogen (nitroblue tetrazolium salt and 5-bromo-4-chloro-3-indolyl phosphate) was added  
30 (Lasker et al., 1992) and color developed for 6 h at 25°C in the dark.

#### "Booster" PCR amplification

"Booster" PCR amplification was performed by the  
35 method of Ruano et al. (Ruano et al., 1989). Briefly, the same protocol as outlined above was used, but after 15 cycles of PCR amplification, samples were removed from the thermal cycler and fresh primers were added to a final concentration



of 40 $\mu$ M. The samples were then returned to the thermal cycler for 15 additional cycles and final extension. The level of sensitivity of detection of the PCR product from cells introduced into blood was improved from 10<sup>5</sup> cells per ml to 10<sup>3</sup> cells per ml as detected by ethidium bromide stained agarose gels. However, the specificity of this system was poor since the negative control became positive.

**Detection of PCR amplified products from C. albicans in saline by agarose gel electrophoresis**

A comparison of C. albicans DNA isolated and purified from saline using the ISOQUICK® kit alone to that obtained by the use of zymolyase plus the kit was performed. C. albicans cells (10<sup>7</sup>/ml saline) were lysed at either 37°C or 25°C. The combined use of zymolyase and the ISOQUICK® kit (at either 25°C or 37°C) resulted in enhanced recovery of purified DNA relative to the kit alone.

To determine the sensitivity of the zymolase plus ISOQUICK® method for cell breakage and DNA purification, C. albicans cells were then serially diluted in saline (10<sup>7</sup> to 10<sup>1</sup> cells per ml) before breakage. Ethidium bromide stained agarose gels demonstrated that 10<sup>3</sup> cells per ml could be detected by this method. Based on these results, all subsequent experiments used zymolyase followed by DNA purification with the ISOQUICK® kit at 25°C.

**Detection of PCR amplified products of C. albicans in blood by agarose gel electrophoresis**

To determine if the zymolyase plus ISOQUICK® kit method could be used to detect C. albicans in blood, 10<sup>7</sup> C. albicans cells per ml was introduced into freshly collected rabbit's blood as described above. Blood was collected into one of the following: ISOLATOR 10® microbial tubes, EDTA-coated tubes, or heparinized tubes. Amplified DNA was detected in the samples prepared from cells introduced into blood drawn into ISOLATOR 10® tubes only. No DNA was detected in samples where blood had been drawn into either only EDTA- or only heparin-coated tubes.

The sensitivity of detection for C. albicans DNA in blood using the zymolyase plus ISOQUICK® kit method was determined by serially diluting C. albicans cells ( $10^7$  to  $10^1$  cells per ml) in blood drawn into ISOLATOR 10® tubes. Using agarose gel electrophoresis and ethidium bromide staining,  $10^5$  cell per ml could be detected.

**Dot blot hybridization for detection of PCR amplified products of *C. albicans* in blood or saline.**

In an effort to improve the sensitivity for detection of *C. albicans* DNA, a comparison was performed of the ethidium bromide-stained agarose gel method to a dot blot hybridization method for the detection of the PCR product. The dot blot method allowed detection of  $10^1$  cells per ml in saline versus  $10^3$  cells per ml detected by agarose gel electrophoresis and ethidium bromide staining. The sensitivity for detection of the PCR product of *C. albicans* cells introduced into blood was  $10^1$  cells per ml by the dot blot method versus  $10^5$  cells per ml for ethidium bromide stained agarose gels detection. The probe used for the above dot blot was *C. albicans*-specific. *C. tropicalis* DNA and human placental DNA did not react in the dot blot, supporting the specificity of the probe. Thus, the methods taught herein are capable of detecting *Candida* DNA in clinical samples such as blood.

Universal fungal primers as described herein provide the potential for amplification of DNA from all fungi. However, by using a *C. albicans*-specific DNA probe, as in the above-described dot blot hybridization step, the test was specific for *C. albicans*. The dot blot assay can be conducted using specific probes for other *Candida* species, as described herein, or other fungi. Furthermore, because the present method can gently extract DNA from clinical samples, the method can also use viral, bacterial or other fungal primers for the PCR reaction followed by specific DNA probes for each genus or species in the dot blot as described above.

