RESEQUENCING PATHOGEN MICROARRAY

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority to U.S. provisional Application Serial No. 60/590,931, filed on 2 July 2004, U.S. provisional Application Serial No. 60/609,918 filed on 15 September 2004, U.S. provisional Application Serial No. 60/631,437 filed on 29 November 2004, U.S. provisional Application Serial No. 60/631,460 filed on 29 November 2004 and U.S. provisional Application Serial No. 60/691,768 filed on 16 June 2005.

STATEMENT REGARDING FEDERALLY FUNDED PROJECT

The United States Government owns rights in the present invention pursuant to funding from the Defense Threat Reduction Agency (DTRA; Interagency Cost Reimbursement Order (IACRO #02-4118), MIPR numbers 01-2817, 02-2292, 02-2219, and 02-2887), the Office of the U.S. Air Force Surgeon General (HQ USAF SGR; MIPR Numbers NMIPR035203650, NMIPRONMIPRO35203881, NMIPRONMIPRO35203881), the U.S. Army Medical Research Acquisition Activity (Contract # DAMD17-03-2-0089), the Defense Advance Research Projects Agency (DARPA; MIPR Number M189/02), and the Office of Naval Research (NRL Work Unit 6456).

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SEQUENCE LISTING

The present application includes a sequence listing on an accompanying compact disk containing a single file named NC97416.txt, created on July 5, 2005, 639 KB in size, and additionally labeled:

Applicant: The Government of the United States of America as Respresented by the Secretary of the Navy

Title: Resequencing Pathogen Microarray

File Reference Number: NC 97,416

The entire contents of that accompanying compact disk are incorporated by reference into this application.

TECHINCAL FIELD

The present invention provides pathogen detection by use of DNA resequencing microarrays. Preferably, the present invention provides for simultaneous detection of multiple pathogens. The present invention also provides resequencing microarrays and microarray chips for differential diagnosis and fine-scale discrimination between closely related pathogens present in a biological sample. The present invention further provides methods of detecting the presence and identity of pathogens present in a biological sample. The invention enables diagnosis and surveillance of known pathogen sequences and pathogens that may be identified due to unanticipated sequence variations, as well as mixtures of such pathogens. Resequencing, combined with several amplification strategies, allows simultaneous clinical diagnosis and performance of traditional surveillance assays for serotyping, antibiotic resistance profiling, genetic drift/shift analysis, forensics, and rapid detection of biological terrorism events.

The present invention is also relevant to a variety of automated selection systems including automated sub-sequence selection systems for usage with any method group of nucleic acid or protein sequences generated by alternative methods. The system is configured to automatically select sets of sub-sequences from incomplete nucleotide sequence data obtained from resequencing DNA microarrays, according to parameters predetermined by the system or determined by a user, for selecting sequence subsets that are optimally suitable for comparison against a collection of predetermined database sequences using one or more similarity search algorithm(s). Embodiments of the invention also enable the further analysis and presentation of relevant results returned by a similarity search resulting from submission of one or more subsequences. Aspects of the invention described herein distinguish between combinations of sequence signatures that arise from a mixture of multiple sequence targets (e.g. microbial organisms) or from a rearrangement of sequences within a single target. Embodiments of the method are also capable of assigning relative abundances of mixed target sequences based on relative signal intensity values from the DNA microarray itself. Moreover, an aspect of the invention is an integral component of an iterative process for *designing* resequencing DNA microarrays using "prototype" sequence tiles to represent a range of related target sequences (e.g. pathogens).

BACKGROUND ART

As we move through the biotechnology age fostered by the human genome project a premium has been placed on the development of high throughput methodologies to obtain and analyze sequence information. To meet this demand, the multifunctional DNA microarray platform has gained notoriety leading to an explosive growth in application methods using the same.

More importantly, the evolution of world events and the emergence of bioterrorism in mainstream society have led to a growing sentiment amongst the scientific community and lay people alike that new, rapid, and accurate techniques for biological threat identification and eradication must be developed. The concept of a microarray used for broad-spectrum pathogen identification has considerable and obvious appeal to both medical practice and national defense. It is within this framework that the present inventors have endeavored.

Heretofore, for the purpose of pathogen identification, approaches generally rely on the ability of immobilized "probe" DNA sequences on the surfaces of microarrays to hybridize with complementary genomic "target" that is uniquely identifying of a particular category or specific strain of microbial pathogen. Various microarray technologies have been developed for this purpose, varying in the density of probes and the time ranges required for assay completion.

One technical challenge for pathogen detection with microarrays arises due to the difficulty in obtaining samples with a sufficient quantity of pathogen nucleic acid. Thus, for a majority of sample types, some sort of target amplification will likely be required to provide sufficient copies of pathogen gene markers for detection by microarray hybridization. Unfortunately, conventional methods for this amplification do not scale well in comparison to the number of probes that can be placed on a microarray chip. However, the most commonly employed means of providing sufficient quantities of genomic target to detect hybridization relies upon genotypic identification methods that utilize molecular biology-based techniques, such as the polymerase chain reaction (PCR). These techniques offer several potential advantages over conventional microbiological approaches. Nucleic acid amplification strategies base pathogen identification on the detection of genetic information contained within the organism, such that culturing the organism is not required.

Although PCR-based assays are sensitive, accurate, and rapid, these methods also introduce a new set of

problems. As successful identification depends almost entirely on appropriately chosen primer sets, as PCR-based testing requires assumptions about the exact sequences pertaining to the identity of the target organism(s). Consequently, there is a critical need for advanced diagnostic systems that can detect both assumed and unanticipated pathogen sequences. DNA microarrays, which enable the simultaneous interrogation of thousands of genetic elements, address this crucial need. Here, the term "microarray" refers to any type of planar substrate or solid beads presenting a high multiplicity (10^2 to 10^6) of individual sites, each presenting nucleic acid probes designed to selectively capture complementary strands of target (i.e. pathogen or host) nucleic acid.

However, the majority of pathogen identification microarrays described in the literature is prepared using oligonucleotides that are robotically spotted onto derivatized glass surfaces (typically 3x1 inch microscope slides). This approach allows the most flexibility with regards to the size of the oligonucleotides that are deposited, ranging from 20-mers to cDNA PCR products of several thousand base pairs (bp). With few exceptions, the detection event is an increased level of fluorescence originating from a spot following hybridization of a fluorophore-labeled target nucleic acid.

Short (14-25mer) oligonucleotides, immobilized inside acrylamide pads, have been applied extensively to pathogen identification (Strizhkov et al., 2000; Vasiliskov et al., 1999) in a collaborative effort between Argonne National Lab (DOE, USA) and the Engelhard Institute of Molecular Biology (Moscow, RU) under the leadership of Andrei Mirzabekov. In addition, low-density microarrays (several hundred features per 3x1 inch microscope slide) have been used for determination of drug resistance determinants (Volokhov et al., 2003). One distinguishing aspect of this body of work is the use of three-dimensional polymer matrices for probe immobilization instead of two-dimensional planar surfaces.

More recently, Cherkasova et al have described the use of glass-immobilized short oligonucleotide spotted microarrays to map poliovirus mutations using overlapping 14-25mer probes (Cherkasova et al., 2003). Two variations of this approach have been used: (1) Microarrays for Resequencing and Sequence Heterogeneity (MARSH) assay, and (2) Microarray Analysis of Viral Recombination (MAVR) assay. MARSH uses a set of overlapping (at half length) nucleotide probes for individual gene sequences. Hybridizations patterns allow the detection of single point mutations or substitution/deletion events to a resolution of half probe lengths (e.g. 7-10 bp) but does not allow for exact determination of position(s) or the nature of the mutation. Accordingly, conventional DNA sequencing technologies must be employed subsequently to determine these changes. MAVR uses organism-specific oligonucleotide probes that cover the entire genome at ~ 150 nt spacings and is used to detect large scale genetic recombinations.

The DeRisi group at UCSF pioneered the use of long (70-mer) oligonucleotide probe microarrays for broad-spectrum pathogen identification (Wang et al., 2002; Wang et al., 2003). The use of long (70 nt) oligonucleotides bears implicit advantages and disadvantages. One advantage is that higher degrees of sensitivity can usually be achieved with 70-mer probes compared to shorter ones (e.g. 20-25mers). However, specificity is reduced because 70-mer target/probe hybridizations are generally insensitive to significant numbers (e.g., 7-10) of single base mismatches, whereas shorter probes provide much greater sequence specificity.

DeRisi's group described the use of spotted microarrays having 1,600 different 70-mer oligonucleotide probes to identify a variety of viruses responsible for common respiratory infections (Wang et al., 2002). The probes were selected for each pathogen using an algorithm that located discriminatory sequences from a list of known viral genomes. A serial combination of a previously described (Bohlander et al., 1992) method and subsequent PCR / Klenow fragment-based amplification was used to achieve non-biased amplification of both viral

RNA and DNA, allowing generation of sufficient amounts of target amplicons for successful microarray hybridization and detection via fluorescent label. (N.B. This protocol was placed into the public domain via the DeRisi lab website (http://derisilab.ucsf.edu)). The time required from sample preparation to obtained result was approximately 24 hours. Because exact sequence information was not attainable from such arrays, pathogen identifications were made on the basis of a hybridization pattern that could be empirically determined for each pathogen or strain. In a related report from the same group (Wang et al., 2003) similar microarrays were prepared using highly conserved sequences in an effort to capture as many microbial species as possible from a sample. Following physical removal of the pathogen sequences from the microarray, the sequences are cloned and sequenced using conventional DNA sequencing technologies. No measure of analytical / clinical sensitivity or specificity for pathogen detection in clinical specimens was provided in the work from the DeRisi group.

In contrast to the above-mentioned approaches using spotted microarrays, Affymetrix, Inc. (Santa Clara, CA) uses high-density probe fabrication technology to construct "tiled" microarrays using 4 probes each in both the sense and anti-sense directions for each nucleotide base to be resequenced. Thus, single base substitutions are directly detected by the hybridization pattern (for additional information see Affymetrix CustomSeq design manual). Several groups described the use of tiled microarrays for pathogen genotyping. (Kozal et al., 1996) utilized this type of microarray to measure mutational drift in HIV while Gingeras et al (Gingeras et al., 1998; Troesch et al., 1999) used a tiled array of 65,000 oligomer probes to resequence and accurately identify 70 clinical isolates of 27 mycobacterial species and 15 rifampin-resistant *M. tuberculosis* strains. More recently, Andersen et al. (Wilson et al., 2002b) described the use of tiled Affymetrix microarrays for the identification of biological warfare agents. Their approach relied entirely on the use of specific PCR reactions performed in parallel to generate sufficient pathogen target DNA for microarray hybridization. In all cases listed above, specific PCR primers were used to amplify DNA targets prior to microarray hybridizations, through the use of conserved primer sites, or in the work of Andersen et al. (Wilson et al., 2002a; Wilson et al., 2002b), by carrying out up to ~150 different PCR reactions in multi-well format and pooling the amplicons.

US Patent 6,228,575 B1 describes the same data as described by Gingeras (Gingeras et al., 1998) and Troesch (Troesch et al., 1999). In this patent, target pathogen sequences are tiled onto arrays. Because several types of variations (esp. insertion/deletion or frequent multiple substitutions) in pathogen sequence can perturb hybridization patterns, Gingeras et al. used differential measures of specific pathogen hybridization patterns to identify individual mycobacterial variants. That is, identifications required *a priori* knowledge of a differential hybridization pattern that was empirically determined in ground truth experiments.

As stated above, there is a critical need for advanced diagnostic systems that can detect known and pathogen genomic sequences as well as variations of those sequences. More particularly, there remains a critical demand for DNA microarray techniques that are fast and reliable, but are free from the systemic bias flowing from the specific PCR based methods that have heretofore been employed.

The convergence of biology with engineering and computer science has led to the emergence of biotechnology and bioinformatics which, among many other goals, aim to rapidly obtain and analyze genomic and proteomic sequence information for diagnosis of disease. The experimental viability and widespread availability of such methodologies are due in no small part to the emergence of DNA microarrays (Stenger et al., 2002).

Generally, microarray fabrication applies methods of microprocessor manufacturing to create "gene chips" capable of rapidly and reliably identifying sequences of DNA or proteins that are present in a biological sample. Here, the term "microarray" refers to any type of planar substrate or alternative matrix presenting a high multiplicity

(10^2 to 10^6) of individual sites, each presenting probes (immobilized nucleic acids or antibodies) designed to selectively capture complementary strands of a target (i.e. gene or gene transcript) analytes in solution. By design, DNA microarrays enable the simultaneous interrogation of thousands of gene or gene transcript elements.

In using a resequencing DNA microarray for genetic analysis, a solution containing amplified and fluorescently-tagged genetic targets are passed across the microarray comprised of a plurality of oligonucleotide probes in a "tiled" format (Kozal et al., 1996). Complementary sequences in the sample bind to the corresponding probes contained on the microarray. The microarray is then analyzed using, for example, a laser scanner that records the intensity of light emission from the microarray's probes. The recorded intensities are then analyzed by array-specific software used to make "base calls," which is a term describing an algorithmic method of identifying to a certain degree of probabilistic certainty the sequence of nucleic acids (adenine; A, thymine; T, cytosine; C, or guanine; G) contained in the biological sample of interest. A broader IUPAC definition code is also used to describe less precise base calls (see U.S. Provisional Application Serial No. 60/590,931 filed on July 2, 2004 entitled "Resequencing Pathogen Microarray", supplemental data, Appendix J "gdas_manual.pdf" page 255). If the target sequence is sufficiently homologous to the appropriate tile region of the resequencing microarray (fewer than 1-2 base substitutions per 25 bases) then a complete resequencing of the target is possible. However, the hybridization to the tile region is interrupted when the target sequence contains insertions, deletions, or base substitutions at frequencies of greater than 2 substitutions per 25 bases of target sequence. This results in the "no [base] call" (N) being made from the corresponding sequences on the microarray tile region. N calls also result when the concentration of the target nucleic acid in solution is low or when there are interfering level of competing background nucleic acids in the hybridization solution. Incomplete biological sequence information can also be generated by a number of other nucleic acid and protein sequencing technologies.

The primary intended application of resequencing microarrays is to detect low probability single nucleotide polymorphisms (SNPs) or mutations within a limited range of target sequences. However, although not conventionally performed currently in industry, sequence output of the microarray can also be compared against sequence databases to allow identification of target sequences. The most prevalent comparison method, or similarity search algorithm, for sequence data currently in use is Basic Local Alignment Search Tool, commonly known as and referred to herein as "BLAST." Numerous variants exist, including Washington University BLAST (WU-BLAST), NCBI-BLAST, FASTA, MPsrch, Scanps, and BestFit (Korf, Yandell & Bedell, 2003). Such comparisons generally yield a number of possible matches in terms of certainty (measured probabilistically) that the tested sample includes the matched biological subject for which a sequence is known. The sequence output by the intensity analysis of the microarray is then often compared to a database that includes known sequences of biological subjects which could include pathogenic microbes. However, one normally skilled in the art of molecular biology would not be capable of visually determining the best sequence sections from a tiled region containing A,C, T and G base calls punctuated and in some cases dominated by varying numbers of no-calls (N).

The use of microarrays for the purposes of genetic sequencing and identification has drastically increased the capability of even a single researcher to extract a large amount of sequence data from a biological sample for comparison against an even larger number of previously sequenced organisms and biological substances. However, the researcher is unable to utilize the information in a time-effective manner. Ambiguous results are also problematic for a researcher submitting sample sequences for comparison due to excessive wait times and poor (inconclusive or conflicting) results associated with attempts to match ambiguous subsequences. Accordingly, a widely-practiced method of obtaining more relevant results from sequence comparison is for a researcher to review

sequence output searching for subsequences that appear to have a higher probability of returning a relevant result. In particular, many researchers often find themselves manually and subjectively selecting, or visually parsing, certain subsequences for comparison against those in the sequence database. As a result, a researcher expends time and resources for relatively slowly and subjectively optimizing the sequence data for submission to the similarity search. Thus, the current solution for the above-noted resource utilization problem leads to additional time and resource requirements demanded of the researcher. Moreover, as the current solution is subjective as well as time-intensive, the net gain with respect to facilitating the advancement (and acceleration) of genomic research is ambiguous at best.

However, as noted above the vast repositories of known biological sequences are often contained in shared computing resources. These shared computing resources require vast amounts of data storage capacity, as well as robust and powerful tools with which to compare a submitted sequence to those contained within the database. As the amount of sequence data produced (and submitted) by researchers increases with the improvement and increasing availability of microarrays for general research use, the burden placed on shared databases (and associated systems) in terms of bandwidth and processing requirements increase dramatically. In other words, the increase in data made possible by widespread use of microarrays often leads to less efficient utilization of shared bioinformatics computing resources.

For example, if sequences containing a large percentage of ambiguous sequence data (Ns) are submitted, the sequence database's computing resources will be spent trying to find matches for inherently ambiguous sequences, resulting in all possible similarity search results with low certainty values. FIG. 10(a) is an exemplary flowchart illustrating a process that might currently be performed with methods available to the industry. In this example, nucleotide or amino acid sequence data 103 corresponding to a sequence of interest is submitted for comparison against a known sequence database using a similarity search 109.

The submitted sequence(s) 103 when compared to database records, 109 might or might not return statistically significant or meaningful results. Here, by definition, to "compare" means to perform a similarity search of a query sequence against a database of sequence records using any one of a large number of algorithms for determining similarity (e.g. BLAST). Sequences that are said to be "comparable" have a sufficient degree of similarity to at least one sequence in a database to result in the return of at least one statistically significant (user defined) result. It is straightforward for an end user to visually identify and select contiguous stretches of nucleotide base calls (comprised of only A, T, C, or G residues) or amino acids that might be comparable. However, as the number or percentage of "Ns" contained within target sequences increases, it becomes exponentially more difficult for the end user to visually determine the comparability of either the entire sequence or subsequences within it.

The results 111 include high probability matches 111a, lower probability matches 111b, and a significant number of statistically insignificant results 111c that can be attributed to a chance match with the database. Ns are treated as "aNy" (wild card) characters by similarity search algorithms meaning the N could be any of the four base residues or gap when the default parameters are used. In the case of a resequencing DNA output, an N indicates the resequencing algorithm could not resolve the call and can correspond to any of the four base residues (A, T, C or G) or to empty space (Korf et al., 2003). In the case that too many non-calls (Ns) are included in the submitted sequence, then the similarity search (e.g. BLAST) will calculate E (expect) values higher than the acceptable E (expect) value (e.g. 1.0e-9) indicating the chances are greater that the returned sequence is not unique. Similarly, shorter sequences may have higher E values indicating their lack of use to the end user in determining the presence

of unique DNA material. The results 111, including the numerous ambiguous results 111c, are then left to be analyzed 113 by the researcher.

In the case of FIG. 10(a), other users are shown submitting their sequences of base calls to the shared sequence database 109, which handles these additional requests for local alignment searches. As described above, the submission of ambiguous sequences by multiple users to a shared sequence alignment resource often results in available computing resources being spent to serve only a small number of sequence submissions.

FIG. 10(b) illustrates this alternative case often found in practice in the industry that is problematic with regard to researcher time consumption. In contrast to the previously illustrated case, the sequence data 103 is altered in a cut and paste operation 119 performed manually by a human researcher. More specifically, the human researcher often visually scans the raw data output and subjectively copies and pastes subsets of the raw data output 119 that appear to contain fewer "Ns" and submits these subjective selections 121 for comparison 109. However, as the selection of subsets is performed subjectively and repetitively for a large amount of raw data, the human-selected submissions 121 often include comparable 121a and non-comparable 121b data. Consequently, the results from the BLAST comparison 123 still include a wide array of possible matches, ranging from high probability matches 123a, to low probability matches 123b which are often caused by selections in which there are to many non-calls 123c as opposed to the anticipated result of a low probability match caused by a less similar sequence match.

As discussed above, FIG. 10(c) is a schematic drawing of a general system layout for interaction with sequence database servers through computer terminals over a wired or wireless network 128. In some case, sequence database (and associated server) 127 is located remotely from a researcher's terminal 129. Alternatively, some facilities have built custom sequence databases 133 which are accessible through a local terminal 131. However, the above-noted problems with time and shared resource consumption are significant in either configuration with a higher increase in time consumption at a public database level.

A variety of different factors can contribute to the inability of a resequencing DNA microarray to make non-ambiguous base calls. In pure target samples, the hybridization patterns necessary for base calling (Cutler et al., 2001; Kozal et al., 1996) are interrupted whenever a stretch of target sequence is sufficiently dissimilar from the probe sequences that are tiled on the microarray surface. This results in the introduction of N calls into the interrupted positions of the resequencing microarray output file. The same effect occurs when the target molecules are present in low concentration and /or when the target sample is not pure but contains varying amounts of other nucleic acid molecules that can bind non-specifically to the tiled probes with low affinity, resulting in a lowered signal-to-noise ratio of hybridization (fluorescence) signals across the probe sets. To illustrate how these factors can determine whether sequences are comparable or non-comparable data, FIG. 10(d) shows an example of a resequencing DNA microarray output file that results when incomplete hybridization occurs. In the illustrated case, the sequences 135 are in FASTA format, however alternative sequence data formats are equally suitable, including, but not limited to plain, EMBL, GCG, GenBank, and IG. Within the example sequence 136 are sequence subsets 140 (subsequences). Example subsequences 140 include a subsequence with an excessive number of non-calls (Ns) 137, a subsequence that is too short to return meaningful results from a similarity search such as BLAST 139, and a subsequence that is likely to produce a meaningful result 143. Additionally, multiple sequences are set off by aliases, located in the sequence header 138, referencing the probe tile set that is physically present on the microarray surface.

Overall, the above-noted problems with the current state of industry practice are fundamentally related to

researcher time consumption and shared resource allocation. More specifically, the increased amount of subsequence data obtained from samples results in rapid increases in the utilization of shared resources such as sequence comparison databases. Such rapid increases necessitate efficient use for supporting a growing community (in terms of researchers and data). With the aim of using shared resources more effectively, researchers are now often faced with the need to devote time and resources to subjectively and manually selecting sequence subsets for comparison.

As stated above, there is a critical need for advanced diagnostic systems that can rapidly detect both known and unanticipated sequences. More particularly, there remains a critical demand for DNA microarray techniques that reduce the need for human work input and increase the efficiency of shared resource utilization, especially in the case of shared similarity search databases and systems.

In addition to the above-described problems in the industry regarding more effective use of researcher and shared computing resources, the evolution of world events and the emergence of infectious disease and bioterrorism in mainstream society have led to a growing sentiment amongst the scientific community and lay people alike that new, rapid, and accurate techniques for threat identification and eradication must be developed. The concept of broad-spectrum pathogen identification has considerable and obvious appeal to both medical practice and national defense. It is within this framework that the present inventors have endeavored. Furthermore, there remains a need for more ready and robust determination of mixtures and recombinants in biological samples from biological sequence data, regardless of the source of the sequence data.

DISCLOSURE OF THE INVENTION

It is an object of the present invention to provide the following preferred embodiments:

In an embodiment of the present invention is a resequencing DNA microarray chip of multiple groups of oligonucleotide primers of a length ranging from 13 to 70 nucleotides immobilized to a solid phase support, wherein each group of oligonucleotide primers is selected to span a particular region of the reference sequence, occupying a discrete area of the array (e.g. a tile), and comprising at least four sets of primers arranged in a parallel fashion on the chip: 1) a first set that is exactly complementary to the reference sequence; and 2) three additional sets of primers, each of which is identical to the first set of primers but for the nucleotide at a central position, which is different in each of the three sets such that all four conventional nucleotide bases are present on said array.

a. In a preferred aspect of this embodiment, the length of the oligonucleotide primers is 25 nucleotides.
b. In a preferred aspect of this embodiment, the region of the reference sequence that is spanned by the oligonucleotide primer moves by (n + 1) nucleotides across the reference sequence for each adjacent tiled region across the microarray surface.
c. In a preferred aspect of this embodiment, the resequencing DNA microarray contains 18 x 18 micron features.
d. In a preferred aspect of this embodiment, the resequencing DNA microarray contains 8 x 8 micron features.
e. In a preferred aspect of this embodiment, the sequences selected for tiling are a single gene or subsequence that may represent a much broader class of organism genus, species and subspecies.
f. In a preferred aspect of this embodiment, the sequences selected for tiling are "prototypes" representing genotypes of pathogen families.
g. In a preferred aspect of this embodiment, the sequences selected for tiling are "prototypes" representing a

family or group of adenoviruses.

h. In a preferred aspect of this embodiment, the sequences selected for tiling are "prototypes" representing a family or group of influenza viruses.

i. In a preferred aspect of this embodiment, the sequences selected for tiling are a single gene or subsequence unique to an individual pathogenic strain.

j. In a preferred aspect of this embodiment, the sequences selected for tiling encode a drug-resistance marker.

k. In a preferred aspect of this embodiment, the resequencing DNA microarray is a Version 1 Respiratory Pathogen Microarray (RPMV1).

l. In a preferred aspect of this embodiment, the resequencing DNA microarray is a Version 2 Respiratory Pathogen Microarray (RPMV2).

m. In a preferred aspect of this embodiment, at least one common pathogen and at least one biological terrorism agent is represented on the same chip.

n. In a preferred aspect of this embodiment, the resequencing DNA microarray embraces any combination of the aforementioned aspects.

In an embodiment of the present invention is a kit containing (a) the aforementioned resequencing DNA microarray, and (b) reagents suitable for specific hybridization of target sequences to the probe sequences present on said resequencing DNA microarray.

In an embodiment of the present invention is a method of detecting the presence of a drug-resistance marker in a microorganism or a microorganism belonging to a particular class of organism species or subspecies, wherein the method comprises: (1) providing a resequencing DNA microarray as described above; (2) contacting to said resequencing DNA microarray a unknown sample; (3) hybridizing the contents of said unknown sample to the probe sequences immobilized on said resequencing DNA microarray under suitable conditions and for a suitable time; (4) detecting the presence and/or identity of a drug-resistance marker in a microorganism or a microorganism belonging to a particular class of organism species or subspecies in said unknown sample, and (5) detecting a sufficient amount of pathogen sequence in order to allow a forensic assessment of the possible source(s) of pathogens.

a. In a preferred aspect of this embodiment, the method is for detecting the presence of a particular pathogenic species.

b. In a preferred aspect of this embodiment, the method is for detecting the presence of a drug-resistance marker.

c. In a preferred aspect of this embodiment, the hybridization time ranges from 15 minutes to 24 hours.

d. In a preferred aspect of this embodiment, the unknown sample is a biological sample, including a nasal wash specimen, a throat swab, a blood sample, and a sputum sample, or an environmental sample, including a soil sample, an air sample, and a water sample.

e. In a preferred aspect of this embodiment, prior to hybridizing the unknown sample is subjected to one or more of the following steps: (1) isolation, (2) enrichment for target sequences of interest, (3) amplification, (4) labeling, and (5) hybridization (e.g., subtractive).

f. In a preferred aspect of this embodiment, prior to hybridizing the target nucleic acids of interest in the unknown sample is amplified by specific reverse transcription (RT), PCR, multiplex PCR, and/or random PCR.

g. In a preferred aspect of this embodiment, prior to hybridizing the target nucleic acids of interest, the

unknown sample is subjected to a random amplification strategy (e.g., random primed, isothermal Klenow polymerase-based, ϕ29DNA polymerase-based, tandem amplification, multiplex PCR, and total amplification).

h. In a preferred aspect of this embodiment, the DNA present in said unknown sample has been enriched.

i. In a preferred aspect of this embodiment, the target nucleic acids of interest present in said unknown sample are enriched by subtraction of the background nucleic acids from said sample.

j. In a preferred aspect of this embodiment, the target nucleic acids of interest present in said unknown sample are enriched by selective removal of said target nucleic acids from a mixture of nucleic acids presenting said unknown sample.

k. In a preferred aspect of this embodiment, the target nucleic acids of interest present in said unknown sample are enriched by selective capture using probes having complete or partial sequence homology, followed by amplification and hybridization to the microarray.

l. In a preferred aspect of this embodiment, said detecting the presence and/or identity is by (a) making base calls based on the hybridization response between the nucleic acids of interest in said unknown sample and the probe DNA on the resequencing DNA microarray and (b) determining the sequence of the corresponding full-length gene or genomic fragment by comparing the sequence of the hybridized region to sequences present in a sequence database.

i. In a particularly preferred aspect, the base calls are made by the Affymetrix GDAS software under "permissive" settings.

ii. In a particularly preferred aspect, sequence determination is by Resequencing Pathogen Identifier (REPI) software (see U.S. provisional Application Serial No. 60/609,918 filed on September 15, 2004, and U.S. provisional Application Serial No. 60/631,460, filed on November 29, 2004).

iii. In a particularly preferred aspect, the sequence database is GenBank.

In an embodiment of the present invention is a method of routine diagnosis of common respiratory pathogens and/or biological terrorism agents by using the method of C above.

In an embodiment of the present invention is the genomic sequences of thirteen adenovirus strains, which were not known as of the date of the present invention, including: Ad3, Ad3FS_navy, Ad4, Ad4vaccine, Ad4FS_navy, Ad4FS_AF, Ad5FS, Ad7, Ad7FS_navy, Ad7 vaccine, Ad16, Ad1, and Ad21, and fragments thereof.

In an embodiment of the present invention is a method of surveillance of common respiratory pathogens and/or biological terrorism agents by using the method of C above.

In an embodiment of the present invention is a method of estimating the relative amount of a pathogen in a biological sample containing the same comprising providing a resequencing DNA microarray as described above; (2) contacting to said resequencing DNA microarray said biological sample; (3) hybridizing the contents of said unknown sample to the probe sequences immobilized on said resequencing DNA microarray under suitable conditions and for a suitable time; and (4) quantifying the presence and/or identity of a drug-resistance marker in a microorganism or a microorganism belonging to a particular class of organism species or subspecies in said unknown sample.

a. In a preferred aspect of this embodiment, said quantifying is by determining the absolute intensity of the hybridization signals on the chip.

b. In a preferred aspect of this embodiment, said quantifying is by determining the percentage of base calls,

both as a percentage of the total tile region size and as a percentage of base calls within a selected subsequence satisfying the sliding window algorithm (i.e., REPI).

Another aspect of the present invention provides a computer-implemented biological sequence identifier (CIBSI) system and method for selecting a subsequence from biological sequence data according to at least one selection parameter. The at least one selection parameter corresponds to a likelihood of returning a meaningful result from a similarity search.

In an additional embodiment of the present invention provides a system for automatic selection of optimal sequences or subsequences for comparison against a predetermined set of known sequences. Optionally, the system automatically takes a highly fragmented sequence interspersed with Ns, and selects comparable subsequences that are likely to return a "meaningful" result from a similarity search.

Optionally, the system utilizes a sliding window-type algorithm for selecting subsequences. Subsequently, the system automatically returns outputs from a similarity search to the end user that allow probabilistic assignments of the likelihood that a given set of base calls correspond to a particular predetermined sequence.

In an additional embodiment of the present invention, sequence information derived from a base-calling algorithm, as applied to a microarray hybridization pattern, is used to identify individual biological entities present in a test sample. Optionally, the sequence of target sequences determined by resequencing probes of the microarray is used to query a database using a similarity search algorithm. Similarity search algorithms include, but are not limited to, commonly used local alignment (*e.g.* Smith-Waterman, BLASTN) sequence alignment algorithms to statistically determine the probability that a given target sequence corresponds to a specific sequence in a database record (Korf et al., 2003).

Further, an additional embodiment of the present invention presents results of the similarity search to a user regarding whether at least one target sequence is present in the sample.

In another embodiment of the present invention, signal intensity data (for example, obtained from a microarray) is handled by the system and associated with the sequence data. The output of a similarity search is assembled or distilled for presentation to a user to communicate whether a biological entity (including, but not limited to, a pathogen) is present or not. Further, intensity data is correlated with the above output to ascribe relative abundances of a present biological entity (including, but not limited to, a pathogen). Optionally, the system provides an end user with an estimate (quantization) of the relative amount of pathogen that was detected in a resequencing microarray assay.

Another aspect of the present invention identifies mixtures of sequences and sequences indicating a recombination event. In one embodiment, the system automatically detects overlapping or homologous sequence fragments on different tiled regions of a microarray, allowing inference of a mixture of sequences. In an additional embodiment, the system determines that the sequence outputs from different tiled regions are not overlapping but correspond to a contiguous sequence that may be used to infer a genetic recombination event. Optionally, the system discriminates between mixtures of different and genetic recombination between different sequences.

Another aspect of the present invention provides a method of designing "prototype" regions (see U.S. Provisional Application Serial No. 60/590,931) of resequencing DNA microarrays. In this case, a set of related target sequences are compared using a multiple sequence alignment algorithm such as ClustalW or Clustal_X (Thompson et al., 1997; Thompson, Higgins & Gibson, 1994) or another method of searching for sequence databases for partially conserved regions such as HMMer (Eddy, 1998) the outputs of which are used to create a consensus sequence comprised of the most frequent nucleotides at a given residue position in an alignment column.

The consensus sequence consists of a mixture of consensus base calls and no-calls (Ns) where no consensus can be achieved for each of the residue positions in the alignment columns.

Optionally, an embodiment of the present invention searches for candidate regions to tile onto a resequencing DNA microarray by determining those regions having the acceptable balance of conserved and variable nucleotides to allow hybridization of target to the resequencing microarray tile region but still allow for enough sequence variability. This will allow sequence similarity search-based identification of the target sequences comprising the alignment used to generate the consensus.

In alternative embodiments, nucleotide or amino acid sequences come from an alternate form of sequence generator, including those described in (Shendure et al., 2004) and partial amino acid sequences that may be assembled to form a protein sequence. Selected embodiments of the system handle amino acid or protein sequence data in which relative position is conserved.

In other selected embodiments, the nucleotide sequences include a ribonucleic acid (RNA) transcript that codes for protein synthesis. In a manner similar to that described for determining mixtures versus recombination events in target nucleic acids, a mixture of RNA transcripts can be hybridized and thus resequenced on a tiled microarray to produce raw data that can be analyzed using the present invention to determine relative quantities of different RNA transcripts as compared to recombination through transcript editing and alternative splicing (Leipzig, Pevzner & Heber, 2004).

Additional embodiments of the present invention are applicable to nucleotides, transcriptional products, amino acids, or any mixture thereof. Further, the present invention is also applicable to various types of sequence databases and similarity search algorithms to the extent that is well known in the art. Moreover, embodiments of the present invention are suited or adaptable for a wide range of methods and/or devices that generate a sequence data, including, but not limited to, manual or automated Sanger sequencing, shotgun sequencing, conventional microarrays, resequencing microarrays, microelectrophoretic sequencing, sequencing by hybridization (SBH), Edman degradation and variants thereof, Cyclic-array sequencing on amplified molecules, Cyclic-array sequencing on single molecules, and non-cyclical, single-molecule, real-time methods such as nanopore sequencing (Shendure et al., 2004).

The above objects highlight certain aspects of the invention. Additional objects, aspects and embodiments of the invention are found in the following detailed description of the invention. Other systems, methods, features, and advantages of the present invention will be or become apparent to one with skill in the art upon examination of the following drawings and detailed description. It is intended that all such additional systems, methods, features, and advantages be included within this description, be within the scope of the present invention, and be protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following Figures in conjunction with the detailed description below.

FIG. 1 shows a graphical description of the Version 1 Respiratory Pathogen Microarray (RPMV1). The geometrical distribution of all tile regions dedicated to each pathogen is represented by assigned colors (right). The Affymetrix spike-in controls are at the top of the microarray (white). Black regions interspersed between tiled regions did not contain probes.

FIG. 2 shows purified adenovirus 4 prototype (accession number AY594253) DNA hybridization to RPMV1 following nucleic acid isolation and amplification using either (A) degenerate primer PCR (Lin et al., 2004) or (B) GenomiPhi total amplification of target DNA, as described in Example 1. Degenerate primer PCR (A) resulted in hybridization of targets within those tiled regions covered by conserved primer sites. Total amplification (B) resulted in target hybridization across the entire Ad4 tile regions. Neither method resulted in significant cross-hybridization across the microarray. In each case, REPI identified the correct strain of adenovirus 4 (AY594253) as having achieved the highest BLAST ("Basic Local Alignment Search Tool") bit score across all Ad4 tile regions where amplicons hybridized, except in one case (described in Example 1).

FIG. 3 shows purified adenovirus 5 field strain (Ad5FS, accession number AY601635) (A, B) and adenovirus 7 prototype (accession number AY594255) (C, D) DNA hybridizations to RPMV1 following nucleic acid isolation and amplification using either (A, C) degenerate primer PCR (Lin et al., 2004) or (B, D) GenomiPhi total amplification of target DNA as described in Example 3. Degenerate primer PCR (A, C) resulted in hybridization of targets within those tiled regions having conserved primer sites for both the Ad5FS and the Ad7 prototype. Total amplification (B, D) resulted in target hybridization across the entire Ad5 and Ad7 tile regions. Neither method resulted in significant cross-hybridization across the microarray. In each case, REPI identified the correct strain of adenovirus 5 (Ad5FS, accession number AY601635) or adenovirus 7 (accession number AY594255) as having achieved the highest BLAST bit score across all respective tile regions where amplicons hybridized. For adenovirus 7, the correct assignment was also made for the Ad7 prototype on the Ad7 vaccine tile region, distinguishing it correctly from Ad7 vaccine strain (AY594256) from which the tile region was derived. Also, it is noteworthy to mention that the degenerate primer solution used for amplification of all adenoviruses herein was unintentionally contaminated with small amounts of Ad4 and Ad7 prototypes (not considered positive for contamination by real-time PCR). The contaminants did not result in easily discernible hybridizations (as shown in FIG. 3) but base calls were made by Genetic Data Analysis Software (GDAS) (packaged with the microarray reader form Affymetrix, Santa Clara, CA) and Resequencing Pathogen Identifier (REPI) assigned all unintentional base calls to the correct contaminant. The GenomiPhi solution did not become contaminated, and no base calls were made on adenovirus tile regions outside of the Ad5 and Ad7 tile regions in respective experiments.

FIG. 4 shows the results of the adenovirus 4,5 breakthrough strain as described in Example 4. An aliquot of purified nucleic acid from culture of throat swab of a patient with febrile respiratory illness (who was previously vaccinated against adenovirus) was amplified using conserved / degenerate primers as described (Lin et al., 2004) and otherwise processed according to the standard Affymetrix CustomSeq protocol. The patient was diagnosed as Ad4 positive via serotypic antibody neutralization, and diagnosed as Ad5 positive via a hexon sequence. The present inventors obtained multiple target hybridizations, resulting in base calls on all the adenovirus 5 and adenovirus 7 prototype tile regions. REPI analysis revealed that the adenovirus was identified with high confidence as Ad5 (Ad5FS, accession number AY601635), while multiple Ad7 prototype regions gave evidence of a B subgroup species other than Ad7, namely Ad21. It is noteworthy again to note that the degenerate primer solution, used for amplification of all adenoviruses herein was unintentionally contaminated with small amounts of Ad4 and Ad7 prototypes, as in the case shown in FIG. 3. The contaminants did not result in easily discernible hybridizations in the Ad4 tiles (as shown in FIG. 4) but base calls were made by GDAS and REPI assigned all unintentional base calls to the correct contaminant (adenovirus 4 prototype; accession number AY594253), not a field strain that circulates in basic military training venues. Moreover, the highest bit score achieved in the Ad7 tiles was not Ad7 prototype (despite low-level contamination) but adenovirus type 21 (Ad 21; AY601633), another member of the B

subgroup of adenoviruses represented by the Ad7 prototype (AY594255). The observation of a mixture of Ad5 and Ad21 in this sample was confirmed using conventional DNA sequencing for Ad5, amplicon sequencing for Ad21, and spotted microarray results (Lin et al., 2004). Yet, the low-level contaminant of Ad7 prototype was still detected and distinguished by high bit scores in a single tile region subsequence. Thus, in this example, an unanticipated mixed adenovirus sample comprised of Ad5 and Ad21, inadvertently contaminated with small amounts of Ad4 and Ad7 prototype (not found in field samples), was completely resolved. Resolution of this fine detail would be impossible using other types of microarrays (i.e. spotted) without anticipation of such types of events and extensive probe design effort.

FIG. 5 shows the results of influenza A strain identification as described in Example 5. Aliquots of a nasal wash from an Influenza A (+) febrile patient (confirmed by standard viral cell culturing techniques) who was previously immunized (using A/Moscow/10/99(H3N2))-based vaccine) during the 2003-2004 flu season were amplified using (A) universal (Hoffmann et al., 2001) or (B) multiplex (Offringa et al., 2000) RT/PCR primers, and processed according to the standard Affymetrix CustomSeq protocol. Because both strategies produce amplicons of the entire HA, NA, and M genes, the respective tile regions on the microarrays were almost completely hybridized in both cases. REPI output for both cases showed that the highest bit score for HA3 was obtained for the Fujian/411/2002 influenza strain (ISDN38157_InfluenzaA/Fujian/411/2002_Hemagglutinin_1042) that evaded vaccine protection during the 2003-2004 flu season. The prototype influenza A HA sequence used to define the HA3 tile region, (A/Panama/2007/99/H3N2), was not present in the REPI output for the base calls on the HA tile. Thus, a prototype region for an expected strain of influenza A allowed identification of an unexpected strain.

FIG. 6 shows the results of the reduced hybridization time assay as described in Example 6. In this example, a nasal wash that was confirmed negative for all targets probed by the microarray except the erythromycin resistance markers SPYERMB, SPYERMTR, and SPYMEFAE was subjected to specific multiplex PCR for each of these three markers. The amplicons were then hybridized to separate microarrays for either 16 hours (A) or 15 minutes (B), otherwise being processed in accordance with the Affymetrix CustomSeq protocol. In comparison, the signal intensities for the 15-minute hybridization microarray (B) were lower than those on the control 16-hour microarray (A) (note incomplete hybridization to the Affymetrix control probes at the top of the microarray in (B)). However, the REPI output for each of the three tile regions showed that the highest bit scores in each region were the same for both (A) and (B), although both the bit scores and expect values were lower in the cases of reduced hybridization times. Similar results were obtained for 30 minute and 1 hour hybridizations, with an increase in the number of base calls made with increasing hybridization times. However, this example clearly illustrates the robustness of the method to make fine scale discrimination between targets with a range of different hybridization patterns.