**Example 3****Detection of DNA from *Candida* SPP. in Blood  
by Use of the Polymerase Chain Reaction**

Detection and identification of *Candida* spp. has become particularly important because of an increase in newly emerging, non-*albicans* *Candida* infections. We used fungus-specific PCR primers and species-specific DNA probes to detect up to three *Candida* spp. in one reaction tube (TaqMan™ PCR, Perkin-Elmer Corp., Foster City, CA). Probes to the internal transcribed spacer region of rDNA were labeled with one of three fluorescent reporter dyes: FAM (6-carboxy-fluorescein), TET (tetrachloro-6-carboxy-fluorescein), or HEX (hexachloro-6-carboxy-fluorescein). Each dye emits a characteristic wavelength upon PCR amplification of specific target DNA so that up to three probes can be used simultaneously during the PCR reaction. A different signal for each probe is then detected immediately after thermal cycling by using a fluorescent microtiter plate reader. Six probes were used in this study: CA-FAM, CT-TET, and CP-HEX were added to one tube for the simultaneous detection and identification of *C. albicans*, *C. tropicalis*, and *C. parapsilosis*, respectively. TG-FAM and CK-TET were added to a second tube for *C. glabrata* and *C. krusei* detection (fluconazole-resistant species). AllCAN-TET, a *Candida* genus probe, was added to a third tube. DNA recovered from 61 positive blood culture bottles, including 23 *C. albicans*, 18 *C. glabrata*, 6 *C. tropicalis*, 6 *C. krusei*, 5 *C. parapsilosis*, and 3 mixed fungemias, were used. Control samples included bacteremia (n=10) or other fungemia (n=3) cultures, or bottles with no growth (n=10). TaqMan™ PCR detected and correctly identified 57 of 61 specimens (93.4%) and gave no false-positive results. This method is rapid, eliminating post-PCR hybridization and incubation steps. It is sensitive and specific for detecting and identifying *Candida* spp. from blood culture bottles, allowing for earlier diagnosis and appropriate targeting of drug therapy.

We describe a clinically useful PCR-based method for rapid detection and identification of *Candida* isolates from positive blood culture bottles. A simple extraction method using heat, detergent, and mechanical breakage was used to obtain *Candida* DNA for PCR amplification without use of expensive enzymes or phenol-chloroform. A simple, rapid, and sensitive microtiter plate format and fluorescently labeled probes with different emission wavelengths were used to detect up to three *Candida* species simultaneously. This method eliminated an additional post-PCR hybridization step since fluorescent probes annealed to the target DNA during PCR amplification and reduced time to species identification from a mean of 3.5 days by conventional methods to 5 h by our method.

#### Clinical samples

A total of 81 samples from cultured BacT/Alert bottles (Organon Teknika Corporation, Durham, N.C.) were tested. Ten milliliters of blood from patients with suspected bacteremia or fungemia were collected at the bedside, and 5 ml each was immediately inoculated into an aerobic and an anaerobic BacT/Alert bottle. Inoculated bottles were agitated continuously in the BacT/Alert instrument (Organon Teknika Corporation, Durham, N.C.) at a rate of 68 cycles per min and were incubated at 35°C for 5 d or until bottles were positive by colorimetric detection of CO<sub>2</sub>. Aliquots from positive bottles were Gram stained and subcultured. Bottles proven to contain *Candida* spp. by Gram staining were selected and 2 ml aliquots were removed and stored at -30°C. During the study period, *Candida* spp. were isolated from 61 culture bottles from 24 patients.

Of 61 bottle sets from which *Candida* spp. were isolated, *C. albicans* blastoconidia were isolated from 23 bottles, *C. glabrata* from 18 bottles, *C. tropicalis* from 6 bottles, *C. krusei* 6 bottles, *C. parapsilosis* from 5 bottles and mixed *C. glabrata* and *C. albicans* from 3 bottles. Ten randomly selected samples from patients with bacteremia due to coagulase-negative Staphylococci (n=2), Enterococcus spp.

(n=2), *Citrobacter freundii* (n=2), *Corynebacterium JK* (n=1), *Corynebacterium*, non-JK (n=1), or due to a mixture of *Enterococcus* spp. and *S. aureus* (n=1), or *Klebsiella pneumoniae* and *A. calcoaceticus* (n=1), were also tested as negative controls. Clinical specimens which never became positive during incubation (n=10) were also tested as negative controls.

In addition to clinical samples, BacT/Alert bottles spiked with *C. albicans* strain B311 at 0,  $10^1$ ,  $10^2$ ,  $10^3$ ,  $10^4$ , and  $10^5$  blastoconidia per 200  $\mu$ l of rabbit whole blood were tested (broth to rabbit blood ratio = 8:1).

#### Extraction of DNA

A mechanical disruption method was used. Two hundred microliters of sample was added to 800  $\mu$ l of TXTE buffer (10 mM Tris, 1mM EDTA, pH 8.0, 1 % Triton X-100) in a sterile, 1.5 ml centrifuge tube and incubated for 10 min at RT. After lysis, cell debris and *Candida* blastoconidia were pelleted by centrifugation at 14,000 rpm for 5 min in an Eppendorf centrifuge (Eppendorf model 5403, Germany). After three washes by centrifugation with 1 ml of TXTE buffer, the pellet was resuspended with 300  $\mu$ l of TXTE buffer and transferred to a 2 ml screw-cap conical-bottom tube containing 200  $\mu$ l of 0.5 mm zirconium beads (Biospec Products, Bartlesville, OK). After boiling for 15 min, the mixture was shaken for 20 min in a mechanical cell disrupter (Mini-beadbeater, Biospec Products). After centrifugation for 20 sec, the supernatant was stored at -20°C until used for PCR amplification.

#### Purified DNA

Purified *Candida* DNA (Fujita et al) including *C. albicans*, *C. tropicalis*, *C. parapsilosis*, *C. glabrata* and *C. krusei* DNA were used as the template standard for each TaqMan® PCR. These DNAs and purified DNA from other *Candida* species, *Saccharomyces cerevisiae*, *Cryptococcus neoformans*, *Aspergillus fumigatus*, *A. flavus*, *Penicillium marneffe*, *Histoplasma capsulatum*, *Blastomyces dermatitidis*, *Staphylococcus aureus*,

Escherichia coli, Pseudomonas aeruginosa and a human placental cell line, were obtained by conventional means as previously described (Fujita, et al). All strains of microorganisms used were described previously except for C. lusitaniae strains and C. pseudotropicalis strain, WO 696, which were from the CDC mycology reference laboratory.