FIG. 7 shows the effects of subtractive hybridization approaches as described in Example 7. (A) Shows the hybridization pattern obtained following total amplification of the isolated nucleic acids from an aliquot of nasal wash from a patient with febrile respiratory illness at Lackland AFB. This sample was positive for Ad4 at an estimated titer of 10^4 genomic copies per microliter. The high background hybridization across the microarray prevents GDAS from making base calls even though the adenovirus type 4 region showed a discernibly higher signal than that of the overall background. Co-hybridizing the same set of total amplicons obtained in (A) with COT-1 fraction human genomic DNA (B) did little to improve this as again no base calls were made by GDAS. (C) Shows that the use of a magnetic bead-based subtraction alone, prior to total amplification, did not result in a sufficient number of base calls to allow similarity searching. However, through the combined use of a bead-based

subtraction (Streptavidin-coated beads conjugated with biotinylated COT-1 human DNA) prior to amplification and co-hybridization with solution phase COT-1 human DNA (D), enough base calls could be made to unambiguously rank the adenovirus 4 Air Force field strain (accession number AY599837) highest in each of three subsequences identified in the Ad4HEXON-1 tile region (D). Moreover, by performing the same set of combined steps using 2 microliters of starting sample material instead of 1 microliter (E), base calling was extended into the Ad4FIBER tile region in addition to Ad4HEXON-1, allowing unambiguous high bit-score ranking for an Ad4 field strain in the Ad4HEXON-1 tiles and in several Ad4FIBER subsequences.

FIG. 8 shows hybridization of Influenza A targets (Fujian 411/2002), spiked into normal nasal wash, following amplification using a recently-described modification (Kessler et al., 2004) of a previous (Wang et al., 2003) protocol for non-biased amplification of viral RNA genomic targets. FIG. 8 (A-C) show hybridization patterns for 10^5, 10^3, and 10^1 plaque-forming unit (pfu) spike-in amounts, respectively (see Example 9). These results demonstrate that the efficacy of the present approach can be retained even when a non-biased amplification scheme is used. This should allow extension of the overall approach to preparation of a multiplicity of unknown RNA targets and for incorporation of this particular protocol into a combined method for universal amplification of both RNA and DNA pathogen targets for the resequencing microarray.

FIG. 9 shows a flowchart representation of an embodiment of the present invention in which the RNA and DNA pathways are converged.

FIG. 10(a) is an exemplary flowchart illustrating the process currently in use by the industry.

FIG. 10(b) illustrates an alternative case often found in practice in the industry.

FIG. 10(c) is a schematic drawing of a general system layout for interaction with a comparison database and server.

FIG. 10(d) shows an example of a sequence output from analyzing a microarray demonstrating poor hybridization.

FIG. 11(a) is an exemplary schematic drawing of an embodiment of the system.

FIG. 11(b) is an exemplary schematic drawing of an embodiment of the Resequencing Pathogen Identifier (REPI).

FIG. 11(c) is an exemplary screen shot of an interface for an ASP.

FIG. 12 is a flowchart describing the general functionality of the ASP.

FIG. 13 is an exemplary flowchart of a control check step.

FIG. 14(a) is an exemplary flowchart of the extract subsequence step.

FIG. 14(b) is an example of a sliding window according to one embodiment of the system.

FIG. 15 is an exemplary flowchart describing in more detail a trim function performed by the system.

FIG. 16 shows an exemplary flowchart detailing actions in the Check Length step.

FIG. 17 shows an exemplary flowchart of the Calculate Percentage step.

FIG. 18(a) is an exemplary flowchart describing in more detail the actions of the system within the Analyze Step.

FIG. 18(b) illustrates an exemplary output of an embodiment of the invention.

FIG. 19 is an exemplary flowchart describing an additional embodiment of the system.

FIG. 20 is a block diagram of a computer system (or server) upon which an embodiment of the present invention may be implemented.

FIG. 21 is an exemplary flowchart of an embodiment for distinguishing between a mixture and a

recombination.

FIG. 22 is a stylized exemplary schematic of an embodiment that incorporates intensity data to provide decision-quality information to a user.

FIG. 23 is an exemplary flowchart illustrating a method for designing or optimizing a resequencing microarray.

FIG. 24 is an additional exemplary flowchart illustrating a method for designing or optimizing a resequencing microarray.

FIG. 25 is an example of a dendrogram.

FIG. 26 is an exemplary graphical representation of a multiple alignment.

FIG. 27 is an example of a consensus sequence generated by a multiple alignment.

FIG. 28 is another exemplary graphical representation of a multiple alignment including a consensus sequence.

FIG. 29 illustrates an example of a modified consensus sequence.

FIG. 30 is an exemplary output of an embodiment of the present invention.

FIG. 31 is an example of simulated hybridization output according to an embodiment of the present invention.

FIG. 32 illustrates another example of a consensus sequence.

FIG. 33 is an exemplary flowchart for formatting resequencing array data according to an embodiment of the present invention.

The components in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the present invention. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

MODES FOR CARRYING OUT THE INVENTION

Unless specifically defined, all technical and scientific terms used herein have the same meaning as commonly understood by a skilled artisan in enzymology, biochemistry, cellular biology, molecular biology, bioinformatics, and the medical sciences.

All methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, with suitable methods and materials being described herein. In case of conflict, the present specification, including definitions, will control. Further, the materials, methods, and examples are illustrative only and are not intended to be limiting, unless otherwise specified.

It is well known that DNA microarrays might be used to analyze the sequence of target nucleic acids from pathogens for diagnostic or surveillance purposes. The effects of oligonucleotide probe sequence selection, length, positioning on surfaces, the physical chemistry of binding, and labeling techniques, have been the topics of vigorous research in the past ten years. However, heretofore, the approaches taken have almost exclusively involved the use of single oligonucleotide probes (13-70mers) that are specifically designed to hybridize to a single recognized pathogen target sequence with high specificity (13-25mers) or to a longer stretch of pathogen target with a lesser degree of specificity (70mers). These microarrays are commonly known as spotted microarrays, but the same content of a spotted microarray can also be embodied in other forms besides two-dimensional planar surfaces, one example being "bead arrays" (Ferguson, Steemers & Walt, 2000).

There have been many fewer descriptions of pathogen identification and characterization using Affymetrix

resequencing microarrays. Kozal (Kozal et al., 1996) measured mutational drift in HIV and Gingeras (Gingeras et al., 1998; Gingeras et al., 2001), and Troesch (Troesch et al., 1999) identified mycobacterial species and Single Nucleotide Polymorphisms (SNPs) relating to antibiotic resistance using resequencing arrays. Wilson et al. (Wilson et al., 2002a) used the same types of arrays for bacterial identification using ribosomal RNA and for detection of multiple biowarfare agents (Wilson et al., 2002b).

The use of resequencing microarrays for simultaneous pathogen identification and surveillance has fundamental advantages over single oligonucleotide approaches because detailed target sequence information becomes directly available as part of the raw microarray data. By definition, spotted microarrays having 10^2 to 10^4 oligonucleotide probes are incapable of resolving subtle sequence variations for more than 10 – 1000 base pairs of total target sequence, even if the array were designed with a tiling strategy. Thus, spotted oligonucleotide microarrays that facilitate identification of a broad spectrum of pathogens at an individual strain or SNP level (Cherkasova et al., 2003; Wang et al., 2002; Wang et al., 2003) require that the pathogen target sequence be determined using conventional DNA sequencing technology, requiring specialized equipment, personnel, and time periods of several days.

Accordingly, the present invention generally relates to the detection and identification of bacterial, viral and protozoan pathogens and virulence markers using DNA microarray technology. The present invention also relates to the design, test, and analysis of resequencing microarrays having defined regions that can be used to assign numeric detection probabilities for a large number of specific pathogen genotypes and mixtures of pathogens. Furthermore, it relates to methods required for the processing of both simple and complex (e.g. clinical and environmental) samples for said microarrays.

More specifically, the present invention relates to the use of high plurality resequencing microarrays as a novel class of devices for purposes that would include diagnosis of infectious disease agents and pathogen surveillance. In particular, it pertains to DNA microarrays that employ a large number (hundreds to thousands) of selected "prototype" nucleic acid sequence regions (typically 250-2000 base pairs each) from target genomic sequences to detect and identify a logarithmically larger number (thousands to tens of thousands) of both unrelated and closely related (strain level) microbial pathogens. More particularly, the invention relates to the design of microarrays fabricated to allow a resequencing of the target nucleic acids using a "tiled" probe approach. Yet even more particularly, the invention concerns the design of Affymetrix resequencing microarrays using tiled probes that will allow for analysis of up to 10^3 to 10^6 base pairs of target sequence.

In a particular embodiment, the present invention provides a method for simultaneously assaying for a large number of pathogens by detecting their nucleic acid sequences and subjecting the detected sequences to an automated similarity search against public domain and private databases. This object is accomplished by a non-obvious adaptation of a commercial technology (Affymetrix CustomSeq™). The program employed, CustomSeq™, was designed for detection of Single Nucleotide Polymorphisms (SNPs) by resequencing target DNA. This so-called SNP-detection calls for: (1) an error rate in base calling that is much lower than the naturally occurring frequency of mutation (in humans approximately (1 per 10^9 base pairs), (2) amplification of the purified starting material, at a concentration of 10^5 genomic copies/ microliter, prior to microarray hybridization using *specific* PCR primers, and (3) combination and processing multiple chips for replicate samples by an algorithm that restricts base calls to those having a degree of confidence at which the presence of low frequency SNPs can be deduced. The present inventors demonstrate that Affymetrix resequencing technology can be adapted for insertion into an integrated system for high multiplicity infectious disease diagnostics and pathogen surveillance in a time

scale and level of sample preparation complexity that are enabling for point-of-care diagnostics applications. This system is substantively different from the intended use of the Affymetrix technology, and is not obvious to the typical skilled practitioner of microarray technology.

At present, there have been few, but relevant literature descriptions of application of Affymetrix resequencing technology to pathogen identification. From the design, experimental, and analysis standpoints, the present invention has substantive advantages over the prior art in pathogen characterization using resequencing. Kozal (Kozal et al., 1996) measured mutational drift in HIV and Gingeras (Gingeras et al., 1998; Gingeras et al., 2001), and Troesch (Troesch et al., 1999) identified mycobacterial species and SNPs relating to antibiotic resistance using resequencing arrays. In each of these cases, optimized sequences were selected for tiling, based on alignments of the possible target sequences. Specific PCR primers were designed to amplify targets for hybridization. Unknown clinical isolate identifications were made using pattern recognition algorithms based on empirically determined differential hybridization patterns to the arrays. As such, this approach would depend on the amplification and hybridization of the full length of the target sequences, and would not be amenable to: (1) contributions of confounding non-specific binding resulting in lost base calls, (2) incomplete hybridization across the length of the target due to low target concentration or gaps caused by low homology, and (3) compromised hybridization integrity caused by non-biased (total) amplification of unknown target sequences from a clinical or environmental sample.

The method proffered by the present inventors does not share the same limitations as those disclosed in the prior art using resequencing microarrays. Moreover, technology enablements for at least one intended use, namely the simultaneous detection of a large number of diverse pathogen species, have only recently occurred with the introduction of Affymetrix microarrays (18 x 18 micron features) for CustomSeq™ RPMV1 chip and higher density (8 x 8 micron features) for Respiratory Microarray Version 2 (RPMV2), allowing 29.7 kb and 300 kb, respectively, to be tiled for resequencing. However, the most significant improvement offered by the present invention is the use of the increased density chips with sequence length-independent similarity searches (BLASTN), which affords that many fewer assumptions must be made in advance of selecting sequences for tiling. Furthermore, the use of length-independent similarity searches (BLASTN) removes the constraint that a particular known subsequence be fully resequenced, making the approach more resistant to variations in target concentration and contributions from nonspecific binding leading to lost base calls.

Thus, in the present invention, sequences selected for tiling are "prototypes" in the sense that a single gene or subsequence may represent a much broader class of organism species and subspecies (alternatively types, strains, variants, or mutants). The resulting method is robust with respect to minor variations in the genotypes of individual pathogens and strains, and enables detection and probable identification among a plurality of candidate pathogens that may not be explicitly represented in the design of the experimental chip layout, including the tiled regions.

The chip layout also takes advantage of partially redundant tile sets (these were discouraged by the manufacturer's design guidelines and by the manufacturer during design), both intragenic and intergenic variation within a single pathogen strain, and between multiple similar or diverse pathogen types. However, the present inventors have determined that the redundancy is important to elevate confidence in results and to minimize likelihood of false positive and false negative results. Advantages of this design/analysis approach will permit incorporation of both conserved and hyper-variable regions of genomes, facilitating group, type, and strain level identification.

There are only a few literature reports describing generic amplification strategies for microarray analysis of

microbial pathogens. Wang et al. (Wang et al., 2002) described a multi-step process for amplification of RNA pathogen targets followed by sequential PCR and Klenow fragment-based amplifications, prior to hybridization on 70mer oligonucleotide arrays. The time and/or number of technical steps required for this amplification were not specified but a subsequent paper from the same group (Wang et al., 2003) reported it to be approximately 24 hours. It was also not specified which of the amplification steps resulted in enhanced detection efficiency. A recent report from our group (Vora et al., 2004) describes a variety of nonspecific nucleic acid amplification techniques, individually and in combination, for hybridization to 70mer oligonucleotide arrays. There are no known reports of prior art in the area of nonspecific amplification of DNA targets, either purified or in a complex mixture (e.g. clinical sample), for hybridization to a resequencing microarray.

The present invention generally advances the art of generic amplification for pathogen detection by microarrays in several ways: (1) it details specific methods for total amplification of purified or highly enriched pathogen nucleic acids for presentation to a high density short (25mer) Affymetrix resequencing array, which is neither previously described nor obvious, since the methods are a large departure from the prescribed Affymetrix protocols, and (2) it describes novel alternative approaches to the use of enzymatic processes, competitive hybridizations, and magnetic bead-based subtractive and enrichment steps to reduce background and subsequent non-biased (i.e. total) amplification and microarray hybridization.

The present invention is embodied by a specific set of design and processing methods that enable broad-scale pathogen identification and characterization by utilizing resequencing microarrays. Specifically, the present invention allows for the precise, sensitive, and high confidence identification of a large multiplicity (thousands) of pathogens in a single assay.

In an embodiment of the present invention is a resequencing DNA microarray chip of multiple groups of oligonucleotide primers of a length ranging from 13 to 70 nucleotides (preferably 25 nucleotides, although it is possible and is within the scope of the present invention to use primer lengths corresponding to each integer value within this recited range) immobilized to a solid phase support, wherein each group of oligonucleotide primers is selected to span a particular region of the reference sequence, occupying a discrete area of the array (e.g. a tile), and comprising at least four sets of primers arranged in a parallel fashion on the chip: 1) a first set that is exactly complementary to the reference sequence; and 2) three additional sets of primers, each of which is identical to the first set of primers but for the nucleotide at a central position, which is different in each of the three sets such that all four conventional nucleotide bases are present on said array.

The present invention further provides methods for processing complex clinical samples (e.g. nasal wash) requiring minimal nucleic acid isolation/amplification step(s).

The present invention is distinct from the overwhelming majority of microarray-based pathogen detection schemes because it uses high-density "tiled" microarrays to determine the actual sequences of pathogen genetic targets. It is further unique from other resequencing pathogen identification strategies in a number of important areas, including incorporation of: (1) a high multiplicity of disparate pathogen "prototype" target regions that exhibit little or no discernible cross-hybridization or interference with one another, (2) a high sequence redundancy within closely related pathogens that allows higher confidence identification of specific strain (e.g. adenoviruses or influenza viruses), (3) "prototype" regions of large tiled segments representative of a class of pathogens allowing for the precise identification of specific pathogen strains and the use of specially-designed software to parse and arrange sequence fragments for presentation to similarity search (e.g. BLAST) algorithms, allowing discrimination of pathogen mixtures and recombination events between pathogens, instead of the more restrictive tile selections

and differential algorithm described in the most closely-related prior art (US Patent 6,228,575), (4) minimally-biased nucleic acid amplification strategies that allow precise, high-confidence pathogen target resequencing without significant interference or cross-hybridization, and (5) sample processing methodologies that allow the resequencing array to be used in conjunction with minimally-biased nucleic acid amplification strategies on complex clinical samples.

The combination of these methods allows the simultaneous detection and identification of a high multiplicity of pathogen(s) from a clinical sample by a single qualified technician within a period of 24 hours, but preferably within 4 hours, more preferably with 2 hours, most preferably within 30 minutes.

Accordingly, owing to its embodiments, the present invention supports: (a) routine diagnosis of infection in a clinical setting within several hours of sample collection, (b) simultaneous interrogation of the sample for indications of a rare infectious event (e.g. unanticipated pathogen, antibiotic resistance pattern or biological warfare agent), (c) routine molecular pathogen surveillance, (d) vaccine quality control and (e) monitoring of genetic changes of a pathogen as a result of natural genetic variations, drug treatment, intentional manipulation, or other events.

High-density resequencing microarrays

High-density microarrays (HDMs) are fabricated by light-directed combinatorial synthesis of DNA oligomers (Kozal et al., 1996). The DNA oligomers synthesized on these sites typically have lengths of 20-30 bases. Through subsequent improvements to the method using high-resolution semiconductor photoresists, Affymetrix has demonstrated fabrication of HDMs having individual features with resolutions approaching 1 μm^2, enabling probe feature densities of 10-100 times greater than that demonstrated in the RPMV1. To date, HDM designs relevant to pathogen identification have been based on a "tiling" strategy. Accordingly, four probes of equal length are synthesized for each base in both the sense and antisense directions, requiring that a total of eight 25-mer probes are used for each base pair in a given reference sequence. One probe in each direction (sense and antisense) exactly complements the reference sequence while three others have a single base mismatch at the position of the interrogated base. Thus, a tiled HDM can effectively allow the target nucleic acid to be "resequenced".

In this manner, the base calls of the unknown target are interrogated at each of one of four possible base positions (one of every four possible base pairings varied at the number 13 position in the tiled 25mer probes), allowing a direct read of the target sequence from the corresponding positions across the array. In the case of CustomSeq arrays, the GCOS (Version 1.1) software is used to reduce the raw image (.DAT) file to a simplified file format (.CEL file) with intensities assigned to each of the corresponding probe positions. Finally, the GDAS (Version 2.0) software is used to apply an embedded version of the ABACUS (Cutler et al., 2001) algorithm to produce an estimate of the correct base calls, comparing the respective intensities for the sense and antisense probe sets. One of the available export file types from GDAS is the FASTA-formatted base calls made for each tiled region of the resequencing array.

HDMs of the type described above have been used to identify pathogen species and detect drug resistance-conferring mutations in a series of *in vitro* experiments using cultured microorganisms, including HIV (Kozal et al., 1996). Troesch et al. (Troesch et al., 1999) designed HDMs to discriminate between 54 different to detect *Mycobacterium* species and *Mycobacterium tuberculosis* rifampin resistance. A tiled array of 65,000 oligomer probes was used to accurately resequence 70 clinical isolates of 27 mycobacterial species and 15 rifampin-resistant

M. tuberculosis strains. More recently, sequence-specific identification of *F. tularensis* and *Y. pestis* was demonstrated in environmental samples using tiled HDMs (Wilson et al., 2002b). Both of these general approaches rely on specific hybridization patterns based on ground-truth (control) measurements. Moreover, the authors have provided no direction on how a quantitative comparison might be made against closely-related or unanticipated organisms for starting concentrations that may vary by six orders of magnitude.

Array types

The present invention is developed using Affymetrix CustomSeq resequencing microarrays. For a discussion of resequencing microarrays, the artisan is directed to U.S. 6,228,575. However, the present invention is not conceptually limited to microarrays produced using that specific fabrication strategy. In principle, resequencing can be performed on the scale described with any technology that is capable of producing microarrays with sufficient feature density to allow this approach. Theoretically this can be accomplished using an oligonucleotide printing technology, but it is more likely accomplished using a photolithographic approach. Whereas the Affymetrix resequencing chips are based on sequential lithographic steps using a separate mask that corresponds to each step, an alternative approach could use maskless lithography (Albert et al., 2003; Nuwaysir et al., 2002) or by nanolithographic methods (Ginger, Zhang & Mirkin, 2004). More generally, any method of producing a plurality of oligonucleotide probes for the purpose of determining target sequence would be applicable, even bead "arrays" that are not in a 2-dimensional format (Ferguson et al., 2000).

The probes themselves could be comprised of variants of DNA, namely RNA or oligomeric peptide-nucleic acids (PNA). The probes can be made sensitive to enzyme digestion, then subject to subsequent handling. In a preferred embodiment, the probes will incorporate dUTP instead of dTTP, making them sensitive to uracil-DNA-glycosylase. This will make them amenable to selective degradation following the capture of target. Moreover, within the scope of the present invention it is also possible to immobilize RNA and obtain complementary sequence recognition thereof. Immobilization of RNA would require chemical stabilization of the RNA. In a more general sense, the probes can be made from chemically modified nucleic acids that would make them more or less susceptible to subsequent chemical processing steps.

Array design

This present invention, using the RPMV1 microarray, illustrates the ability of tiled prototype sequences to identify a wide variety of specific pathogen strains without assuming that specific hybridization patterns are required for specific pathogen identification. In the current apparatus, the prototypes for tiled regions, particularly those for adenoviruses 4, 5, and 7, were empirically chosen to be representative of adenovirus subgroups E, C, and B, respectively.

A more preferred and systematic approach to the design would involve the use of multiple sequence alignments to produce consensus sequences, where consensus sequences are defined as those representing the most frequent bases at the alignment position. In a preferred embodiment, the alignment algorithm will produce a hierarchical phylogenetic tree for target gene sequences from individual pathogen strains or for a group or family of pathogens. A consensus sequence will first be formed for members of each node or group of nodes on the tree, whose distance measures fall within a threshold, using an appropriate algorithm (Lee, 2003). The actual target sequences would then be compared individually to the consensus sequence, and the effects of hybridization to a tiled microarray region defined by the consensus sequence would be simulated. Known effects such as insertion or

deletion of bases, as well as the effects of multiple base substitutions within an oligonucleotide probe region would define rules for the simulated hybridization. Subsequent analysis of the resultant hybridization and base call pattern would then indicate the suitability of a proposed tile for acting as a prototype for a given range of pathogens. This process would be reiterated until the most suitable set of prototype regions were defined for coverage of a given set of pathogens. In one very preferred embodiment, this process would be used to maximize the efficiency of space usage on a chip, resulting in the greatest reduction in the overall physical dimensions of a resequencing microarray, and thus, the greatest reduction in manufacture cost per microarray.

In one preferred embodiment, the resequencing array would be designed in combination with another less complex solid phase capture device (array, gel, or otherwise) that that would be used initially to queue the resequencing array. For example, an array comprised of a multiplicity of long oligonucleotide probes would be used initially for the detection of pathogen by recognizing conserved sequences within a family of pathogens. The resequencing array could then be used to interrogate variable regions associated with the conserved probes on the initial array, providing detailed sequence information on the pathogen. In a very preferred embodiment, the sample preparation would be common for both the solid phase capture device and the resequencing microarray. In yet another very preferred embodiment, the initial array would be used to capture target that would be isolated and then amplified using non-biased amplification techniques for presentation to the resequencing array.

Overall design philosophy for the intended use

This invention leverages pathogen genome information from various public and/or private sources to design, fabricate, evaluate, validate and integrate an advanced diagnostics platform as part of an effective biodefense surveillance and operational medicine system. It is an integral facet of the Epidemic Outbreak Surveillance (EOS) program biodefense model that the system would most effectively be enabled through the adoption of a widely distributed device that would find utility in routine diagnostics of infectious diseases, most particularly in diagnosis of infectious respiratory disease (see the Defense Sciences Board Summer 2000 Study Report and the Health Sciences Biodefense System (HSBS) final briefing). It is important that the device (e.g. microarray) will provide a cost-effective alternative to conventional approaches to the diagnosis, management, and surveillance of infectious diseases, most particularly respiratory infections. It is equally important that the device is supported with design and analysis informatics, and to ensure that decision quality information from that device will be transmissible and interpretable by a variety of care providers, public health officials, and decision makers. Thus, it is a critical objective of this invention that the device (e.g. microarray) be a key component of an integrated *system* comprised of a local point-of-care diagnostic device that provides automated, two-way data sharing between health care providers, public health officials, and decision makers (this a maybe a cross-reference to the business model patent that is in the queue). The invention described herein might fulfill this role in at least two ways: (1) through reduction in array size (i.e. lower cost), process automation, and the availability of portable hardware for processing resequencing arrays, the invention could become the object of the point-of-care device itself, and (2) in the event of lower-cost or easily automated microarray alternatives, the resequencing array can be a higher echelon component in a diagnostics/surveillance pipeline. In the latter case, the lower-cost alternative device will provide for initial sample processing, pathogen target enrichment, amplification, decision information at the point-of-care, while the resequencing capability provides for a sequential testing capability by facilitating a more detailed interrogation of the sample when desired.

General strategy for resequencing microarray chip design

According to the present invention, the process of designing resequencing microarray chips is carried out by selecting pathogen genomic sequences having sequence properties that make them unique to a small number (ideally one) of pathogens, or are highly conserved, allowing them to detect many types of microbial species at the family or genus level, or are moderately conserved and selected as "prototype" regions. Prototype regions will have an intermediate level of sequence homology across a group of microbial species and allow for both efficient hybridization and unique identification of most or all of a subtype of pathogenic species. The design strategy for layout of resequencing tiles includes leveraging from alignment of similar sequences and application of a consensus probe sequence for tiling to the chip. The consensus sequence might not be identical to any of selected pathogens, but will interact with a plurality of similar pathogen genomes. The patterns of perfect and imperfect matching of real pathogen genome sequences with the consensus sequence will provide diagnostic discrimination power.

In a particular embodiment of the present invention is a general protocol for designing resequencing microarray chips that permit the identification and designation of pathogens present in a sample (e.g., a partially purified sample, a purified sample, an enriched sample, a biological sample, etc.). The various aspects of this design and validation protocol are embodied in the following 6 "phases."

Phase 1: Pathogen Identification:

a. Pathogen list (e.g. Adenovirus; Influenza; *Streptococcus pyogenes*) – provided by pathogen experts or public domain
b. Genus/species (new pathogen i.e. Severe acute respiratory syndrome (SARS) variant of corona virus)
c. Species/subspecies (Epidemiologic tracking; forensics)
d. Pathogen unique segments (cross hybridization issues)
e. Issues of genetic shift/drift (e.g. Influenza, HIV)
f. Drug resistance markers
g. Pathogenicity-related genes or virulence markers (useful for diagnostic and prognostic purposes)
h. Markers for genetically engineered traits
i. Plasmid DNA sequence (Bluescript, PUC etc.)
    i. Multiple cloning sites
    ii. Drug resistance markers (ampicillin, kanamycin, penicillin etc.) (or could list as : Amp, Kan, PBP, etc.)
    iii. Toxins (botulinum; ricin etc)

Phase 2: Pathogen identification in relation to sample sources:

a. Common respiratory pathogens (and close relatives)
b. Biothreat agents: (identified by Centers for Disease Control)
c. Consideration of background or commensal organisms in:
    i. Clinical samples (nasal wash, swab, stool, etc.)
    ii. Vectors (e.g. mosquito)
    iii. Environment (water, food, soil)

Phase 3: Gene Identification: (Most complicated issue associated with pathogen design)

a. Sequence Homology (relative to pathogen identity)
    a. Highly conserved (Genus/Species identification) Identification of novel or unanticipated)
        i. Identify new/ unanticipated organisms
            1. chimeras (bacterial genetic exchange)
            2. genetic shift/drift variants (i.e. Influenza)
            3. man-made
        ii. Distinguish complicated pathogen families
            1. Rhinovirus (many disparate variants)
    b. Less conserved to hypervariable (Species/subspecies)
    c. Pathogen-unique sequence segments (cross hybridization)
        i. Potentially important for a total amplification approach
b. Functional Sequences (relative to pathogenicity and patient management)
    a. Drug Resistance genes in commensal microbes
    b. Pathogenicity related genes
        i. Toxin genes
        ii. Transmission (Infectivity) related genes
        iii. Pathogenicity islands
        iv. Virulence factors
    c. Other Host-pathogen interacting genes
        i. Immune response
        ii. Tumorogenesis
        iii. DNA repair

Phase 4: Gene Selection (What sequences should actually be placed on the chip)

a. Identify Gene Accession Number(s)
    a. Complete gene
    b. Pathogen genome for flanking sequences (Controls)
    c. Most recent/prevalent variants available
        i. Especially important for rapidly evolving pathogens (Influenza)
b. BLAST search: (Inclusion/Exclusion criteria)
    a. Human sequence homology (exclusion criteria)
    b. Related pathogen sequences
        i. Possible exclusion/annotation criteria
        ii. If > 90% homology, sequence needs only to be deposited once
            1. Use consensus sequence for identity and annotate as such
        iii. Identify pathogen specific genes/ sequences
c. Pragmatic Issues
    a. Horizontal gene transfer issues in bacteria
    b. Number of copies of gene in pathogen

c. Sequence homology with human sequence (cross hybridization)

d. Sequence homology with less pathogenic species (i.e. Bacillus; variola [pox])

Phase 5: RPM chip prioritization

a. Define chip "real estate" (total sequences represented)

a. Target gene tile sizes

i. Associate accession numbers with tiles

ii. Associate accession numbers with consensus sequences

b. Refer to primary objectives for prioritization criteria. Key issue include:

a. Prevalence of pathogen depending on targeted population, geographic location, season, and other disease transmission factors

b. Clinical, operational, and public health relevance

c. Chip functionality issues:

i. Mixed pathogens

ii. Data annotation and presentation to end-user

Phase 6. Microarray Validation:

a. Design controls

a. Nested primers sets:

i. Outer primer set: Develop controls

ii. Inner primer set. Assay positive control

iii. Control and RPM sequence should be 100% sequence match

b. Control clones developed

c. Control clones sequence validated for match.

b. Develop pathogen chip annotation schema:

a. Sites of poor hybridization

i. Poor signal

ii. Incorrect signal

b. Sites of cross hybridization

i. Human cross hybridization

ii. Other pathogens (especially bioterrorism agents and toxins)

c. Level of specificity of sequence

i. Markers that can identify subspecies/variants

1. Forms the basis of a forensics database

ii. Markers that can identify genus or species only

iii. Identification of new variant markers as discovered

c. Chip Validation Experimental Framework:

a. Human hybridization to detect cross hybridization regions

b. Plasmid-based validation schema:

i. Titrate plasmid for PCR sensitivity

ii. Titrate for RPM detection sensitivity

iii. Estimate base-calling accuracy with varied concentrations

1. Annotate any errors

c. Culture-based validation schema

i. Titration of virus

1. Efficiency of nucleic acid isolation
2. Chip hybridization sensitivity/specificity
   a. Total amplification sensitivity/specificity
   b. PCR comparison
3. Chip hybridization sensitivity from titrated culture
4. Sequence validation of culture sequence

d. Spiked pathogens into complex media

i. Titration of virus into solution

ii. Hybridization to chip (background interference)

iii. Sequence validation of virus if different than culture pathogen

e. Estimation of target concentration from complex matrices.

i. Nasal wash

ii. Cotton swab

1. Nasal swab
2. Throat swab

iii. Stabilization of virus in solution

1. Nasal wash
2. Swabs

iv. Freeze/thaw effects of virus solution

v. Sequence validation of target pathogen

The following table (Table 1) represents a preferred (but not limiting) set of pathogens (both viral and bacterial) that may be used within the context of the present invention as designed for the detection and diagnosis of common respiratory pathogens:

Table 1 Microarray Pathogens

Viral Pathogens	Bacterial Pathogens
Adenovirus (Serotypes/Genus level)	*Streptococcus pyogenes* (emm types/resistance)
Influenza A and B (strains)	*Mycoplasma pneumoniae*
Coronavirus/SARS	*Bordetella pertussis*
Parainfluenza 1,2,3,4	*Chlamydia pneumoniae*

Respiratory Syncitial Virus	*Streptococcus pneumoniae*
Metapneumovirus	*Legionella* (genus level)
Rhinoviruses	*Moraxella catarrhalis*
Coxsackie virus	*Haemophilus influenza*
Echoviruses	*Neisseria meningitidis*
West Nile Virus	*Mycobacterium tuberculosis*
Varicella (HHV-3)	*Staphylococcus aureus*
Hantaviruses	*Arcanobacterium hemolyticum*
Rubella, Rubeola	*Chlamydia psittact*
Herpes simplex types 1 and 2	
Enteroviruses (mumps, polio)	
Parvovirus	

For the intended use of a broadly distributed respiratory diagnostic device with built-in surveillance capability for agents of bioterrorism, the list of pathogens chosen for inclusion onto the chip would also include those selected from the U.S. Centers for Disease Control (CDC) Category A, B, and C bioterrorism agents. These are most notably, but not limited to, include:

CDC Category A

Bacillus anthracis (targets: lethal factor, protective antigen)
Yersinia pestis
Smallpox (variola major)
Francisella tularensis
Viral hemorrhagic fevers (filoviruses [e.g. Ebola, Marburg] and arenaviruses [e.g. Lassa, Machupo]

CDC Category B

Brucella abortus (2308 B37), *Brucella melitensis* (F6145), *Brucella suis* (A44)
Burkholderia mallei (Glanders)
Burkholderia pseudomallei (Meliodosis)

Psittacosis (*Chlamydia psittaci*)

Typhus fever (*Rickettsia prowazekii*)

Viral encephalitis (alphaviruses [e.g., Venezuelan equine encephalitis, eastern equine encephalitis, western equine encephalitis])

CDC Category C

Emerging infectious diseases such as Nipah virus and hantavirus

A complete and updated listing of these agents may be found on the CDC website (http://www.cdc.gov/).

For purposes of illustration of the present invention, two resequencing microarray chips (RPMV1 and RPMV2) will be described herein below:

Resequencing respiratory pathogen microarray version 1 (RPMV1 chip)

RPMV1 was made using a high-density Affymetrix microarray fabrication process having an individual probe feature size of 18 x 18 microns. At this density, 29.7 kb of total pathogen target sequence was tiled for resequencing. The fabrication was performed as part of a pre-production beta-test of an Affymetrix commercial product (CustomSeq) that was intended for SNP detection in an arbitrary collection of sequences.

The following overall design strategy was used for the RPMV1:

The Affymetrix CustomSeq design protocol was followed. While there were a variety of ongoing efforts within the project consortium to non-specifically amplify targets for microarray analysis, the present inventors made every effort to tile sequences on the array that could interrogate conventional (specific primer pair) PCR amplicons. Whenever possible, primer pairs were developed or adapted for conserved sequences that flanked the variable regions to be interrogated with tiled microarray probe sets. This allowed for the ability to: (1) directly amplify with an existing hardware platform (e.g. RAPID Light Cycler, Idaho Technologies), (2) provide control measurements for comparison with generic or total amplification strategies that are on the immediate horizon. In general, our strategy was to match the hybridization patterns with specific strains of organisms and to detect subtle variations in sequence that corresponds to pathogenicity and drug resistance.

Adenovirus (double-stranded DNA virus) types 4, 5, and 7 were designated as "prototypes" for the E, C and B subgroups, respectively. Specifically, the present inventors postulated that resequencing on the prototype-tiled regions would allow detection and identification of subtle sequence variations between the subgroup members. Three target gene regions were selected, specifically from E1A, hexon, and fiber genes. However, it was not postulated nor anticipated which regions or which sections of any of the tiles would allow unique identification.

Thirteen adenovirus genomes were completely sequenced as part of the Epidemic Outbreak Surveillance program. The names, accession numbers, and sources for these are listed in Table 6 of the Examples section. Multiple sequence alignments were performed to determine variable regions of the E1A, hexon, and fiber genes that were flanked by conserved regions that could be used to amplify multiple adenoviruses with a single set of degenerate primers (Lin et al., 2004). These common regions for E1A, hexon, and fiber genes were obtained for each of the 3 prototype adenoviruses that are associated with respiratory illness: 7 (subgroup B), 5 (subgroup C), and 4 (subgroup E) were submitted to Affymetrix as part of the 29.7 kb total pathogen target sequence for tiling on the RPMV1 microarray.

Adenovirus Taxonomy:

Sub-Group B: 3, 7, 11, 14, 21, 34, 35 and 50

Sub-Group C: 1, 2, 5, and 6

Sub-Group E: 4

The present inventors made the hypothesis that if they tiled three genes (E1A, Fiber and Hexon) on the array for prototype sub-group representatives, types 7, 5, and 4 (for subgroups B, C, and E, respectively), they would be able to identify any of the fully-sequenced types (listed above) by variations in the hybridization patterns that map to their sequence differences.

Influenza A and B viruses, which are negative-polarity single stranded RNA viruses (ssRNA), were represented with prototype regions for hemagglutinin (HA) neuraminidase (NA) and matrix (M). These genes were represented for three types of Influenza A (H1N1, H3N2 and H5N1) and Influenza B. Influenza is one of the best examples of a prototype model system, as hundreds, if not thousands of influenza strains have been at least partially sequenced, and most have been sequenced for the hemagglutinin and neuraminidase segments.

Prototype Influenza HA, NA and M genes were chosen from strains that were either identical of closely related to the three vaccine strains recommended for the Northern hemisphere by the World Health Organization;

- A/New Caledonia/20/99/(H1N1)
- A/Moscow/10/99/(H3N2)
- B/Hong Kong/330/2001

These sequences were publicly available from the Los Alamos National Laboratory influenza Internet database. The present inventors postulated that the sequence calls made for unknown Influenza A or B on the prototype tile regions would allow the identification of that target if it was sufficiently similar to allow similarity search-based querying.

The remainder of RPMV1 was populated with tiles for a variety of common respiratory pathogens, the first set being viruses:

Rhinovirus A (pos)SSRNA

Rhinovirus B (pos)SSRNA

Coronavirus (pos)SSRNA; no DNA stage

Parainfluenza (neg)SSRNA

RSV (neg)SSRNA

These viral pathogens had relatively little sequence available compared to adenovirus and influenza, complicating efforts to perform analogous tests for use of prototype sequences to identify a large number of related strains.

Common bacterial pathogens were also chosen:

Streptococcus pyogenes

Mycoplasma pneumoniae

Bordetella pertussis

Chlamydia pneumoniae

Streptococcus pneumoniae

Neisseria meningitidis

In addition, the following plasmid-conferred antibiotic resistance genes were represented on the RPMV1 chip:

ermA

ermB

ermTR

macrolide-efflux determinant (*mef*)A

The following biological threat agents were also included on the RPMV1 chip:

Bacillus anthracis (targets: lethal factor, protective antigen)

Yersinia pestis

Smallpox (variola major)

Francisella tularensis

Viral hemorrhagic fevers (filoviruses [e.g. Ebola, Marburg] and arenaviruses [e.g. Lassa, Machupo])

In addition to the hybridization controls prescribed by Affymetrix (see CustomSeq protocol), it was considered necessary to include internal process controls to verify target isolation, reverse transcription (RT) and cDNA/DNA amplification. Thus, we included a specialized vector containing gene inserts from the plant *Arabidopsis thaliana* (Yang et al., 2002) and provided tile regions on the array for several genes inserts from that vector.

For all targets other than adenovirus and influenza, the present inventors selected targets from the open literature (e.g., NCBI GenBank) for genes containing diagnostic (via PCR) regions and tiled that diagnostic region or a larger coding region containing that region. The full listing of all target genes, PCR primer sites, and primers for the RPMV1 are shown in Table 8 (*infra*) and the attached Sequence Listing. The sequences submitted for tiling and chip fabrication are summarized in Table 7 (*infra*) and the attached Sequence Listing.

However, the present invention is not limited to the specific sequences and/or microorganisms (bacteria or virus) listed above. It is well within the purview of the skilled artisan to tailor the "pathogen chip" to meet the particular requirements of the intended field test. Such tailoring may be on a gene-level or on a microorganism level. Clearly, the artisan would be greatly assisted in the efforts by the general protocol above.

Resequencing microarray chip version 2 (RPMV2 chip)

RPMV2 is built on a high-density Affymetrix microarray having an intended feature size of 8 x 8 microns. At this density, approximately 300 kb of target sequence information may be tiled for resequencing.

The general layout strategy described in Tables 2-4 (*infra*). The RPM V2 design allowed for roughly 10 times the sequence content of the RPMV1, and thus allowed inclusion of a large number of pathogens, which included expanded representations of all the pathogens present on the RPMV1, numerous other respiratory pathogens, and virtually the entire set of CDC Category A, B, and C bioterrorism agents. The full listing of the RPMV2 content is provided in Example 8. The RPMV2 design expanded molecular epidemiology capability by enabling inclusion of probes, such as the emm types for *Streptococcus pyogenes*. This feature will provide the

epidemiologist/public health professional an ability to determine a likely index disease case and to study transmission of the typed pathogen in enclosed populations (jails, dormitories, nursing homes, military barracks, etc.). These probes may also predict pathogen virulence and clinical presentation of disease in the population.

The number of pathogens represented can also be expanded with increasing probes per unit area of microarray. The chips of the present invention take advantage of high feature density to simultaneously probe and discriminate among a large number of candidate pathogens that may be present in a single clinical specimen.

It is also important to note that gene expression markers can conceptually be tiled onto the array in the same manner as genomic markers. Thus, sequences representing pathogen transcripts (RNA templates coding for protein synthesis) can be simultaneously positioned on arrays with those allowing resequencing of genomic markers. This would enable the microarray to detect not only the presence of a pathogen, but would also allow determination of viability, since transcriptional markers would only be present in intact pathogens.