### Fluorescent probe design and synthesis

Probes consisted of oligonucleotides, labeled at the 5' end with one of three available fluorescent reporter dyes; FAM (6-carboxy-fluorescein), TET (tetrachloro-6-carboxy-fluorescein) or HEX (hexachloro-6-carboxy-fluorescein). Probes also contained a quencher dye, TAMRA (6-carboxy-tetramethyl-rhodamine), attached to a linker-arm-modified nucleotide near the 3' end and a 3'-blocking phosphate. The six probes used in this study are listed in Table 1: All-CAN-TET to detect all *Candida* spp., and CA-FAM, CT-TET, CP-HEX, CG-FAM and CK-TET to detect *C. albicans*, *C. tropicalis*, *C. parapsilosis*, *C. glabrata* and *C. krusei* DNA, respectively.

### TaqMan® PCR

PCR was performed using primers ITS3 and ITS4 (Fujita, et al) and a modification of a previously published PCR protocol (Fujita et al) by using TaqMan® fluorescently-labeled probes. Based upon G+C content, the predicted melting temperatures (Tms) of the CA, CG, CP, CK, and CT probes (Fujita et al) were 70°C, 70°C, 70°C, 76°C and 72°C. In addition, a probe to detect all *Candida* species was designed from the 5.8s region of rDNA (All-CAN probe, Tm = 80°C). On the other hand, the Tms of the ITS 3 and 4 primers were 62°C and 58°C. Since PCR amplification with ITS primers is carried out in the presence of the fluorescently-labeled *Candida* probes, probes were re-designed so that Tms would optimize primer extension and allow multiple probes to bind with similar frequency when admixed in one reaction tube.

Three sets of probe mixtures were designed. First, CA-FAM, CT-TET, and CP-HEX were added simultaneously to the

PCR mixture for the detection and identification of *C. albicans*, *C. tropicalis* and *C. parapsilosis*, respectively (PCR "A"). Second, probes CG-FAM and CK-TET were added to the PCR mixture for the detection and identification of *C. glabrata* and *C. krusei* (innately fluconazole-resistant strains; PCR "B"). Third, the All-CAN-TET probe was used to detect all *Candida* spp. (PCR "C"). PCR was performed on a 1  $\mu$ l sample in a total of 50  $\mu$ l volumes containing 10 mM Tris-HCl, 50 mM KCl (pH 8.3),  $MgCl_2$  (from 2.5 to 5.0 mM), 0.2 mM (each) dNTP, 0.2  $\mu$ M of each primer, 2.5 U of Taq DNA polymerase (Boehringer Mannheim, Germany) and one, two or three fluorescent probes (10 to 50 nM final concentration). A two-step PCR using a combined annealing and extension temperature was performed in a Perkin Elmer 9600 thermocycler (Emeryville, CA). All cycles began with a DNA denaturation step for 5 min at 94°C. After this, cycles consisted of 30 s at 95°C (denaturation) and 90 s at 58°C (annealing and extension) for 40 cycles. Other two-step cycles used consisted of 30 s at 95°C and 1 min at 58°C for 45 cycles. Primer extension, at 72°C for 10 min, followed the final cycle.

Negative controls (no template control) were carried out using the same reaction mix under the amplification conditions described but in the absence of template. Positive standards for multiplex PCR used 1 ng of purified DNA for each *Candida* spp. to be detected.

#### **Fluorescent detection of TaqMan® PCR**

Either immediately or within 24 h (samples stored in a dark refrigerator) following PCR, 40  $\mu$ l of each PCR product was transferred to a clean, white 96-well microtitration plate designed for the detection of fluorescence (Perkin-Elmer). Forty  $\mu$ l of TE buffer (10 mM Tris, 1mM EDTA, pH 8.0) was used as a buffer blank. The plate was read on a Perkin-Elmer LS 50B Luminescence Spectrometer with a microtitration plate reader attachment. The excitation wavelength used was 488 nm. The emission wavelength for each reporter dye was as follows: FAM, 518 nm; TET, 538 nm; HEX, 556 nm. The emission wavelength for the quencher dye (TAMRA) was 582 nm. The

excitation slit width was 488 nm, and the emission slit width was 10 nm. Fluorescent data management system using EXCEL-compatible macros were used for data analysis.

## 5     **Data analysis and interpretation**

### **PCR using All-CAN-TET probe for the detection of all *Candida* spp.**

Using the TaqMan® data worksheet and macro, the  
10     delta RQ for each sample was automatically calculated. The  
delta RQ is an increase in the emission intensity ratio of the  
reporter dye after release from the quencher dye on the  
TaqMan® probe (RQ+) minus the baseline emission intensity of  
the quenched reporter dye on the intact TaqMan® probe (RQ-).  
15     A threshold RQ is calculated to assure a statistically high  
confidence level (99%) using the standard deviation obtained  
from triplicate, no template control samples. We established  
a cutoff value for positivity to be 3SD above the mean delta  
RQ for all negative controls (n=20) used in this study.