Table 2: RPMV2 layout (Name)

Respiratory Pathogen Name BT Agent Name (CDC A;B;C)	Species/Sub-species	Species/Sub-species	Species/Sub-species	Genus/Species	Rx Res
Adenovirus					
Subgroup A	Hexon	Fiber		E1A	
Subgroup B1					
Adenovirus 3	Hexon	Fiber		E1A	
Adenovirus 7	Hexon	Fiber		E1A	
Adenovirus 16	Hexon	Fiber		E1A	
Adenovirus 21	Hexon	Fiber		E1A	
Subgroup B2					
Adenovirus 11	Hexon	Fiber		E1A	
Adenovirus 35	Hexon	Fiber		E1A	
Subgroup C					
Adenovirus 1	Hexon	Fiber		E1A	
Adenovirus 2	Hexon	Fiber		E1A	
Adenovirus 5	Hexon	Fiber		E1A	
Adenovirus 6	Hexon	Fiber		E1A	
Subgroup D					
Subgroup E					
Adenovirus 4	Hexon	Fiber		E1A	
Subgroup F	Hexon	Fiber		E1A	
Influenza					
Influenza A					
	Hemagglutinin 1 (Full)	Neuraminidase 1 (Full)	Neuraminidase 1 (H5N1)	Matrix	
	Hemagglutinin 2	Neuraminidase 2 (Full)			
	Hemagglutinin 3 (Full)	Neuraminidase 3			
	Hemagglutinin 4	Neuraminidase 4			
	Hemagglutinin 5	Neuraminidase 5			
	Hemagglutinin 6	Neuraminidase 6			
	Hemagglutinin 7	Neuraminidase 7			
	Hemagglutinin 8	Neuraminidase 8			
	Hemagglutinin 9	Neuraminidase 9			
	Hemagglutinin 10				
	Hemagglutinin 11				
	Hemagglutinin 12				
	Hemagglutinin 13				
	Hemagglutinin 14				
	Hemagglutinin 15				
Influenza B	Hemagglutinin B	Neuraminidase B		Matrix	
Influenza C	Hemagglutinin-esterase			Matrix	

Parainfluenza								
Parainfluenza 1	Hemagglutinin-neuraminidase						Matrix	
Parainfluenza 2	Hemagglutinin-neuraminidase						Matrix	
Parainfluenza 3	Hemagglutinin-neuraminidase						Matrix	
Parainfluenza 4A	Hemagglutinin-neuraminidase						Matrix	
Rhinovirus	**5' NCR HRV 9501486**	5' NCR HRV21	5' NCR HRV29	5' NCR HRV 9501821	5' NCR HRV62			
	5' NCR HRV1A	5' NCR HRV58	5' NCR HRV14	5' NCR HRV87				
Coronavirus								
SARS	**Membrane Glycoprotein**	Nucleocapsid	Spike				Matrix	
043	**Hemagglutinin-esterase**	Nucleocapsid	Spike					
229E	**Surface Glycoprotein**	Nucleocapsid	Spike					
Respiratory Syncitial Virus								
Type 1 (RSV A)	**Nucleocapsid**						Matrix	
Type 2 (RSV B)	**Nucleocapsid**						Matrix	
Streptococcus								
Streptococcus pyogenes	emm 1	ST2035	ST4529L	ST4532	ST4264	ST4547	GyrA	Erm(A); Erm (B);Erm(TR);MefA ; MefE ; prtF1 ; put. Rx resist prot. ; tet(O)
	emm 75	emm13L ST2267 ST448L ST6949	ST3018 U50336 ST3365 ST1160	U92492 ST2980 ST1135	STI4973 ST230-2 ST1161	STCMUK16 ST436 ST1432		
		emm1	emm2	emm3	emm4	emm5		
		emm6	emm7	emm8	emm9	emm10		
		emm11	emm12	emm13	emm14	emm15		
		emm16	emm17	emm18	emm19	emm20		
		emm21	emm22	emm23	emm24	emm25		
		emm26	emm27	emm28	emm29	emm30		
		emm31	emm32	emm33	emm34	emm35		
		emm36	emm37	emm38	emm39	emm40		
		emm41	emm42	emm43	emm44	emm45		
		emm46	emm47	emm48	emm49	emm50		
		emm51	emm52	emm53	emm54	emm55		
		emm56	emm57	emm58	emm59	emm60		

		emm61 emm66 emm71 emm76 emm81 emm86 emm91 emm96 emm101 emm106 U74320 Csr R & Csr S	emm62 emm67 emm72 emm77 emm82 emm87 emm92 emm97 emm102 emm107 sic	emm63 emm68 emm73 emm78 emm83 emm88 emm93 emm98 emm103 emm108 SpeB	emm64 emm69 emm74 emm79 emm84 emm89 emm94 emm99 emm104 emm109	emm65 emm70 emm75 emm80 emm85 emm90 emm95 emm100 emm105 emm110		
Streptococcus pneumoniae	**ponA (Pbp1A)**						GyrA	GyrB; ParC
Staphylococcus aureus	antQ	entK	tst	seb			GyrA	MSR(A); mecR1 ; VanA ; BlaZ ; dfrA ; qacC
Mycoplasma pneumoniae	**P1 gene**						GyrA	
Bordetella pertussis	Pertussis toxin	PrnA						
Chlamydia								
Chlamydia pneumoniae	**OmpB**						DNA Gyrase	
Chlamydia psittaci	OmpA	SigA						
Neisseria meningitidis	MviN						GyrA	
Bacillus								
Bacillus anthracis	protective antigen	rpoB	lethal factor	edema factor (Cya)			GyrA	
Bacillus cereus		rpoB						
Bacillus thuringensis	cry	rpoB						
Bacillus subtilus		rpoB						
		rpoB						
Yersinia pestis	OmpA	cve2155 sequence					GyrA	
Smallpox (variola major)	Hemagglutinin	SOD					Chemokine binding protein	
Monkeypox	Hemagglutinin	IA						
Varicella	Hemagglutinin							
Francisella tularensis	TUL4	Region of Difference (RD1)					mdh	

Filoviridae					
Ebola	L gene	NP Protein			
Marburg	L gene	NP Protein			
Arenaviridae					
Lassa	L protein	NP Protein			
Machupo	L protein	NP Protein			
Burkholderia					
Burkholderia mallei (Glanders)	PenA			WaaF	
Burkholderia pseudomallei (Melidosis)	PenA			WaaF	
Burkholderia cepacia	recA				
Typhus fever (Rickettsia prowazekii)	Omp1			GyrA	ompB
Alphaviruses					
Venezuelan equine encephalitis	nonstructural polyprotein	nucleocapsid proteins			
Eastern equine encephalitis	nonstructural polyprotein	nucleocapsid proteins			
Western equine encephalitis	nonstructural polyprotein	nucleocapsid proteins			
Brucella	**Omp25**	Omp2	RB51_WBOA_IS711J INSERT		
Brucella abortus (2308 B37)					
Brucella melitensis (F8145)					
Brucella suis (A44)				GyrA	
Brucella canis					
Brucella ovis					
Brucella neotoma					
Arcanobacterium hemolyticum	16S rRNA	pld			
Haemophilus influenzae	OmpP6 (OmpA-family)			GyrA	
Moraxella catarrhalis	hemagglutinin			GyrA	
Mycobacterium tuberculosis	Omp A			GyrA	
Clostridium					

Clostridium botulinum	Ntnh	Bont		
Clostridium perfringens	TmpC	Epsilon Toxin		GyrA
Clostridium tetani	L & H chain			
Coxiella burnetii	TolC			GyrA
Cryptosporidium parvum	Sod	CP2		
E. coli 0157:H7	Omp A	Shiga Toxin I	Shiga Toxin II	GyrA
Ricinus communis	Ricinus communis toxin			
Salmonella				
Salmonella enterica	OmpA			GyrA
Salmonella typhimurium	OmpA precursor			
Shigella				
Shigella dysenteriae	OmpA			
Shigella flexneri	OmpA			GyrA
Vibrio cholerae	OmpA	CtxA & CtxB		GyrA
Nipah virus	Nucleocapsid			Matrix
Hantavirus				
Sin Nombre	Nucleocapsid	Glycoprotein		
Legionella pneumophilia	MompS			GyrA
Histoplasma capsulatum	M antigen	H antigen		
Blastomyces dermatidilis	WI-1	bys1		
Coccidioides immitis	bg12	Ag2		
Varicella				
Varicella HHV-6	major capsid protein	Major antigenic structural protein		
Varicella HHV-3	major capsid protein	Immediate early transactivator		
Epstein-Barr Virus	major capsid protein	Immediate early transactivator		

Corynebacterium Corynabacterium diphtheriae	Obx gene		GyrA	
Enterovirus (genus) Coxsackie (subgroup) Echo (subgroup) Polio (subgroup)	Enterovirus Coxsackie Echovirus Poliovirus			
Paramyxoviridae Paramyxoviridae morbillivirus (Rubeola) Newcastle	Hemagglutinin		Matrix	
	Hemagglutinin-Neuraminidase		Matrix	
West Nile Virus	Envelope	Nonstructural protein 5		
Yellow Fever	Envelope	Nonstructural protein 5		
Metapneumovirus	Nucleocapsid		Matrix	
Norwalk Virus	RNA-dependent RNA polymerase	Nucleocapsid		
Dengue Virus	capsid protein ©	pre-M protein		
Foot & Mouth	VP1 gene	3D gene		
St. Louis Encephalitis	polyprotein	NS5		
Rift Valley Fever	nucleoprotein	nonstructural protein		
Usutu	polyprotein			
tsutsugamushi fever	GroEL	lsa		
Chandipura	G Glycoprotein		Matrix	
Man-made Insertion Sequences Multiple Cloning Sites Rx Resistance Markers	Bluescript II (KS+)	pUC	pGEM	

Table 3: RPMV2 layout (Accession Number)

Respiratory Pathogen Name BT Agent Name (CDC A;B;C)	Species/Sub-species	Species/Sub-species	Species/Sub-species	Species/Sub-species	Species/Sub-species	Genus/Species	Rx Res
Adenovirus							
Subgroup A	NC_001460	NC_001460				NC_001460	
Subgroup B1							
Adenovirus 3	AF542129	AY224415				AF492352	
Adenovirus 7	X76551	Z48954				AY495969	
Adenovirus 16	X74662	U06106					
Adenovirus 21	AB053168	U06107				AF492353	
Subgroup B2							
Adenovirus 11	AF532578	L06232				BK001453	
Adenovirus 35	AB052912	AB098563				AY128640	
Subgroup C							
Adenovirus 1	AF534906	AB108423				AF534906	
Adenovirus 2	AY224391	AY224410				BK000407	
Adenovirus 5	AF542130	AY224411				AY147066	
Adenovirus 6	X67710	AB108424				E1A	
Subgroup D	NC_002067	NC_002067				NC_002067	
Subgroup E							
Adenovirus 4	X84646	X76547				E1A	
Subgroup F	NC_001454	NC_001454				NC_001454	
Influenza	Criteria: Human; Swine; Avian (Newest 1st)						
Influenza A							
	AJ344014 (vaccine)	AJ518092	AY526746			AJ456301	
	L11125	U42776					
	ISDN38157 (vaccine)	AY300947					
	ISDN13277 (vaccine)	K01030					
	AF285685						
	AY525745	M24740					
	AJ507203	AF285887					
	AY338459	AY340079					
	AF310968	AY300946					
	AY294658	AY180830					
	AF311750						
	AF310966						
	AF310990						
	M26089						
	M35997						
	L43918						
Influenza B	AB126838	AY139074				AB036877	

Influenza C	AB093473					AB086809	
Parainfluenza							
Parainfluenza 1	NC_003461					NC_003461	
Parainfluenza 2	NC_003443					NC_003443	
Parainfluenza 3	AY263063					NC_001796	
Parainfluenza 4A	E02727					E03809	
Rhinovirus	AF108164	AF108180	AF542420	AF542420	AF108184		
	AF108179	AF108183	AF108186	AF108187			
Coronavirus							
SARS	AY323974	AY365036	AY429079			AY390556	
OC43	M76373	NC_005147	L14643				
229E	NC_002645	X51325	X16816				
Respiratory Syncitial Virus							
Type 1 (RSV A)	AF035006					AF035006	
Type 2 (RSV B)	AF013254					AF013254	
Streptococcus	emm source						
Streptococcus pyogenes	ST2035	ST4529L	ST4532	ST4264	ST4547	AE006557	Emm(A) ; AY357120 ; Emm(TR); U70055 ; MefE ; prtF1 ; AE006513
	emm13L	ST3018	U92492	STI4973	STCMUK16		
	ST2267	U50338	ST2980	ST230-2	ST436		
	ST448L	ST3365	ST1135	ST1161	ST1432		
	ST6949	ST1160					
	emm1	emm2	emm3	emm4	emm5		
	emm6	emm7	emm8	emm9	emm10		
	emm11	emm12	emm13	emm14	emm15		
	emm16	emm17	emm18	emm19	emm20		
	emm21	emm22	emm23	emm24	emm25		
	emm26	emm27	emm28	emm29	emm30		
	emm31	emm32	emm33	emm34	emm35		
	emm36	emm37	emm38	emm39	emm40		
	emm41	emm42	emm43	emm44	emm45		
	emm46	emm47	emm48	emm49	emm50		
	emm51	emm52	emm53	emm54	emm55		
	emm56	emm57	emm58	emm59	emm60		
	emm61	emm62	emm63	emm64	emm65		
	emm66	emm67	emm68	emm69	emm70		
	emm71	emm72	emm73	emm74	emm75		
	emm76	emm77	emm78	emm79	emm80		
	emm81	emm82	emm83	emm84	emm85		
	emm86	emm87	emm88	emm89	emm90		
	emm91	emm92	emm93	emm94	emm95		

	emm96 emm101 emm106 U74320 U11956	emm97 emm102 emm107 AF085713	emm98 emm103 emm108 AY228859	emm99 emm104 emm109 AB051298	emm100 emm105 emm110		
Streptococcus pneumoniae	X67867					AY157689	GyrB; ParC
Staphylococcus aureus	U93686	U93688	U93686	M11118		D10489	AF467080 ; AF142100 ; AE017171
Mycoplasma pneumoniae	AF290002					X53555	
Bordetella pertussis	M13223	AJ507642				BX640413 (codon 286253)	
Chlamydia							
Chlamydia pneumoniae	X63511					AB103369	
Chlamydia psittaci	AF269261	U04442					
Neisseria meningitidis	AE002384					AE002487	
Bacillus							
Bacillus anthracis	AF306783	AF205335	M29081	M24074		AY291534	
Bacillus cereus		AF205342					
Bacillus thuringensis	AF278797	AF205349					
Bacillus subtilus		AF205356				X02369 (orf 621)	
Yersinia pestis	NC_003143	AF350077				AE013896	
Smallpox (variola major) **Monkeypox** **Varicella**	L22579	L22579				L22579	
Francisella tularensis	M32059	AF469619				AF513319	
Filoviridae							
Ebola	NC_004161	NC_004161					
Marburg	NC_001608	NC_001608					
Arenaviridae							
Lassa	NC_004297	NC_004296					
Machupo	NC_005079	NC_005078					
Burkholderia							
Burkholderia mallei (Glanders)	AY032868					AY124769	

Burkholderia pseudomallei (Melidosis)	AY032869			AF097748	
Burkholderia cepacia	U70431				
Typhus fever (Rickettsia prowazekii)	AJ235270			AJ235270 (codon 250672)	AJ235270
Alphaviruses					
Venezuelan equine encephalitis	L04653	L04653			
Eastern equine encephalitis	NC003899	NC003899			
Western equine encephalitis	NC003908	NC003908			
Brucella	Consensus	Consensus	Consensus		
Brucella abortus (2308 B37)					
Brucella melitensis (F6145)					
Brucella suis (A44)				AE014411	
Brucella canis					
Brucella ovis					
Brucella neotoma					
Arcanobacterium hemolyticum	X73952	L16583			
Haemophilus influenzae	L20309			U32808	
Moraxella catarrhalis	AY077637			AF058198	
Mycobacterium tuberculosis	BX842574			AE006915	
Clostridium					
Clostridium botulinum	Y13630	X62683			
Clostridium perfringens	AP003181	X60694		AP003165	
Clostridium tetani	X04436				
Coxiella burnetii	AE016960			AE016960	
Cryptosporidium parvum	AF529280	AY471868			
E. coli 0157:H7	AE005562	AB083044	AB048837	NC_002655	
Ricinus communis	X52908				
Salmonella					

Salmonella enterica	AL627269		AE016836 (codon 70224)
Salmonella typhimurium	AE008746		
Shigella			
Shigella dysenteriae	V01344		
Shigella flexneri	AE015125		AE016988
Vibrio cholorae	AF030877	Gary Custom	NC_002505
Nipah virus	NC_002728		NC_002728
Hantavirus			
Sin Nombre	NC_005216	L33474	
Legionella pneumophilla	AF078136		AY091594
Histoplasma capsulatum	AF026268	U20346	
Blastomyces dermatidilis	S63772	AF277079	
Coccidioides immitis	AF022893	U32518	
Varicella			
Varicella HHV-6	NC_001664	NC_001664	
Varicella HHV-3	NC_001348	NC_001348	
Epstein-Barr Virus	NC_001345	NC_001345	
Corynebacterium			
Corynebacterium diphtheriae	A04646		BX248354
Enterovirus (genus)	NC_001612		
Coxsackie (subgroup)	AF499635		
Echo (subgroup)	NC_003988		
Polio (subgroup)	NC_002058		
Paramyxoviridae			
Paramyxoviridae morbillivirus (Rubeola)	AY623561		NC_001498
Newcastle	AY510092		NC_002617
West Nile Virus	AF346319	AF208017	
Yellow Fever	AY359908	AF013417	
Metapneumovirus	AY145272		AY145271

Norwalk Virus	NC_001959	NC_001959
Dengue Virus	NC_001474	NC_001474
Foot & Mouth	NC_004004	NC_004004
St. Louis Encephalitis	AY289618	AF013416
Rift Valley Fever	X53771	X53771
Usutu	AF452643	
tsutsugamushi fever	AY191589	AY283160
Chandipura	J04350	
		AF128668
Man-made Insertion Sequences		
Multiple Cloning Sites	Stratagene Provided	X06404 X65312
Rx Resistance Markers		

Table 4: RPMV2 layout (Size)

Respiratory Pathogen Name BT Agent Name (CDC A;B;C)	Species/Sub-species	Species/Sub-species	Species/Sub-species	Genus/Species	Rx Res
Adenovirus					
Subgroup A	836	660		597	
Subgroup B1					
Adenovirus 3	685	629		660	
Adenovirus 7	605	629		660	
Adenovirus 16	673	906			
Adenovirus 21	759	637		819	
Subgroup B2					
Adenovirus 11	629	1025		789	
Adenovirus 35	641	711		789	
Subgroup C					
Adenovirus 1	667	802		870	
Adenovirus 2	789	696		870	
Adenovirus 5	884	926		1055	
Adenovirus 6	785	578			
Subgroup D	844	783		578	
Subgroup E					
Adenovirus 4	2811	1375		618	
Subgroup F	628	659		909	
Influenza					
Influenza A					
	1692	1459	575	734	
	757	1410			
	1042	804			
	1323	257			
	303	865			
	839	691			
	770	648			
	849	795			
	593	444			
	727				
	680				
	690				
	813				
	715				
	745				
Influenza B	737	761		715	
Influenza C	401			862	
Parainfluenza					
Parainfluenza 1	1649			910	

Parainfluenza 2	1646					693	
Parainfluenza 3	1581					498	
Parainfluenza 4A	639					607	
Rhinovirus	508	499	338	503	501		
	611	604	520	506			
Coronavirus							
SARS	686	1269	3766			666	
OC43	628	567	1042				
229E	753	769	1393				
Respiratory Syncitial Virus							
Type 1 (RSV A)	907					956	
Type 2 (RSV B)	554					826	
Streptococcus							
Streptococcus pyogenes	675	425	713	661	340	619	Erm(A): 763 ; 732 ; 583 ; MefE ; prtF1
	200	316	371	415	680		
	413	364	401	688	350		
	358	554	619	475	684		
	690	639					
	325	380	391	337	490		
	437	emm7	emm8	509	emm10		
	500	364	emm13	439	652		
	emm18	167	emm16	381	emm20		
	emm21	620	258	421	561		
	936	317	333	328	265		
	338	299	328	340	emm38		
	410	270	481	369	340		
	488	408	306	391	emm45		
	315	331	489	485	287		
	423	499	414	293	405		
	369	336	391	433	452		
	325	334	429	538	640		
	528	335	528	568	440		
	300	256	328	306	451		
	353	450	415	322	354		
	432	497	421	324	448		
	404	420	346	379	483		
	393	363	403	518	406		
	358	357	351	372	340		
	360	354	emm103	emm104	emm105		
	emm106	emm107	emm108	emm109	emm110		
	533						
	292	904	1008	681			