20

### **TaqMan® PCR using two or three fluorescent probes simultaneously**

We used the multicomponented data program for  
interpretation of TaqMan® PCR results. The multicomponented  
25     data program automatically showed the results as 'No DNA',  
template 1 (or allele 1), template 2 (allele 2), or template 3  
(allele 3) when either the TaqMan® 3 Allele-Genotype Worksheet  
or the 2-reporter multicomponent worksheet for WPR (wellplate  
reader software) was used. The No DNA threshold was  
30     automatically calculated from values for 2SD above the mean  
(value = 1.00) of the negative controls. We normalized no DNA  
values as 'DNA values' by subtracting each no DNA value from  
1. We established cutoff values for the DNA value as 1SD  
above the mean for control values and for each probe, as 2SD  
35     above the mean for control values in TaqMan® PCR reactions.

### **Quality control**



Each reaction was carried out in duplicate or triplicate. One nanogram of *C. albicans* and *C. glabrata* DNA was used as positive controls for each sample run. Carry over was eliminated by using aerosol-resistant pipet tips and separate laboratory areas for DNA sample preparation and PCR amplification.

## RESULTS

### Optimization of TaqMan® PCR

Probes used for the TaqMan® PCR assays are shown in Table 1. We evaluated the effect of  $MgCl_2$  concentration, extension time, number of PCR cycles and probe concentration on delta RQ values. The optimal magnesium ion concentration was determined by testing concentrations from 2.5 nM to 5.0 nM, using 40 cycles consisting of 30 s at 95°C and 90 s at 58°C. The delta RQ was highest when a  $MgCl_2$  concentration of 3.5 nM was used ( $4.37 \pm 0.38$ ,  $n=4$ ; range 3.33 to 5.16). This  $MgCl_2$  concentration range did not change the (RQ-) values (0.71 to 0.84).

Using a constant PCR mixture composition, we then compared the effects of PCR extension time and cycle number on delta RQ values. No increase in delta RQ values were obtained when 45 cycles and a 1 min extension time (delta RQ =  $3.33 \pm 0.45$ ,  $n=2$ ) was used compared to 40 cycles with 90 s extension time (delta RQ =  $3.46 \pm 0.13$ ,  $n=2$ ). All experiments therefore used 40 cycles and a 1 min extension time. Concentration of each probe was optimized by testing concentrations from 10 to 50 nM. Optimum probe concentrations were: All-CAN-TET, 25 nM; CA-FAM, CT-TET and CG-FAM, 10 nM. In TaqMan® PCR for simultaneous detection and identification of *C. albicans*, *C. tropicalis* and *C. parapsilosis* (PCR "A"), and in TaqMan® PCR using CG-FAM and CK-TET probes for simultaneous identification of *C. glabrata* and *C. krusei* (PCR "B"), the delta RQ was highest when a probe concentration of 10 nM was used. Therefore, probes were used at 10 nM concentrations for TaqMan® PCR.

Delta RQ values were consistently higher for probes labeled with FAM, followed by those labeled with TET, followed

by those labeled with HEX. When different batches of the CK probe were labeled with one of the three fluorescent labels, the mean delta RQ for FAM-labeled CK probes was  $1.34 \pm 0.04$  ( $n=3$ ), while that for the TET-labeled CK probe was  $0.61 \pm 0.27$  ( $n=6$ ) and for the HEX-labeled CK probe was  $0.30 \pm 0.01$  ( $n=3$ ).

#### **Sensitivity and specificity of the TaqMan<sup>®</sup> PCR assay for clinical samples**

Among 61 clinical samples from patients with candidemia, 58 samples were proved to contain a single *Candida* spp. (Table 2). The mean delta RQ values using the All-CAN-TET probe against homologous spp. were: *C. albicans*,  $3.42 \pm 0.67$  (range = 1.15 to 4.58); *C. tropicalis*,  $1.92 \pm 1.34$  (range = 0.45 to 3.48); *C. parapsilosis*,  $1.78 \pm 1.48$  (range = 0.80 to 4.22); *C. glabrata*,  $2.81 \pm 1.24$  (0.53 to 4.66); and *C. krusei*  $3.38 \pm 0.92$  (1.87 to 4.40) (Table 3). Delta RQ values for the All-CAN-TET probe using three samples identified as mixed cultures of both *C. glabrata* and *C. albicans* were 4.14, 3.46, and 3.58, respectively.

The mean delta RQ values for *Candida* species-specific probes against homologous species were: CA-FAM for *C. albicans* isolates,  $0.95 \pm 0.62$  ( $n=23$ ); CT-TET for *C. tropicalis* isolates,  $0.48 \pm 0.38$  ( $n=6$ ); CP-HEX for *C. parapsilosis* isolates,  $0.37 \pm 0.12$  ( $n=5$ ); CG-FAM for *C. glabrata* isolators,  $0.63 \pm 0.39$  ( $n=18$ ); and CK-TET for *C. krusei* isolates,  $0.73 \pm 0.33$  ( $n=6$ ) (Table 3). Specimens tested by the PCR "A" assay were considered positive when the DNA value was above 0.16 (1SD), the delta RQ was above 0.7 (2SD) for the CA-FAM probe, above 0.13 (2SD) for the CT-TET probe, and above 0.19 (2SD) for the CP-HEX probe. The sensitivity and specificity of the PCR "A" assay was therefore 91.9% (34/37) and 100% (44/44), respectively.

Specimens tested by the PCR "B" assay were considered positive when the DNA value was above 0.15 (1SD), the delta RQ was above 0.04 (2SD) for the CG-FAM probe, and above 0.08 (2SD) for the CK-TET probe. The sensitivity and specificity of the PCR "B" assay (to detect fluconazole-

resistant *Candida* spp.) was therefore 96.3% (26/27) and 100% (54/54), respectively.

Specimens tested by the PCR "C" assay were considered positive when the delta RQ value was above 0.25 (3SD). The sensitivity and specificity of the PCR "C" assay (to detect all *Candida* spp.) was therefore 100% (61/61) and 100% (20/20), respectively (Table 3).

#### Detection and identification of *Candida* spp. by PCR with fluorescent probes

PCR-EIA identification (Fujita et al) of *Candida* spp. from 61 blood cultures of 24 patients with candidemia were identified as: *C. albicans* (n=23), *C. glabrata* (n=18), *C. parapsilosis* (n=5), *C. tropicalis* (n=6), *C. krusei* (n=6), and mixed candidemias due to *C. albicans* and *C. glabrata* (n=3). The PCR "C" assay, using the All-CAN-TET probe, detected all *Candida* spp in all 61 samples. The PCR "A" and "B" assay results matched those for the PCR-EIA for 55 of the 58 samples reported to contain a single *Candida* spp. (23 *C. albicans*, 17 *C. glabrata*, 4 *C. parapsilosis*, 5 *C. tropicalis*, and 6 *C. krusei*). Two of three samples identified as mixed candidemia specimens by conventional and by PCR-EIA were also identified to contain both *C. glabrata* and *C. albicans* but one mixed candidemia was identified as *C. glabrata* only (*C. albicans* was not detected) by the PCR "A" and "B" assays (Table 2).

Five *C. albicans*-positive bottles revealed the coexistence of *C. albicans* with bacteria including *Enterococcus* spp. (n=4) and coagulase-negative *Staphylococci* (n=1). All were correctly identified to contain *C. albicans*. Ten randomly selected samples from patients with bacteremia were all negative by TaqMan® PCR (Table 3).

Therefore, PCR using the All-CAN-TET probe detected all *Candida* spp. (100%) and TaqMan® PCR assays "A" and "B" rapidly and correctly identified all *Candida* spp. in 57 (93.4%) of 61 clinical blood cultures (Table 2).

#### Sensitivity and specificity of the All-CAN-TET probe

The All-CAN-TET probe detected all *Candida* spp., *S. cerevisiae*, *A. fumigatus* and *A. flavus*, but no other fungal, bacterial or human DNA tested (Table 4). Although purified *Aspergillus* spp., DNA was detected with the All-CAN-TET probe, the mechanical sample preparation method used did not release *Aspergillus* DNA from intact cells. Therefore, a different sample preparation method would need to be used to obtain *Aspergillus* DNA from clinical samples and only *Candida* and *S. cerevisiae* DNA would be expected to be detected in clinical materials processed as described in this paper.

#### **TaqMan® PCR sensitivity**

We compared Taqman® PCR results with those from a PCR-EIA method developed in our laboratory (Fujita et al) using *C. albicans* blastoconidia suspended in Bact/Alert culture bottles inoculated with rabbit blood. *C. albicans* strain B311 blastoconidia were introduced at concentrations of 0,  $10^1$ ,  $10^2$ ,  $10^3$ ,  $10^4$ , or  $10^5$  per 200  $\mu$ l of Bact/Alert blood culture broth containing whole rabbit blood (broth to rabbit blood ratio = 8: 1).

The mean delta RQ values for the All-CAN-TET probe for each 200  $\mu$ l sample in three experiments was  $3.10 \pm 0.45$  for  $10^5$  cells,  $2.75 \pm 0.18$  for  $10^4$  cells,  $0.69 \pm 0.12$  for  $10^3$  cells, and  $0.34 \pm 0.07$  for  $10^2$  cells (Table 5). The sensitivity of detection by EIA was therefore  $10^2$  cells per 200  $\mu$ l of sample, or 1 cell per 2  $\mu$ l sample relative to control samples containing no *C. albicans* blastoconidida ( $P < 0.01$ ). This was equal to the detection limit of the PCR-EIA method. The detection limit by EtBr staining was ten-fold lower than either method ( $10^3$  cells per 200  $\mu$ l of sample).

The detection limit for TaqMan® PCR using CA-FAM, CT-TET and CP-HEX probes were  $10^3$  Cells per 200  $\mu$ l of sample, or 10 cells per 2  $\mu$ l of sample. This represented a ten-fold lower sensitivity than the PCR-EIA method and equal sensitivity to detection by EtBr staining of agarose gels (Table 5).