Streptococcus pneumoniae	1237				815	GyrB ; ParC	
Staphylococcus aureus	771	728	705	713	821	400 ; 692 ; 1032 ; 846 ; ## ; ##	
Mycoplasma pneumoniae	2526				809		
Bordatella pertussis	824	730			815		
Chlamydia							
Chlamydia pneumoniae	992				824		
Chlamydia psittaci	991	635					
Neisseria meningitidis	658				941		
Bacillus							
Bacillus anthracis	551	777	838	935	732		
Bacillus cereus		777					
Bacillus thuringensis	805	777			812		
Bacillus subtilus		760					
Bacillus globigii					812		
Yersinia pestis	913	517			762		
Smallpox (variola major)	842	378			960		
Monkeypox		764					
Varicella							
Francisella tularensis	786	3322					
Filoviridae							
Ebola	752	756					
Marburg	1170	709					
Arenaviridae							
Lassa	973	703					
Machupo	1540	715					
Burkholderia							
Burkholderia mallei (Glanders)	1117						
Burkholderia pseudomallei (Melidosis)	1117				1100		
Burkholderia cepacia	563						
Typhus fever (Rickettsia prowazekii)	985				868	1560	

Alphaviruses				
Venezuelan equine encephalitis	823	1512		
Eastern equine encephalitis	1312	975		
Western equine encephalitis	876	902		
Brucella	582	2428	1291	
Brucella abortus (2308 B37)				
Brucella melitensis (F6145)				895
Brucella suis (A44)				
Brucella canis				
Brucella ovis				
Brucella neotoma				
Arcanobacterium hemolyticum	1489	1111		
Haemophilus influenzae	937			886
Moraxella catarrhalis	653			321
Mycobacterium tuberculosis	932			816
Clostridium				
Clostridium botulinum	489	1000		
Clostridium perfringens	1113	572		610
Clostridium tetani	1138			
Coxiella burnetii	1651			812
Cryptosporidium parvum	375	2304		
E. coli 0157:H7	660	948	990	612
Ricinus communis	1133			
Salmonella				
Salmonella enterica	904			912
Salmonella typhimurium	904			
Shigella				
Shigella dysenteriae	907			
Shigella flexneri	898			812

Vibrio cholerae	942	984	687	
Nipah virus	858		1359	
Hantavirus				
Sin Nombre	639	1293		
Legionella pneumophilia	1157		238	
Histoplasma capsulatum	919	1082		
Blastomyces dermatiditis	942	912		
Coccidioides immitis	965	1234		
Varicella				
Varicella HHV-6	890	1236		
Varicella HHV-3	822	781		
Epstein-Barr Virus	971	1317		
Corynebacterium				
Corynebacterium diphtheriae	913		816	
Enterovirus (genus)	1758			
Coxsackie (subgroup)	920			
Echo (subgroup)	1277			
Polio (subgroup)	1225			
Paramyxoviridae				
Paramyxoviridae	1854		1008	
morbillivirus (Rubeola)				
Newcastle	1734		1232	
West Nile Virus	1504	917		
Yellow Fever	1547	1035		
Metapneumovirus	1185		765	
Norwalk Virus	961	712		
Dengue Virus	300	496		
Foot & Mouth	633	799		
St. Louis Encephalitis	679	1035		
Rift Valley Fever	738	798		

Usutu	1035			
tsutsugamushi fever	546	1011		
Chandipura	704			755
Man-made Insertion Sequences Multiple Cloning Sites Rx Resistance Markers	2961	3914	2912	
		Chip Size		283826

The sequences submitted for RPMV2 tiling and chip fabrication were based on the Affymetrix instruction file summarized in Table 5, which corresponds to the sequences appearing as SEQ ID NOs: 59-421.

Table 5: RPMV2 Affymetrix instructions file for tiling and chip fabrication

Name	Alias	Start	End	SEQ ID NO:	StartSeq	EndSeq
ATTIM1	ATTIM1	1	523	59	ACATCGAC	GAGCTTGC
Ad3E1A	Ad3E1A	1	879	60	TGAGACAC	GGCAATGA
Ad3HEXON	Ad3HEXON	1	595	61	CCAGCACA	CATGTGGT
Ad3FIBER	Ad3FIBER	1	746	62	AAGCGGCT	AACCCTCA
Ad7E1A	Ad7E1A	1	868	63	TGAGACAC	AAACTGCC
Ad7HEXON	Ad7HEXON	1	513	64	CCAGCACA	TGCTGACG
Ad7FIBER	Ad7FIBER	1	977	65	TGACCAAG	ACGACTGA
Ad7NAVYE1A	Ad7NAVYE1A	1	879	66	ATGAGACA	AGGCAATA
Ad7NAVYHEXON	Ad7NAVYHEXON	1	504	67	CCAGCACA	TGCTGACG
Ad7NAVYFIBER	Ad7NAVYFIBER	1	975	68	TGGCTTTA	CCCCACGC
Ad16E1A	Ad16E1A	1	878	69	TGAGACAC	GGCAATGA
Ad16HEXON	Ad16HEXON	1	667	70	CGTTGACC	AGGACACC
Ad16FIBER	Ad16FIBER	1	652	71	GGGAGATG	AGGAAGCC
Ad21E1A	Ad21E1A	1	878	72	TGAGACAC	GACAATGA
Ad21HEXON	Ad21HEXON	1	807	73	CGCCACAG	GTGTACAA
Ad21FIBER	Ad21FIBER	1	685	74	GCTCAGTG	CCTTTATG
Ad11E1A	Ad11E1A	1	872	75	TGAGAGAT	GACAATAA
Ad11HEXON	Ad11HEXON	1	677	76	CGCCACAG	TCAGAAAG
Ad11FIBER	Ad11FIBER	1	977	77	TGACCAAG	ACGACTGA
Ad35E1A	Ad35E1A	1	872	78	TGAGAGAT	GACAATAA
Ad35HEXON	Ad35HEXON	1	689	79	CGCCACAG	TGAAAAAA
Ad35FIBER	Ad35FIBER	1	971	80	TGACCAAG	ACAACTAA
Ad1E1A	Ad1E1A	1	986	81	TGAGACAT	GGCCATAA
Ad1HEXON	Ad1HEXON	1	715	82	AGTGGTCT	TGCTACGG

Ad1FIBER	Ad1FIBER	1	750	83	GATGCTGT	AAGAATAA
Ad2E1A	Ad2E1A	1	983	84	TGAGACAT	GGCCATAA
Ad2HEXON	Ad2HEXON	1	837	85	AGTGGTCT	CGACCGGC
Ad2FIBER	Ad2FIBER	1	750	86	ATAGCTAT	AGGAATAA
Ad5E1A	Ad5E1A	1	985	87	TGAGACAT	GGCCATAA
Ad5HEXON	Ad5HEXON	1	732	88	AGTGGTCT	TGTAAAGC
Ad5FIBER	Ad5FIBER	1	747	89	ACAGCCAT	AAGAATAA
Ad6E1A	Ad6E1A	1	985	90	TGAGACAT	GGCCATAA
Ad6HEXON	Ad6HEXON	1	833	91	GAATGAAG	AATTGGGA
Ad6FIBER	Ad6FIBER	1	750	92	TCCTCAAA	CAGAAAAT
Ad4E1A	Ad4E1A	1	865	93	TGAGGCAC	GGCATTAA
Ad4HEXON	Ad4HEXON	1	2810	94	TGGCCACC	CCACATAA
Ad4FIBER	Ad4FIBER	1	1277	95	TGTCCAAA	AACAATAA
Ad4AFE1A	Ad4AFE1A	1	832	96	TGAGGCAC	GACATTAA
Ad4AFHEXON	Ad4AFHEXON	1	2810	97	TGGCCACC	CCACATAA
Ad4AFFIBER	Ad4AFFIBER	1	1277	98	TGTCCAAA	AAGAATAA
Ad12E1A	Ad12E1A	1	597	99	ATGAGAAC	GGAGGTGA
Ad12HEXON	Ad12HEXON	1	884	100	CCTACTTC	TGCAAGAC
Ad12FIBER	Ad12FIBER	1	908	101	CAGCAGAA	CGTTGCCG
Ad17E1A	Ad17E1A	1	579	102	ATGAGACA	GAGGCTGA
Ad17HEXON	Ad17HEXON	1	692	103	CTTCAGCC	GAAGAATA
Ad17FIBER	Ad17FIBER	1	829	104	TCCTGTCA	TATCAGCC
Ad40E1A	Ad40E1A	1	824	105	CTTGAGTG	ATAGAAGA
Ad40HEXON	Ad40HEXON	1	876	106	CGCAATGG	TAATTACA
Ad40FIBER	Ad40FIBER	1	707	107	CACTGACA	TCAGTGTC
FluAHA1	FluAHA1	1	1692	108	ATGAAAGC	GAATATGC
FluAHA2	FluAHA2	1	805	109	AAGGTCGA	TTTGGGAG
FluAHA3	FluAHA3	1	1042	110	CAAAAACT	AATGGTGG
FluAHA4	FluAHA4	1	1371	111	AGGAAATC	GACAAAGG

FluAHA5	FluAHA5	1	303	112	ATGCCCCA	TTTAACAA
FluAHA6	FluAHA6	1	887	113	CCGTCACA	GACTAAGA
FluAHA7	FluAHA7	1	818	114	AAATCCTG	TGGGAATT
FluAHA8	FluAHA8	1	897	115	CTCTTGGC	GCAAACCC
FluAHA9	FluAHA9	1	601	116	ACTCCACA	CCAAGGCC
FluAHA10	FluAHA10	1	775	117	CCTGGAGC	GTATGGTT
FluAHA11	FluAHA11	1	728	118	CTGCATTC	AGAGGCAA
FluAHA12	FluAHA12	1	738	119	CACTGTTC	GGCCAAAC
FluAHA13	FluAHA13	1	1765	120	AGCAAAAG	TTTCTACT
FluAHA14	FluAHA14	1	763	121	CACAAATG	CAAGAGGC
FluAHA15	FluAHA15	1	793	122	ACGGAGAC	CCCTTTGC
FluANA1-1	FluANA1-1	1	1459	123	CAAAAGCA	TTTCTACT
FluANA1-2	FluANA1-2	1	575	124	TGCCATGA	ATGATTTG
FluANA2	FluANA2	1	1062	125	TCATGCGA	TTTTAGAA
FluANA3	FluANA3	1	852	126	GCCCTTTC	TGAAGTCA
FluANA4	FluANA4	1	257	127	AGCAAAAG	CAGCCCCC
FluANA5	FluANA5	1	913	128	CGGTGAGA	GCGGGAAG
FluANA6	FluANA6	1	739	129	AGAGGATG	TTGCATTC
FluANA7	FluANA7	1	994	130	AGCAGGGT	ACACCAGC
FluANA8	FluANA8	1	843	131	CAATACAG	ATTAGCAG
FluANA9	FluANA9	1	444	132	AACCTGAA	GTCAATAT
FluAH1N1MATRIX	FluAH1N1MATRIX	1	734	133	ATGGAATG	TAAACACG
FluAH5N1MATRIX	FluAH5N1MATRIX	1	657	134	AGACCAAT	TTGCACTT
FluBHA	FluBHA	1	785	135	GGGAAGTC	AGGTAATA
FluBNA	FluBNA	1	809	136	GCCCTCAT	CTCGAACG
FluBMATRIX	FluBMATRIX	1	763	137	GGAGAAGG	ATGGCTTG
FluCHA	FluCHA	1	401	138	CTTCTTGC	ATGATCAT
FluCMATRIX	FluCMATRIX	1	862	139	ATGTCCGA	TTATATAA
PIV1HN	PIV1HN	1	1728	140	ATGGCTGA	CATCTTGA

PIV1MATRIX	PIV1MATRIX	1	958	141	CCGGAGAA	CAGTAGAA
PIV1NC	PIV1NC	1	1682	142	AGGGTTAA	AAGAAAAA
PIV2HN	PIV2HN	1	1716	143	ATGGAAGA	TACCTTAA
PIV2MATRIX	PIV2MATRIX	1	741	144	CTTGCCTC	CAGGTCGG
PIV2NC	PIV2NC	1	1849	145	AGATTCGG	AGAAAAAA
PIV3HN	PIV3HN	1	1725	146	ATGGAATA	AATCATAA
PIV3MATRIX	PIV3MATRIX	1	544	147	CCAACAAA	CCTGGCGA
PIV3NC	PIV3NC	1	1548	148	ATGTTGAG	GCAACTAA
PIV4HN	PIV4HN	1	686	149	GACGGGAG	AAAGATTG
PIV4MATRIX	PIV4MATRIX	1	855	150	GGAACGGT	TTGGCTCA
HRV14NCR	HRV14NCR	1	520	151	TGATGTAC	GTTTCTCA
HRV1ANCR	HRV1ANCR	1	511	152	TTCCGGTA	GTTTCACT
HRV21NCR	HRV21NCR	1	499	153	TTCCGGTA	GTTTCACT
HRV29NCR	HRV29NCR	1	676	154	CGAAAACA	TTGGGTGT
HRV58NCR	HRV58NCR	1	504	155	TCACGGTA	GTTTCCTG
HRV62NCR	HRV62NCR	1	501	156	TTCCGGTA	GTTTCACT
HRV87NCR	HRV87NCR	1	506	157	TCTTGGTA	GTTTCACT
HRV95NCR	HRV95NCR	1	508	158	TTCCGGTA	GTTTCTTG
RSVABL	RSVABL	1	379	159	AAGTGCTC	AAGCAAAC
RSVAMATRIX	RSVAMATRIX	1	958	160	GGGGCAAA	ATAAAAAA
RSVANC	RSVANC	1	955	161	TCCAACGG	CCGAGGAA
RSVBMATRIX	RSVBMATRIX	1	770	162	ATGGAAAC	GAGGATTA
RSVBNC	RSVBNC	1	602	163	GATGGGAG	TACGCCAA
HCV229ESPIKE	HCV229ESPIKE	1	1534	164	GTTGATTG	GCCGTGGT
HCV229EMEM	HCV229EMEM	1	678	165	ATGTCAAA	TTTTCTAA
HCV229ENC	HCV229ENC	1	924	166	ATGGCTAC	GTCACATT
HCVOC43SPIKE	HCVOC43SPIKE	1	1456	167	ATTGATTG	GCCTTGGT
HCVOC43MEM	HCVOC43MEM	1	693	168	ATGAGTAG	ATATCTAA
HCVOC43NC	HCVOC43NC	1	966	169	AGAGCTCA	GTACACTT

SARSSPIKE	SARSSPIKE	1	1438	170	GTAGATTG	GCCTTGGT
SARSMEM	SARSMEM	1	666	171	ATGGCAGA	TACAGTAA
SARSNC	SARSNC	1	932	172	ATGGGGCA	ACAAAGAT
HCVNL63SPIKE	HCVNL63SPIKE	1	1534	173	GTTGATTG	GCCTTGGT
HCVNL63ORF3	HCVNL63ORF3	1	678	174	ATGCCTTT	TTAATTGA
HCVNL63MEM	HCVNL63MEM	1	681	175	ATGTCTAA	TAATCTAA
HCVNL63NC	HCVNL63NC	1	879	176	ATGGCTAG	GTGAGGTT
MPVMATRIX	MPVMATRIX	1	765	177	ATGGAGTC	CCAGATAA
MPVNC	MPVNC	1	1185	178	ATGTCTCT	ATGAGTAA
HHV1L	HHV1L	1	1061	179	TACCAGGG	AAGCGCCT
HHV1CAPSID	HHV1CAPSID	1	993	180	CGGGCGCC	GTGGGCGT
HHV3L	HHV3L	1	1061	181	TATAAAGG	CGTCGCTT
HHV3CAPSID	HHV3CAPSID	1	993	182	CGGGAGCC	ATGGGCAT
HHV4L	HHV4L	1	1067	183	TACCAGGG	ACCCAGAT
HHV4CAPSID	HHV4CAPSID	1	992	184	CGCCGACA	CTGGGCAT
HHV5L	HHV5L	1	1136	185	TACCAGGG	TCTAACCT
HHV5CAPSID	HHV5CAPSID	1	998	186	CGCGCAGC	CTGGGCCT
HHV6L	HHV6L	1	1058	187	TACAAAGG	CCGAATCT
HHV6CAPSID	HHV6CAPSID	1	1001	188	CGCGCAGC	TTGGGCAT
ENTEROVIRUS	ENTEROVIRUS	1	1758	189	CACCAATG	GATAGATA
COXSACKIEVIRUS	COXSACKIEVIRUS	1	920	190	CAATGCAA	TCTTGAGG
ECHO	ECHO	1	1277	191	CACTTGCC	ACAAAGAG
POLIO	POLIO	1	1226	192	TGGATAGT	ACTTATGT
POLIO1NCR	POLIO1NCR	1	436	193	CAAGCACT	TGACAATC
POLIO2NCR	POLIO2NCR	1	437	194	CAAGCACT	TGACAATC
POLIO3NCR	POLIO3NCR	1	437	195	CAAGCACT	TGACAATC
MEASLESHA	MEASLESHA	1	1854	196	ATGTCACC	GCGGATAG
MEASLESMATRIX	MEASLESMATRIX	1	1008	197	ATGACAGA	TTCTGTAG
NEWCASTLEHN	NEWCASTLEHN	1	1734	198	ATGGACCG	CTGGCTAG

NEWCASTLEMATRIX	NEWCASTLEMATRIX	1	1232	199	ACGGGTAG	CATCAAGT
WNE	WNE	1	1504	200	TTCAACTG	GCACGCTG
WNNS	WNNS	1	917	201	GGCTGCTG	GGGAAGGA
WNCM	WNCM	1	432	202	GGCCAATA	TGATCCAG
YFE	YFE	1	1547	203	CTGCATTG	TAGAGACT
YFNS	YFNS	1	1035	204	AAGCTGTC	AGGGAGAG
VMVG3R	VMVG3R	1	762	205	ATGAAACA	GTGTCTGA
VMVHA	VMVHA	1	942	206	ATGACACG	AAGTCTAG
VMVSOD	VMVSOD	1	378	207	ATGGCTGT	GCGTTTGA
VMVCRMB	VMVCRMB	1	291	208	TCGGGAAC	CGTCTGTT
MONKEYPOX	MONKEYPOX	1	812	209	GTGAATGC	TTTCGACG
EBOLAL	EBOLAL	1	800	210	AGTTGGAC	GAAACACG
EBOLANP	EBOLANP	1	806	211	AGGAGTAA	CGACAATC
EBOLAMATRIX	EBOLAMATRIX	1	1498	212	GATGAAGA	AAGAAAAA
MARBURGL	MARBURGL	1	1218	213	GCGGCACT	CAATTGAC
MARBURGNP	MARBURGNP	1	847	214	TCACAGAA	GTCATTTG
LASSAL	LASSAL	1	1021	215	GCATCTGG	ACTACCTC
LASSANP	LASSANP	1	751	216	ATGGAGTG	AGTTCAGG
LASSAGP	LASSAGP	1	1476	217	ATGGGACA	AGAGATGA
MACHUPOL	MACHUPOL	1	1588	218	GTGGCTGA	GAGGCTAA
MACHUPONP	MACHUPONP	1	763	219	TTGAAGAC	GGCACTAT
MACHUPOG	MACHUPOG	1	1491	220	ATGGGGCA	GACATTAA
VEEVNS	VEEVNS	1	923	221	GACAGCCC	AAAGTGAC
VEEVNC	VEEVNC	1	1512	222	GGCCACCT	AGCATATC
EEEVNS	EEEVNS	1	1312	223	GAGATAGA	ATTGCGTC
EEEVNC	EEEVNC	1	975	224	CCTGACTT	TCAGCTAT
WEEVNS	WEEVNS	1	878	225	CGTATGTC	CCACAATG
WEEVNC	WEEVNC	1	902	226	TGTTCTAG	TGGCGACT
NIPAHMATRIX	NIPAHMATRIX	1	1359	227	AGGAGACA	ACAAAAAA

NIPAHN	NIPAHN	1	858	228	AGGAATCT	CAATCAGC
SINNOMBREGP	SINNOMBREGP	1	1293	229	ATAGCTGG	GGATGGAT
SINNOMBRENC	SINNOMBRENC	1	639	230	TCACTCTC	TGTGATTG
NORWALKL	NORWALKL	1	739	231	TTCTCCAT	ATTCGTAA
NORWALKCAPSID	NORWALKCAPSID	1	760	232	TGGTACCG	CTGGATGG
DENGUECAPSID	DENGUECAPSID	1	300	233	ATGAATGA	GACGTAGA
DENGUEM	DENGUEM	1	498	234	TTTCATCT	CAATGACA
DENGUE1NCR	DENGUE1NCR	1	157	235	GGTTAGAG	GCTGTCTC
DENGUE2NCR	DENGUE2NCR	1	159	236	GGTTAGAG	GCTGTCTC
DENGUE3NCR	DENGUE3NCR	1	156	237	GGTTAGAG	GCTGTCTC
DENGUE5NCR	DENGUE5NCR	1	162	238	GGTTAGAG	GCTGTCTC
FMDVVP1	FMDVVP1	1	633	239	ACCACCTC	CAAAACAG
FMDV3D	FMDV3D	1	846	240	GTTGATCG	ACGGAGCA
SLEVNS5	SLEVNS5	1	1035	241	AAGACTGG	AGGGTGAG
SLEVPP	SLEVPP	1	727	242	CTCGGTAG	GTTTCACG
RVFVN	RVFVN	1	738	243	ATGGACAA	CAGCCTAA
RVFVNS	RVFVNS	1	798	244	ATGGATTA	TTGATTAG
USUTUPP	USUTUPP	1	1035	245	AAGCTCGG	CAGGTGAG
JEVPP	JEVPP	1	1035	246	AAGCCTGG	AAGGAGAG
CHANDIPURAMATRIX	CHANDIPURAMATRIX	1	755	247	AACAGAAA	GAAAAAAA
CHANDIPURAGP	CHANDIPURAGP	1	752	248	ATCACTCT	GTAGTTGT
ATTIM2	ATTIM2	1	523	249	ACATCGAC	GAGCTTGC
ATTIM3	ATTIM3	1	523	250	ACATCGAC	GAGCTTGC
SPYEMM1	SPYEMM1	1	398	251	GCTTCAGT	CAGGCAAG
SPYEMM2	SPYEMM2	1	360	252	GCATCCGT	GAGAAGTC
SPYEMM3	SPYEMM3	1	391	253	ACGGCTTC	GGAATATC
SPYEMM4	SPYEMM4	1	337	254	AGCATCAG	GTCAATAT
SPYEMM5	SPYEMM5	1	490	255	ACTGCATC	AAAAGATA
SPYEMM6	SPYEMM6	1	437	256	TACTGCAT	CTTAAAAA

SPYEMM9	SPYEMM9	1	509	257	CAGGTACA	CTGCTCTT
SPYEMM11	SPYEMM11	1	500	258	GCATCCGT	AATCACCA
SPYEMM12	SPYEMM12	1	364	259	GCTTCAGT	AAATGATG
SPYEMM13L	SPYEMM13L	1	325	260	CAGCATCC	AAAAATCA
SPYEMM18	SPYEMM18	1	524	261	ACTGCTTC	GAAGAACA
SPYEMM22	SPYEMM22	1	620	262	GCATCAGT	GACGCAAG
SPYEMM28	SPYEMM28	1	333	263	CAGCATCC	AGAACGTC
SPYEMM29	SPYEMM29	1	328	264	TGCATCAG	AAGAACAG
SPYEMM44	SPYEMM44	1	391	265	CAGCATCA	CAAGAACA
SPYEMM61	SPYEMM61	1	325	266	GCATCAGT	AGAACGTC
SPYEMM75	SPYEMM75	1	451	267	TCCGTAGC	AAGCCGTG
SPYEMM77	SPYEMM77	1	450	268	GCTCAGTA	AGCTGAGC
SPYEMM89	SPYEMM89	1	378	269	CATCAGTA	AGAAAAGC
SPYEMM94	SPYEMM94	1	516	270	GCATCAGT	CAGACGCA
SPYCSR	SPYCSR	1	952	271	TGGTCCTA	CCCAGGCT
SPYSFB1	SPYSFB1	1	615	272	AGAACCTG	GGCATGAG
SPYSPEB	SPYSPEB	1	729	273	ACTCTACC	TATCGATG
SPNGYRA	SPNGYRA	1	815	274	GAGGATTT	ACTGATAC
SPNLYTA	SPNLYTA	1	125	275	TATCGAAC	CTCAGACC
SPNPLY	SPNPLY	1	99	276	GGTTTGGC	ATCAAGAT
SAUGYRA	SAUGYRA	1	821	277	GAAGACTT	ACTAATGC
SAUTST	SAUTST	1	705	278	ATGAATAA	TTAATTAA
SAUENTK	SAUENTK	1	729	279	ATGAAAAA	CGATATAA
SAUENTQ	SAUENTQ	1	771	280	ATGCCTAT	CTGAATAA
CPNGYRA	CPNGYRA	1	824	281	GAAGACAT	TCGAGTCA
CPNOMPB	CPNOMPB	1	1030	282	GCGAAGCT	TCAGGTCC
CPNMOMPVD4	CPNMOMPVD4	1	150	283	ATGCTGAT	TCAGATCA
CPNMOMPVD2	CPNMOMPVD2	1	133	284	AGCGTTCA	TAGGCGCT
CPNRPOB	CPNRPOB	1	346	285	AAGGACTT	CTGCAGGC

CPSOMPA	CPSOMPA	1	991	286	GGAACCCA	TCGATTCA
CPSSIGA	CPSSIGA	1	883	287	CGCAAGCT	GGTTCAGC
CDIDTX	CDIDTX	1	913	288	GACGTGGT	TTCTCCGG
CDIGYRA	CDIGYRA	1	818	289	GAAGACCT	ACCTCCGC
CDIDTXR	CDIDTXR	1	1124	290	AATGAGTG	GCGCCTGT
HINGYRA	HINGYRA	1	896	291	GAAGATTT	ACTGATGC
HINOMPA	HINOMPA	1	937	292	GCGTTAAA	CCAGACCG
LPNGYRA	LPNGYRA	1	236	293	GATGTCGG	GACCGTCG
LPNMOMPS	LPNMOMPS	1	1157	294	GTCCTTAC	TCATTAGA
MCAGYRA	MCAGYRA	1	321	295	AACTGGAA	AGATTCCC
MCAHA	MCAHA	1	653	296	GATCAATC	AATGGTCA
MTUGYRA	MTUGYRA	1	818	297	GAGGATTT	ACTTCCGG
MTUOMPA	MTUOMPA	1	932	298	GACGAACT	TCAACTAA
MTURPOB	MTURPOB	1	411	299	TACGGTCG	ACGCCGTA
MPNGYRA	MPNGYRA	1	809	300	GAGGACTT	TCTTCAGC
MPNP1	MPNP1	1	2570	301	CAGTTGCA	ACGCGAGC
NMEGYRA	NMEGYRA	1	941	302	GAAGACCT	ACCAGCGG
NMEMVIN	NMEMVIN	1	904	303	GATGAATA	ATACGGAA
NMECTRA	NMECTRA	1	135	304	TTGGATGC	TTTTGCTG
NMECRGA	NMECRGA	1	254	305	GGTGCTGC	TGCCGGTC
AHE16S	AHE16S	1	1489	306	CGAACGCT	CCGGAAGG
AHEPLD	AHEPLD	1	1111	307	GCAAAGTG	CTCCTTTT
BANGYRA	BANGYRA	1	732	308	GAAGACTT	AGACTTGT
BANLEF	BANLEF	1	685	309	ATATCGAG	CTAGGTGC
BANPAG	BANPAG	1	599	310	CAGAAGTG	GGATAGCG
BANRPOB	BANRPOB	1	777	311	TAGTTCGC	AGGGGATA
BANCYA	BANCYA	1	545	312	GCGATGAT	CTGTCGAG
BANCAPB	BANCAPB	1	246	313	TTACACGT	ACCTATTA
BCERPOB	BCERPOB	1	777	314	TAGTTCGC	AGGGGATA

BSUGYRA	BSUGYRA	1	812	315	GAAGATCT	ACAGCTAG
BSURPOB	BSURPOB	1	780	316	TTGTTCGG	AGGCGACA
BTHCRY	BTHCRY	1	853	317	AGAACACA	ATCGCATC
BTHRPOB	BTHRPOB	1	777	318	TAGTTCGC	AGGGGATA
BPEGYRA	BPEGYRA	1	815	319	GAAGACCT	ACCACCGG
BPEPRNA	BPEPRNA	1	777	320	GGTTCAAG	CGCCGACA
BMEGYRA	BMEGYRA	1	995	321	GAAGACCT	TCGGATGG
BABRB51	BABRB51	1	1339	322	ATCCCATA	AGCTAGTA
BABOMP25	BABOMP25	1	630	323	AAGTCTCT	AGTTCTAA
BABOMP2	BABOMP2	1	1434	324	TGTTCTTC	GAGAGCAG
BCAOMP2	BCAOMP2	1	1434	325	TGTTCTTC	GAGAGCAG
BMEOMP2	BMEOMP2	1	1434	326	TGTTCTTC	GAGAGCAG
BNEOMP2	BNEOMP2	1	1434	327	TGTTCTTC	GAGAGCAG
BOVOMP2	BOVOMP2	1	1449	328	TGTTCTTC	GAGAGCAG
BSUIOMP2	BSUIOMP2	1	1434	329	TGTTCTTC	GAGAGCAG
BMAPENA	BMAPENA	1	1117	330	GAGAGCTG	AAGGTTCA
BMAWAAF	BMAWAAF	1	1015	331	CGTTGGTT	GGGATGCT
BPSPENA	BPSPENA	1	1117	332	GAGAGCTG	AAGGTTCA
BPSWAAF	BPSWAAF	1	1100	333	AGCGCGGC	GTCCGCGG
BCEPRECA	BCEPRECA	1	611	334	CATGGAAG	CAACCAGA
CPEGYRA	CPEGYRA	1	810	335	GAAGACTT	ATAAATAG
CPETMPC	CPETMPC	1	1113	336	ATGAAAAA	TAAATTAA
CBUGYRA	CBUGYRA	1	812	337	GAAGATTT	AGTGATAA
CBUTOLC	CBUTOLC	1	745	338	ATTTAGAC	CTAGGAAA
FTURD1A	FTURD1A	1	531	339	ATGAAAAA	CAATTTAG
FTURD1B	FTURD1B	1	285	340	ATGGCTTT	TAGACTAG
FTUTUL4	FTUTUL4	1	834	341	GGCGAGTG	CCAACCAC
FTUMDH	FTUMDH	1	960	342	ATGGCTAG	CAAAATAA
FTU13KD	FTU13KD	1	431	343	ATCGTAAT	TAAGTATG

FTUFOPA	FTUFOPA	1	111	344	CAGATATA	GATACTAC
OTSGROEL	OTSGROEL	1	546	345	GTTGAAGT	AAGAAAAA
OTSSTA56	OTSSTA56	1	1059	346	CTAGTGCA	AGCAGTAG
RPRGYRA	RPRGYRA	1	968	347	GAAGATTT	ACAAATAG
RPROMP1	RPROMP1	1	985	348	TATATAAA	ACAAGCTA
YPEGYRA	YPEGYRA	1	812	349	GAAGACCT	ACTGATGC
YPEOMPA	YPEOMPA	1	913	350	GTGGTAAA	CCAGATCG
YPECVE	YPECVE	1	517	351	GTACAGAT	TGAGGTAC
YPECAF1	YPECAF1	1	525	352	TATGAAAA	ATATAGAT
ACAHAG	ACAHAG	1	1082	353	GGTTGCGC	TGCTCTCG
ACAMAG	ACAMAG	1	919	354	CCGTCTGT	GTCATGTA
ACAGH17	ACAGH17	1	810	355	ACACAGCA	AAAAAAAA
BDEWI-1	BDEWI-1	1	942	356	GGATCCAT	TTTTTGTG
BDEBYS1	BDEBYS1	1	912	357	ATGCATCT	ATGATAAC
CIMAG2	CIMAG2	1	1234	358	CTCTCCCT	TTTTGTTA
CIMBG12	CIMBG12	1	965	359	ATAGAGGG	GAAACGAT
CPACP2	CPACP2	1	735	360	CTGAGGAA	TTCAAAAA
CPASOD	CPASOD	1	375	361	TTGAATTC	GTGATGTA
ECOGYRA	ECOGYRA	1	812	362	GAAGATCT	ACCGATGC
ECOOMPA	ECOOMPA	1	660	363	ATGAAGAA	CGCTGTAA
SENGYRA	SENGYRA	1	812	364	GAAGATCT	ACGGATGC
SENOMPA	SENOMPA	1	904	365	GTGCTAAA	CCGGATCG
SDYOMPA	SDYOMPA	1	907	366	GTGCTAAA	CCGGATCG
SFLGYRA	SFLGYRA	1	812	367	GAAGATCT	ACCGATGC
SFLOMPA	SFLOMPA	1	898	368	GTGCTAAA	CCGGATCG
VCHGYRA	VCHGYRA	1	887	369	GAAGAGCT	ACCAATGC
VCHOMPA	VCHOMPA	1	942	370	ATGAAAAA	TCCCTGAA
MSRA	MSRA	1	400	371	GCAAATGG	ATCACATG
MECR1	MECR1	1	652	372	ATGGAGGT	GAATCGAT

MEFA	MEFA	1	611	373	AATATGGG	ACTACGGC
ERMTR	ERMTR	1	732	374	ATGAAACA	TTCAATAA
ERMB	ERMB	1	763	375	GATGTATC	GGAAATAA
EMRB	EMRB	1	1560	376	ATGCCAAA	TTCACTAA
GYRB	GYRB	1	1947	377	ATGACAGA	ATGTCTAA
PARC	PARC	1	2637	378	GAGTTTGC	AATATAAG
PARE	PARE	1	2008	379	AAAATTTT	TGTTTTAA
PBP1	PBP1	1	1282	380	TTCGACCA	ACGAGCTA
PBP5	PBP5	1	668	381	TGACGATC	AACGAGCA
MECA	MECA	1	729	382	ATCGATGG	ATGAATAA
BLAZ	BLAZ	1	846	383	TTGAAAAA	AATTTTAA
DFRA	DFRA	1	486	384	ATGACATT	GGAAATAG
VANA	VANA	1	1032	385	ATGAATAG	AGGGGTGA
QACC	QACC	1	324	386	ATGCCTTA	CGCATTAA
RMTB	RMTB	1	756	387	ATGAACAT	ATGGATAA
STRA	STRA	1	804	388	TTGAATCG	GGGGTTGA
STRB	STRB	1	837	389	ATGTTCAT	CATACTAG
AADA1	AADA1	1	792	390	ATGAGGGA	GCAAATAA
SULII	SULII	1	816	391	ATGAATAA	TTCGTTAA
CTXM	CTXM	1	436	392	CAAGAAGA	ATGGCACC
KPC2	KPC2	1	918	393	CGTTGATG	CCACCACC
AMPC	AMPC	1	1140	394	ATGAAAAA	TGGAATAA
BLACMY2	BLACMY2	1	1146	395	ATGATGAA	TGCAATAA
AMPR	AMPR	1	876	396	ATGGTCAG	CGGCGTAA
SULI	SULI	1	840	397	ATGGTGAC	ATGCCTAG
AACAAPHD	AACAAPHD	1	1440	398	ATGAATAT	AAGATTGA
FLOR	FLOR	1	1215	399	ATGACCAC	TCGTCTAA
TETM	TETM	1	536	400	CACGCCAG	CGGAAATG
TETC	TETC	1	502	401	TATCGTCC	CAGTCAGC

TETS	TETS	1	555	402	GCTACATT	GGCATTCA
TETA	TETA	1	494	403	TGGCATTC	GCTATACG
TETG	TETG	1	550	404	CTCGGTGG	GGCTTTGC
TETL	TETL	1	548	405	CTGGGTGA	ATTCCTGA
TETB	TETB	1	571	406	AGTGCTGT	TCCAAGCC
PTX	PTX	1	872	407	ATCACTAC	CAGGAGCT
BONT	BONT	1	792	408	TGATGGAA	TTCTACGG
NTNH	NTNH	1	496	409	AATATTTG	AATATGGT
BOTE	BOTE	1	1000	410	GATAAAAT	TAACTATG
EPSILON	EPSILON	1	620	411	ATGCGAAA	GGAGGAGC
TETANUS	TETANUS	1	1185	412	CCTGATAA	CTAACGGA
STX1A	STX1A	1	948	413	ATGAAAAT	GCAGTTGA
STX2A	STX2A	1	960	414	ATGAAGTG	GTAAATAA
RICINUSTOXIN	RICINUSTOXIN	1	1133	415	ATGGTCCA	CATCGGAT
CTXAB	CTXAB	1	984	416	CGGGCAGA	CCTGAGGA
PBLUEVEC	PBLUEVEC	1	236	417	CTGCAGGA	TGCGTTGC
PGEMVEC	PGEMVEC	1	226	418	GAATATGC	TGCGTTGC
PUCVEC	PUCVEC	1	252	419	AGACAGTT	TGCGTTGC
ATTIM4	ATTIM4	1	523	420	ACATCGAC	GAGCTTGC

Sample Preparation

In any embodiment of the present invention, the target nucleic acids (DNA and/or RNA) may be contained within a biological sample. The term "biological sample", as used herein, refers to a sample obtained from an organism or from components (e.g., cells) of an organism. The sample may be of any biological tissue or fluid. Alternatively, the sample may be one taken from the environment (air, soil or water). Frequently the sample will be a "clinical sample" which is a sample derived from a patient. Such samples include, but are not limited to, sputum, nasal wash, nasal aspirate, throat swab, blood, blood cells (e.g., white cells), tissue or fine needle biopsy samples, urine, peritoneal fluid, visceral fluid, and pleural fluid, or cells therefrom. Within the context of the present invention it is preferred that the clinical sample be a nasal wash, nasal aspiration or a throat swab. In a particularly preferred embodiment the clinical sample is a nasal wash. Biological samples may also include sections of tissues such as frozen sections taken for histological purposes, or from non-human animal sources, plants, or environmental sources such as water, air, or soil.

In order to be detected using microarrays, the target nucleic acids may require some degree of processing.

For the intended purposes, this will involve one or more of the following target processing steps: (1) isolation, (2) enrichment for target sequences of interest, (3) amplification, (4) labeling, and (5) hybridization. Preferred embodiments corresponding to each of these processing strategies are described below; however, the present invention is not intended to be limited thereto. To this end, the skilled artisan would readily appreciate alternative methods corresponding to the aforementioned processing strategies both based on those commonly in use and as described in U.S. 6,638,717, U.S. 6,376,191, U.S. 5,759,778, U.S. 6,268,133, and U.S. 6,613,516.

Target nucleic acid isolation

In an embodiment of the present invention, the target nucleic acids (RNA and/or DNA) to be assayed are isolated prior to amplification of the same. Methods of isolating nucleic acids are well known to the skilled artisan.

In a preferred embodiment, the target nucleic acid isolation may be performed using a MasterPure™ DNA Purification Kit (Epicentre Technologies, Madison, WI) ethanol purification method (per manufacturer's instructions). In another preferred embodiment, the target nucleic acids will be isolated using a rapid microcentrifuge technique, as in the use of Xtra Amp Kit (XTRANA, Inc. Broomfield, CO). In yet another preferred embodiment, the nucleic acids will be isolated using an automated device for said purpose, such as a GeneXpert (Cepheid, Sunnyvale, CA) or using a robot for magnetic bead-based isolation (e.g. Qiagen or Beckman).

A variety of other commercial products are available that are geared towards purification and concentration of nucleic acids from complex matrices. In addition to the methods described above and in the invention, alternatives include:

QIAamp DNA Mini Kit (Qiagen)-

(For purification of genomic, mitochondrial, bacterial, parasite, or viral DNA)

The QIAamp DNA Mini Kit simplifies isolation of DNA from human tissue samples with fast spin-column or vacuum procedures. DNA binds specifically to the QIAamp silica-gel membrane while contaminants pass through. PCR inhibitors such as divalent cations and proteins are completely removed in two efficient wash steps, leaving pure DNA to be eluted in either water or a buffer provided with the kit. QIAamp DNA technology yields genomic, mitochondrial, bacterial, parasite, or viral DNA from human tissue samples ready to use in PCR and blotting procedures.

RNeasy Mini Kit (Ambion)-

The RNeasy Mini Kit allows efficient purification of total RNA from very small amounts of tissue or cells. Total RNA is easily purified from animal cells or tissues, Gram-positive or Gram-negative bacteria, or yeast. RNeasy technology simplifies total RNA isolation by combining the stringency of guanidine-isothiocyanate lysis with the speed and purity of silica gel–membrane purification.

UltraClean™ Tissue DNA Kit (Mo Bio Laboratories, Inc.)-

Fresh or frozen tissue samples are homogenized using bead-beating technology to lyse the cells. Lysates are loaded onto a silica spin filter. During a brief spin, the DNA selectively binds to the silica membrane while contaminants pass through. Remaining contaminants and enzyme inhibitors are removed by a wash step. Pure DNA is then eluted into certified, DNA-free Tris buffer.

UltraClean™ Tissue RNA Kit (Mo Bio Laboratories, Inc.)-

Prepared fresh or frozen tissues are homogenized using a tissue homogenizer or mortar and pestle in the presence of lysis solutions. The RNA is captured on a silica membrane spin filter while contaminants are passed through the filter by centrifugation. The filter is washed to remove any remaining contaminants and salts. The RNA is then eluted into certified RNase-free water (provided). RNA is of high quality and is ready for any downstream applications.