Table 1. Probes used for TaqMan® PCR assay

Probes	Nucleotide Sequence (5' to 3') and Chemistry
All-CAN-TET	5'TET AG GGC ATG CCT GTT TGA GCG TC(GA) TT-3'-P
CA-FAM	5'FAM AT TGC TTG CGG CGG TAA CGT CC-3'-P
CT-TET	5'TET CA AAA CGC TTA TTT TGC TAG TGG CC 3'-P
CP-HEX	5'HEX GG TAC AAA CTC CAA AAC TTC TTC CA 3'-P
CG-FAM	5'FAM TA GGT TTT ACC AAC TCG GTG TT GAT-3'-P
CK-TET	5'TET AG TGG CCC GAG CGA ACT AGA CTT TT 3'-P

Table 2. Identification of Candida species in BacT/Alert blood culture bottles by TaqMan® PCR

Routine culture and ID		TaqMan® detection of PCR product	
Reported as:	No	Identified as:	No
<u>C. albicans</u>	23	<u>C. albicans</u>	23
<u>C. glabrata</u>	18	<u>C. glabrata</u>	17
<u>C. krusei</u>	6	<u>C. krusei</u>	6
<u>C. tropicalis</u>	6	<u>C. tropicalis</u>	5
<u>C. parapsilosis</u>	5	<u>C. parapsilosis</u>	4
<u>C. glabrata</u> + <u>C. albicans</u>	3	<u>C. glabrata</u> + <u>C. albicans</u>	2
		<u>C. glabrata</u> only	1
Total	61		57/61 (93.4%)

Table 3. Identification of *Candida* spp. in positive blood cultures by TaqMan® PCR using multiple fluorescent probes

PCR USING:	Mean delta RQ $\pm$ SD					
	PCR "A" Three probes			PCR "B" Two probes		PCR "C" One probe
	CA-FAM	CT-TET	CP-HEX	CG-FAM	CK-TET	AI-CAN-TET
<i>C. albicans</i> (n = 23)	0.95 $\pm$ 0.62	0.07 $\pm$ 0.06	0.09 $\pm$ 0.10	0.01 $\pm$ 0.01	0.02 $\pm$ 0.02	3.42 $\pm$ 0.67
<i>C. tropicalis</i> (n = 6)	0.03 $\pm$ 0.04	0.48 $\pm$ 0.38	0.07 $\pm$ 0.06	0.02 $\pm$ 0.02	0.03 $\pm$ 0.03	1.92 $\pm$ 1.34
<i>C. parapsilosis</i> (n = 5)	0.03 $\pm$ 0.03	0.02 $\pm$ 0.02	0.33 $\pm$ 0.12	0.01 $\pm$ 0.01	0.01 $\pm$ 0.02	1.78 $\pm$ 1.48
<i>C. glabrata</i> (n = 18)	0.01 $\pm$ 0.02	0.03 $\pm$ 0.04	0.03 $\pm$ 0.05	0.63 $\pm$ 0.39	0.01 $\pm$ 0.02	2.81 $\pm$ 1.24
<i>C. krusei</i> (n = 6)	0.02 $\pm$ 0.03	0.01 $\pm$ 0.03	0.07 $\pm$ 0.05	0.01 $\pm$ 0.02	0.73 $\pm$ 0.33	3.38 $\pm$ 0.92
No growth (n = 10)	0.02 $\pm$ 0.02	0.01 $\pm$ 0.01	0.04 $\pm$ 0.05	0.01 $\pm$ 0.01	0.04 $\pm$ 0.03	0.05 $\pm$ 0.05
Bacteremia (n = 10)	0.02 $\pm$ 0.02	0.01 $\pm$ 0.03	0.01 $\pm$ 0.02	0.01 $\pm$ 0.01	0.03 $\pm$ 0.03	0.07 $\pm$ 0.07

Notes: Mean  $\pm$  SD for all control samples for CA-FAM probe (n = 55) = 0.02  $\pm$  0.023, for CT-TET probe (n = 72) = 0.03  $\pm$  0.048, for CP-HEX probe (n = 73) = 0.05  $\pm$  0.070, for CG-FAM probe (n = 60) 0.01  $\pm$  0.012, for CK-TET probe (n = 72) = 0.02  $\pm$  0.029.

Table 4. Sensitivity/specificity of the All-CAN-TET probe used in the TaqMan® PCR assay

Genomic DNA tested	Delta RQ values (Mean $\pm$ SE) <sup>a</sup>
<i>C. pseudotropicalis</i>	4.59 $\pm$ 0.16 <sup>b</sup>
<i>C. parapsilosis</i>	4.59 $\pm$ 0.16 <sup>b</sup>
<i>C. krusei</i>	4.56 $\pm$ 0.38 <sup>b</sup>
<i>C. albicans</i>	4.36 $\pm$ 0.10 <sup>b</sup>
<i>C. glabrata</i>	3.33 $\pm$ 0.18 <sup>b</sup>
<i>C. tropicalis</i>	3.27 $\pm$ 0.02 <sup>b</sup>
<i>S. cerevisiae</i>	2.27 $\pm$ 0.17 <sup>b</sup>
<i>C. guilliermondii</i>	2.18 $\pm$ 0.09 <sup>b</sup>
<i>A. fumigatus</i>	1.66 $\pm$ 0.18 <sup>b</sup>
<i>A. flavus</i>	1.13 $\pm$ 0.18 <sup>b</sup>
<i>H. capsulatum</i>	0.21 $\pm$ 0.04
<i>P. aeruginosa</i>	0.19 $\pm$ 0.06
<i>E. coli</i>	0.18 $\pm$ 0.05
<i>C. neoformans</i>	0.17 $\pm$ 0.06
<i>P. marneffe</i>	0.16 $\pm$ 0.05
Human cell line	0.12 $\pm$ 0.09
<i>B. dermatitidis</i>	0.11 $\pm$ 0.11
<i>S. aureus</i>	0.06 $\pm$ 0.05

<sup>a</sup> Data for triplicate tubes from 1 to 3 experiments<sup>b</sup> Positive value based on cutoff value criterion



Table 5. Comparative sensitivity of fluorescent TaqMan<sup>®</sup> PCR, colorimetric PCR-EIA and EtBr staining to detect *C. albicans* DNA from blastoconidia spiked into BacT/Alert blood culture bottles containing rabbit's blood

No of <i>C. albicans</i> per 200 $\mu$ l	TaqMan <sup>®</sup> PCR		PCR-EIA		EtBr Staining of Agarose Gel
	All-CAN-TET	Mean Fluorescence $\pm$ SD <sup>a</sup>	Mean A650nm $\pm$ SD <sup>a</sup>	CA-DIG	
10 <sup>5</sup>	3.100 $\pm$ 0.450 <sup>b</sup>	1.140 $\pm$ 0.400 <sup>b</sup>	0.580 $\pm$ 0.050 <sup>b</sup>		+
10 <sup>4</sup>	2.750 $\pm$ 0.180 <sup>b</sup>	0.690 $\pm$ 0.100 <sup>b</sup>	0.440 $\pm$ 0.060 <sup>b</sup>		+
10 <sup>3</sup>	0.690 $\pm$ 0.120 <sup>b</sup>	0.190 $\pm$ 0.030 <sup>b</sup>	0.130 $\pm$ 0.030 <sup>b</sup>		+
10 <sup>2</sup>	0.340 $\pm$ 0.070 <sup>b</sup>	0.070 $\pm$ 0.020 <sup>b</sup>	0.020 $\pm$ 0.010 <sup>b</sup>		-
10 <sup>1</sup>	0.060 $\pm$ 0.030	0.040 $\pm$ 0.060	0.010 $\pm$ 0.001		-
0	0	0	0		-
Purified <i>C. albicans</i> DNA (1 ng)	4.380 $\pm$ 0.170 <sup>b</sup>	1.000 $\pm$ 0.080 <sup>b</sup>	0.550 $\pm$ 0.100 <sup>b</sup>		+

<sup>a</sup> Data from three experiments, duplicate wells per experiment.

<sup>b</sup> P<0.01 or P<0.05 by Student's t test versus mean for samples containing no DNA.

Throughout this application various publications are referenced within parentheses. Full citations for these publications may be found at the end of the specification immediately preceding the Sequence Listing. The disclosures  
5 of these publications in their entireties are hereby incorporated by reference into this application in order to more fully describe the state of the art to which this invention pertains.

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## SEQUENCE LISTING

## (1) GENERAL INFORMATION:

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(ii) TITLE OF INVENTION: METHODS AND COMPOSITIONS FOR THE DETECTION OF CANDIDA SPP

(iii) NUMBER OF SEQUENCES: 10

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(v) COMPUTER READABLE FORM:

(A) MEDIUM TYPE: Floppy disk  
(B) COMPUTER: IBM PC compatible  
(C) OPERATING SYSTEM: PC-DOS/MS-DOS  
(D) SOFTWARE: PatentIn Release #1.0, Version #1.30

(vi) CURRENT APPLICATION DATA:

(A) APPLICATION NUMBER:  
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(viii) ATTORNEY/AGENT INFORMATION:

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(2) INFORMATION FOR SEQ ID NO:1:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 19 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

TCCGTAGGTG AACCTGCGG

19

(2) INFORMATION FOR SEQ ID NO:2:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 20 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

GCATCGATGA AGAACGCAGC

20

(2) INFORMATION FOR SEQ ID NO:3:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 20 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

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

TCCTCCGCTT ATTGATATGC

20

(2) INFORMATION FOR SEQ ID NO:4:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 20 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:



GCTGCGTTCT TCATCGATGC

20

(2) INFORMATION FOR SEQ ID NO:5:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 151 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

CTCCCTCAAA CCGCTGGGTT TGGTGTTGAG CAATACGACT TGGGTTTGCT TGAAAGACGG	60
TAGTGGTAAG GCGGGATCGC TTTGACAATG GCTTAGGTCT AACCAAAAAC ATTGCTTGCG	120
GCGGTAACGT CCACCACGTA TATCTTCAAA C	151

(2) INFORMATION FOR SEQ ID NO:6:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 124 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:

CTCCCTCAAA CCCTCGGGTT TGGTGTTGAG CGATACGCTG GGTTTGCTTG AAAGAAAGGC	60
GGAGTATAAA CTAATGGATA GGTTTTTTCC ACTCATTTGGT ACAAACCTCCA AAACCTTCTTC	120
CAAA	124

(2) INFORMATION FOR SEQ ID NO:7:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 140 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:7:

CTCCCTCAAA CCCCCGGGTT TGGTGTGAG CAATACGCTA GGTTTGGTTG AAAGAATTTA 60  
CCGTGGAAAC TTATTTTAAG CGACTTAGGT TTATCCAAAA CGCTTATTTT GCTAGTGGCC 120  
ACCACAATTT ATTTTCATAAC 140

## (2) INFORMATION FOR SEQ ID NO:8:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 231 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

## (ii) MOLECULE TYPE: DNA (genomic)

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:8:

CCTTCTCAAA CACATTGTGN TTGGTANTGA GTGATACNCN NTTTTGATNT AACTTNAAAT 60  
TGTAGGCCAT ATCAGTATGT GGGACACGAG NGCAAGCTTC TCTATTAATC TGCTGCTGCT 120  
TTGCGCGAGC GGCAGGGGTT AATACTCTAT TAGGTTTTAC CAACTCGGTG TTGATCTAGG 180  
GAGGGATAAG TGAGTGTTTT GTGCGTGCTG GGCAGACAGA CGTCTTTAAG T 231

## (2) INFORMATION FOR SEQ ID NO:9:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 177 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

## (ii) MOLECULE TYPE: DNA (genomic)

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:9:

GAGCGTCGTT TCCATCTTGC GCGTGCGCAG AGTTGGGTGA GCGGANGTAC CGACGTGTAA 60  
AGAGCGTCGG AGCTGCGACT CNNCTGAAAG GGAGCNNANT GGCCCGAGCG AACTAGACTT 120  
TTTTTNAGGG NCCGTTTTGG GCCCCAGAAC CNAGTTTTNC CNAGGNCAAC AAAAAGN 177

## (2) INFORMATION FOR SEQ ID NO:10:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 16 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:10:

GTAAAACGAC GGCCAG

16

## WHAT IS CLAIMED IS:

1        1.    An isolated double-stranded nucleic acid consisting  
2        essentially of the nucleotide sequence corresponding to the  
3        following sequence and its complement:

4            AG GGC ATG CCT GTT TGA GCG TC(GA) TT

1        2.    An isolated nucleic acid that specifically hybridizes  
2        with the nucleic acid of Claim 1 and which contains at least  
3        the first four bases of the sequence in Claim 1 or the  
4        complement to the first four bases.

1        3.    An isolated nucleic acid that specifically hybridizes  
2        to one of the nucleic acid sequences provided in Table 1.

1        4.    A method for detecting *Aspergillus sp.* and *Candida sp.*  
2        in a sample comprising subjecting the sample to an isolated  
3        nucleic acid of claim 2 under nucleic acid hybridization  
4        conditions and then detecting for a hybridization complex  
5        between sample nucleic acid and that of claim 2.

1        5.    A kit for the detection of *Candida sp.* comprising a  
2        nucleic acid probe of claim 2 and instructions for the  
3        detection method.

1        6.    A kit of claim 5 wherein *Aspergillus sp.* is further  
2        detected.

1        7.    A kit of claim 5 wherein the kit further contains at  
2        least one probe that specifically hybridizes to a nucleotide  
3        sequence defined in the group of sequences consisting of SEQ  
4        ID NOs:5-9.

# INTERNATIONAL SEARCH REPORT

Internat. Application No.

PCT/US 97/16423

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 C12Q1/68

According to International Patent Classification(IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 C12Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	SHIN J ET AL: "Rapid identification of up to three Candida Spp. in one reaction tube using Taqman PCR" ABSTRACTS OF THE INTERSCIENCE CONFERENCE ON ANTIMICROBIAL AGENTS AND CHEMOTHERAPY, vol. 36, no. 0, 15 September 1996, page 72 XP002053344 see the whole of D70 ---	1-7
Y	US 5 426 027 A (LOTT TIMOTHY J ET AL) 20 June 1995 see the whole document ---	1-7
Y	WO 96 21741 A (CIBA CORNING DIAGNOSTICS CORP ;SANDHU GURPREET S (US); KLINE BRUCE) 18 July 1996 see the whole document ---	1-7
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

\* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

26 January 1998

Date of mailing of the international search report

18/02/1998

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# INTERNATIONAL SEARCH REPORT

Intern      ional Application No

PCT/US 97/16423

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication where appropriate of the relevant passages	Relevant to claim No.
Y	FUJITA S-I ET AL: "Microtitration plate enzyme Immunoassay to detect PCR-amplified DNA from Candida species in blood" JOURNAL OF CLINICAL MICROBIOLOGY, vol. 33, no. 4, April 1995, pages 962-67, XP002053345 see the whole document ---	1-7
A	EP 0 422 869 A (GENE TRAK SYSTEMS) 17 April 1991 see the whole document ---	1
A	EP 0 335 633 A (INTEGRATED GENETICS INC) 4 October 1989 see the whole document -----	1

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information on patent family members

International Application No

PCT/US 97/16423

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