Wizard® Genomic DNA Purification Kit (Promega)-

The Wizard® Genomic DNA Purification Kit is designed for isolation of DNA from white blood cells, tissue culture cells and animal tissue, plant tissue, yeast, Gram-positive and Gram-negative bacteria. The Wizard® Genomic DNA Purification Kit is based on a four-step process. The first step in the purification procedure lyses the cells and the nuclei. For isolation of DNA from white blood cells, this step involves lysis of the red blood cells in the Cell Lysis Solution, followed by lysis of the white blood cells and their nuclei in the Nuclei Lysis Solution. An RNase digestion step may be included at this time; it is optional for some applications. The cellular proteins are then removed by a salt precipitation step, which precipitates the proteins but leaves the high molecular weight genomic DNA in solution. Finally, the genomic DNA is concentrated and desalted by isopropanol precipitation.

SV Total RNA Isolation System (Promega)-

The SV Total RNA Isolation System provides a fast and simple technique for the preparation of purified and intact total RNA from tissues, cultured cells and white blood cells using this membrane-based purification system. The system incorporates a DNase treatment step directly on the membrane of the minicolumn. Purification is achieved without the use of phenol:chloroform extractions or ethanol precipitations, and there is no DNase carryover in the final RNA preparation.

RNAqueous Technology (Ambion, Inc.)-

RNAqueous kits can be used to purify total RNA from many different tissues and cells. Cells or tissue are disrupted in a guanidinium thiocyanate solution; this chaotropic agent effectively lyses cells and inactivates endogenous ribonucleases. The lysate is then diluted with an ethanol solution and applied to an RNA-binding glass fiber filter. Proteins, DNA and other contaminants are removed in three rapid washing steps, and the bound RNA is then eluted in concentrated form.

Nucleic Acid Isolation Robotics

In addition to those methods described above, several vendors (e.g. PSS BIO Instruments, Roche Diagnostics, Qiagen, Caliper) manufacture both small (benchtop) and/or high-throughput liquid handling robots and associated reagents that can be used instead of the manual methods described above. In a preferred embodiment, one or more such robots and their associated reagents will be used to automatically isolate nucleic acids for the subsequent processing (background removal and amplification).

Target Amplification

One set of technical challenges for pathogen detection with microarrays arises because of the difficulty in obtaining samples with a sufficient quantity of pathogen nucleic acids. Thus, for a majority of sample types, some

sort of amplification will likely be required to provide sufficient copies of pathogen gene markers for detection by microarray hybridization. Multiplex PCR as a microarray preparative step is practically limited to tens of different primer pairs, not thousands, and increasing numbers of primer pairs give rise to varying numbers of spurious amplicons. However, discrimination occurs when the labeled amplicons are required to hybridize to specific probes on the array surface and, fortuitously, spurious amplicons may not detected by the microarray assay (Chizhikov et al., 2001).

Multiplex PCR

Conserved (degenerate) multiplex PCR serves to reduce the systemic bias introduced with specific PCR protocols by designing a series of primers selected to target the conserved regions flanking species-specific variable regions of a gene(s) to be probed. In the examples of the present application, the strategy for *E1A*, *fiber*, and *hexon* genes has been illustrated; however, the skilled artisan may expand this strategy to target any gene that is conserved across a broad spectrum of species, but still has species-specific variable regions. To this end, candidate genes and the specific regions (conserved and variable) can be readily identified by global or local homology searches (i.e., sequence alignment).

Applicants describe below a general strategy for the selection of targets and primer design:

As used herein the term "primer" (and generally appreciated in the art) refers to an oligonucleotide that is capable of acting as a point of initiation of polynucleotide synthesis along a complementary strand when placed under conditions in which synthesis of a primer extension product that is complementary to a polynucleotide is catalyzed. Typical polynucleotide synthesis conditions include the presence of four different nucleotide triphosphates or nucleoside analogs and one or more enzyme to catalyze polymerization (e.g., a DNA polymerase and/or reverse transcriptase) in an appropriate buffer ("buffer" includes substituents which are cofactors, or which affect pH, ionic strength, etc.), and at a suitable temperature.

To facilitate specific PCR, amplification primers typically range from 13 to 35 nucleotides, preferably from 20 to 25 nucleotides. The nucleotide sequence of the primer must have sufficient sequence complementarity to the target sequence in order to facilitate hybridization. Although the degree of complementarity will depend in large part on the length of the primer, the degree of complementarity generally is at least 80%, preferably at least 90%, more preferably at least 95%.

For random PCR protocols, the preferred primer length is from 6 to 10 nucleotides. The sequence would ideally include all permutations of a hexameric (2^6 permutations) to a decameric (2^{10} permutations).

For the case of "prototype" region design, the preferred scenario would be to have conserved primers that flank variable regions of target genes. This was the case in RPMV1 for adenovirus and has been adopted by present inventors for Influenza A (using conserved 3' and 5' ends of Influenza A segments for hemagglutinin (HA) neuraminidase (NA) and matrix (M). This concept can be extended to any of a large number of pathogen types because highly conserved regions are ubiquitous in nature and degenerate primers can be designed for those sequences.

When targets are not selected as "prototypes", the amount of real estate on the chip can be greatly reduced compared to prototype regions. The objective in these cases is not necessarily to identify a particular strain or sub-variant of the species, but rather to allow for enough base calls to be made for an unambiguous statistical estimate demonstrating that the sequence corresponds to the pathogen of interest and not to a closely related species or non-virulent strain. With this chip design of multiple, small targets, it is not feasible to design and optimize conditions

for the large number of specific PCR reactions that would be needed and total amplification becomes the optimal amplification strategy.

Homology, sequence similarity or sequence identity of nucleotide or amino acid sequences may be determined conventionally by using known software or computer programs such as the *BestFit* or *Gap* pairwise comparison programs (GCG Wisconsin Package, Genetics Computer Group, 575 Science Drive, Madison, Wisconsin 53711). *BestFit* uses the local homology algorithm of Smith and Waterman, Advances in Applied Mathematics 2: 482-489 (1981), to find the best segment of identity or similarity between two sequences. *Gap* performs global alignments: all of one sequence with all of another similar sequence using the previously described methods (Needleman & Wunsch, 1970). When using a sequence alignment program such as *BestFit*, to determine the degree of sequence homology, similarity or identity, the default setting may be used, or an appropriate scoring matrix may be selected to optimize identity, similarity or homology scores. Similarly, when using a program such as *BestFit* to determine sequence identity, similarity or homology between two different amino acid sequences, the default settings may be used, or an appropriate scoring matrix, such as *blosum45* or *blosum80*, may be selected to optimize identity, similarity or homology scores.

Targets may also be amplified using a combination of specific PCR reactants in what is referred to as "multiplexed PCR". In this strategy, PCR primer pairs for all target regions on the RPM are combined into one reaction mixture. This is a preferred method in cases where one or more of the pathogens is present in too low a concentration to be detected using random amplification strategies alone (described below).

Random Amplification Strategies

Despite the sensitivity and specificity associated with PCR amplification, the inherent bias and limited throughput of this approach limits the principal benefits of downstream microarray-based applications. As successful identification depends almost entirely on appropriately chosen primer sets, all PCR-based testing requires *a priori* knowledge pertaining to the identity of the contaminating organism. As such, there remains a critical need for advanced diagnostic systems that can rapidly screen clinical and environmental samples without bias for specifically anticipated sequences. The advantage of microarray-based detection is that it can combine unbiased (e.g. random) nucleic acid amplification strategies with the subsequent discriminatory capability of microarrays, resulting in high sensitivity, specificity and throughput capacity.

The inventors have addressed the aforementioned issues through the use of alternative approaches and have investigated four front-end amplification strategies: random primed, isothermal Klenow polymerase-based, ϕ29 DNA polymerase-based and multiplex PCR (Vora et al., 2004).

Klenow-based amplification – The Klenow fragment of DNA polymerase I can be used for isothermal, random amplification of target DNA of unknown sequence with random octamers oligonucleotide primers. For the present invention, this can be performed using the BioPrime® DNA Labeling System (Invitrogen). Biotinylated amplicons are generated (following the manufacturer's recommended labeling protocol with minor modifications). This process is typically performed at 37°C for 4 hours. Klenow amplification results in some high molecular weight amplification products, but the vast majority of amplicons are 50-450 basepairs (bp) in length. As such, these amplicons are suitable for direct hybridization to DNA microarrays.

Random PCR amplification – Random PCR (rPCR) amplicons can be generated using the 2.5X Random Primers

Solution and 10X dNTP mix from the Invitrogen BioPrime DNA Labeling System. The reaction components typically include: 1X PCR buffer (Qiagen), 2.5 mM $MgCl_2$, 1X dNTP Mix (containing biotin-14-dCTP), 5 µl of 2.5X random octamers and 5 U Taq DNA polymerase (Qiagen). The amplification reactions are performed using the following conditions for 35 cycles: 94°C for 30 sec, 26°C for 2 min, and 72°C for 1 min.

ϕ29-based amplification – Isothermal ϕ29 DNA polymerase-based amplification with random hexamers can be performed using the TempliPhi™ 100 Amplification Kit (Amersham Biosciences Corp., Piscataway, NJ). Biotinylated amplicons are generated following the manufacturer's recommended protocol with minor modifications (14.4 µl amplification reactions contained 0.4 µl enzyme mix and 3 µl of 350 µM biotin-14-dCTP and are incubated at 30°C for 16 h).

The majority of both the rPCR and ϕ29 DNA polymerase amplification products are too large to migrate into electophoretic gels (> 1500 bp). Large amplification products hybridize poorly to immobilized probes on two-dimensional surfaces due to spatial and steric constraints (Vora et al., 2004). Thus, the rPCR and ϕ29 polymerase amplification products are digested with a DNase I fragmentation buffer to achieve amplicon sizes that are comparable to the Klenow and multiplex amplicons prior to hybridization.

Tandem Amplification

Increased sensitivity to pathogen targets can be achieved using a combination of the random amplifications strategies described above. Tandem [Klenow + Klenow] and [ϕ29 + Klenow] tandem random amplification strategies can provide better sensitivity to enriched pathogen targets than multiplex PCR. The same random amplification strategies are also able to detect diagnostic genomic targets in spiked environmental water samples containing a 63-fold excess of contaminating DNA (Vora et al., 2004). The results presented underscore the feasibility of using random amplification approaches and begin to systematically address the versatility of these approaches for unbiased pathogen detection from environmental sources.

Combination of Target Enrichment and Random Amplification

Random amplification methods result in amplification of non-target DNA as well as target DNA. Thus, the inventors describe herein a variety of methods for enrichment of pathogen diagnostic target sequences in advance of random amplification steps. This is especially important to improve sensitivity and/or specificity of detection of analytes in complex matrices such as clinical (e.g. nasal wash or throat swab) or environmental (e.g. water, soil, air collector) samples.

Complex samples (clinical and environmental) contain significant, and sometimes overwhelming amounts of unknown genomes and genomes not of interest (non-specific background). One approach to reduce the non-specific background is to expose the nucleic acids to enzymatic processes that selectively digest the background genomic sequences. This process is described below within the examples.

Another strategy for reducing non-pathogen genomic content is to use background genomic sequences from a comparable complex sample known to be negative for the organism(s) of interest and use it to directly remove background genomic sequences. Such "subtractive" methods can include: (1) immobilization of the background genomes on solid phase surfaces such as gels or beads, followed by hybridization with the test sample to absorb background genomes from the samples. One can also use unlabeled background genomes during hybridization of targets on microarray to block the effects of non-specific binding due to the labeled background

genomes. This blocking approach has the advantage in that it does not require additional steps during assaying. Both such strategies are also described in the Examples section.

Alternatively or concurrently, one can also use strategies to selectively enrich for the pathogen target nucleic acids prior to random amplification. One possibility for direct selection (also known as positive selection) from samples is to use immobilized probes on a solid phase support (magnetic beads or gel matrices) to selectively enrich for genomic targets of interest. Ideally, the probes on the solid support should not be detectable on the array, as they would result in false signals in the event that the enrichment molecules are carried over or inadvertently amplified. As such, the probes on the beads should select for target genomes via an adjacent region or slightly overlapping with the region of the analytes' genomes to be queried on the microarray. If there is a slight overlap between the probe sequences and the analytes' sequences that is detectable on the array, then this queried region should be masked out during *in silico* analysis. In the event that it is desirable that the enrichment probes have homologous sequence to that on the microarray, then those probes should be comprised so as to not undergo subsequent amplification, or be made susceptible to selective enzymatic digestion prior to amplification. One can use combinations of the above and other strategies if necessary according to the specifics of the sample and applications of interest.

Alternative subtraction or enrichment methods

Immunoprecipitation is another way to enrich the pathogens' nucleic acids. Antibodies for pathogens of interest could be mixed with clinical samples, then precipitated with anti-IgG to pull down pathogens, thereby removing background genomic DNA. This will be of particular importance when it is desirable to correlate specific genomic traits with a single pathogen, such as antibiotic resistance markers or indicators of intentional genetic manipulation.

Size exclusion is another method by which to subtract or enrich pathogen DNA. Exemplary size exclusion methods include: gradient centrifugation, column, or centrifugal filter units. Gradient centrifugation or column separation methods are time-consuming and require special set-up in the laboratory. The use of "centrifugal filter units" for separation of high- from low-molecular-weight species suffers from inconsistent and, often, low recovery rates. Each of these methods requires a large volume of starting material. Other size exclusion methods include: flow cytometry or electrophoresis methods, such as fluorescence-activated cell sorting (FACS) or with a special electrophoretic chip used in an Agilent bioanalyzer.

General target enrichment and amplification strategies

The present inventors have described methods for subtraction of "normal" human and microbial nucleic acids from nasal wash specimens. This same principle can also be applied to samples of any origin (clinical or environmental) where a representative "normal" mixture of nucleic acids can be collected, pooled, and prepared as a subtractive reagent.

A variety of approaches can also be applied to enrich for the pathogens or specific targets that are tiled on the array prior to performing a total amplification strategy. One such approach would use immobilized variants of the sequences that are tiled on the array. These variants would be bound to a solid phase component used for separation (beads, matrices, etc.) and serve to enrich for targets that will be amplified without being amplified themselves. Making the enrichment probes susceptible to enzymatic degradation can do this or they might be comprised of modified nucleic acids that would not be amplifiable.

A more preferred embodiment would utilize probes that recognize sequences that are adjacent to target gene sequences and not represented on the tiled regions of the chip. In this manner, their amplification in a non-biased amplification strategy would not result in artifacts.

As conventional DNA sequencing technologies can be considered as part of an overall information collecting process in basic research, so can the described resequencing approach be considered a component of an overall pathogen detection / characterization scheme. Wang et al. (Wang et al., 2003) describe a method for using a spotted DNA microarray comprised of long oligonucleotides (70-mers) that recognized conserved sequences, which are within a family of pathogens. Target sequences bound to these locations were isolated and used in a conventional DNA sequencing approach to allow further characterization. In an analogous manner, a very preferred embodiment would involve the use of the resequencing array to replace the steps related to alternative forms of DNA sequencing, thus providing specific pathogen characterization within hours instead of days and enablement of an effective biodefense system.

The method of the present invention preferably does not make use of *specific* sequences for amplification (PCR). The invention illustrates that there are alternate methods for enrichment of pathogen nucleic acids, for example: using solid phase support separations, prior to applying reduced bias, and isothermal (e.g. random-primed Klenow or strand displacement) amplification. In a preferable embodiment, a skilled technician in a conventional laboratory setting would be capable of performing time- and cost-effective sample preparation using a minimal set of automated steps to perform microarray experiments. In a highly preferred embodiment, a minimally skilled technician (medical technologist or medic) in a field environment (medical level 1) would be capable of performing manual separation / enrichment of pathogen target nucleic acids using a handheld instrument and perform isothermal amplification of pathogen targets with few reagents and technical steps.

Amplification and hybridization following background subtraction

In addition to random RT-PCR using primer D: GTTTCCCAGTCACGATCNNNNNNNNN (SEQ ID NO: 573), and Primer E: GTTTCCCAGTCACGATC (SEQ ID NO: 574) (Kessler et al., 2004), analogous, previously described primer sets (Wang et al., 2002), variants of those primer sets, and/or random (6-9mers) to synthesize first strand cDNA from RNA viruses (pathogens) may be employed. A subtractive hybridization protocol could be employed after first strand cDNA synthesis is complete to reduce the amount of background DNA in clinical samples before subjecting complex (i.e. clinical or environmental) samples to one or more DNA amplification step(s).

One method is direct subtraction of the background genomic DNA from amplified products (first strand cDNA synthesis, then total amplification) in hybridization solution with COT-1 human DNA (which consists largely of rapidly annealing repetitive elements). Another method is bead-based subtraction of background genomic DNA from clinical sample after first strand cDNA synthesis and prior to the DNA amplification step.

The third method is the combination of the above methods. In this case, the human genomic background DNA from complex samples would be subtracted using bead-based subtraction after first strand cDNA synthesis and prior to the DNA amplification step(s). Subsequently, the background DNA could be further subtracted from complex sample in hybridization solution with sequences designed to selectively capture human DNA and RNA. The DNA amplification step itself could be aimed at amplifying the cDNA products formed in the random RT step specifically, non-specifically, or through a combination of methods to amplify both the specific primer site-labeled RT-PCR products as well as pathogen genomic DNA targets and other non-cDNA targets that did not arise from the

random RT-PCR step. One approach for doing so would be to ligate a specific primer sequence to the pathogen DNA genomic targets (this could be the same primer as used attached to cDNA products or a separate one), allowing a single PCR step to amplify all RNA and DNA pathogen targets.

RNA substraction

Where separate processing pathways exist for detection of RNA and DNA pathogens the following may be used. For development of the RNA processing pathway, spiked and clinical (nasal wash and throat swab) Influenza A positive specimens were processed using different methods (random, universal, and multiplexed PCR). However, to achieve acceptable levels of sensitivity with random amplification approaches, human messenger and ribosomal RNA should be subtracted using the MICROBEnrich™ kit (Ambion, Inc., Austin, TX) in accordance with the manufacturer's instructions. A preferred random amplification strategy may be empolyed adapted from a previously described method (Wang et al., 2002).

It was found by the present inventors that by employing this method positive detection of H3N2 and H1N1 Flu A detection in 16/19 different culture-positive Flu A nasal wash and throat swab specimens at concentrations as low as 0.45-3.75 pfu/150 µL sample aliquot may be achieved. It was further determined it was possible to detect Flu A in 6/8 specimens in the low concentration range following subtraction of human RNA.

Using random amplification approach, without background subtraction, the flu sensitivity is about 0.25 pfu/µl (1 ng/µl) in spiking nasal wash. In clinical samples, the sensitivty without subtraction is estimated to be about 1-10 pfu/µl.

DNA substraction

Random amplification for DNA samples may be performed with either bacteriophage ϕ29 DNA polymerase or modified random amplification protocol from previously published paper (Wang et al. 2002; Wang et al.2003). Briefly, DNA amplification utilizing bacteriophage ϕ29 DNA polymerase with random hexamers can be conducted according to the instruction of GenomiPhi™ DNA Amplification Kit (Amersham Biosciences Corp., Sunnyvale, CA). The amplified products are then ethanol precipitated according to manufacture recommended protocol. DNA amplification utilizing modified random amplification may be performed with initial round of DNA synthesis with Sequenase™ version 2.0 DNA polymerase (United States Biochemical, Cleveland, OH) using primer D, followed by PCR amplification with primer E. For RNA amplification, viral samples are then amplified by a modified version of a random PCR protocol (Wang et al. 2002; Wang et al. 2003; Kessler et al. 2004). Briefly, 10 µl of total RNA can be reverse transcribed by using primer D and superscript III reverse transcriptase (Invitrogen Corp. Carlsbad, CA), and was then amplified by PCR with primer E.

Convergence of RNA and DNA pathways-

The combination of the RNA and DNA pathways is described in FIG. 9. In an embodiment of the present invention, the pathways for RNA and DNA are merged. This protocol is adapted from the lab of Joseph DeRisi at University of California San Francisco (http://derisilab.ucsf.edu/pdfs/Round_A_B_C.pdf) and randomly incorporates a single, fixed-sequence PCR primer binding site into all pathogen DNA or cDNA molecules, allowing them to all be amplified in a subsequent step using a conventional PCR thermal cycling protocol.

Data acquisition and processing-

Affymetrix/Microarray apparatus

In general, a "microarray" is a linear or two-dimensional array of preferably discrete regions, each having a defined area, formed on the surface of a solid support. The density of the discrete regions on a microarray is determined by the total numbers of different target polynucleotides to be detected on the surface of a single solid phase support, preferably at least about $10^2/cm^2$, more preferably at least about $10^4/cm^2$, even more preferably at least about $10^5/cm^2$, and still more preferably at least about $10^6/cm^2$. As used herein, a DNA microarray is an array of oligonucleotide primers placed on a chip or other surfaces used to detect and/or isolate target polynucleotides. Since the position of each particular group of primers in the array is known, the identities of the target polynucleotides can be determined based on their binding to a particular position in the microarray.

One embodiment of the invention utilized standard Affymetrix hardware (Agilent GeneChip Scanner (phased out) and the Affymetrix Scanner 3000 workstation and Fluidics Station 450. In principle, the described invention does not require this equipment. Given the manufacturer's intended uses of the GeneChip system for quantitative gene expression profiling and high confidence SNP detection, the existing apparatuses are not optimized for the dynamic range of signal intensities or background interferences inherent to the present invention. Thus, a preferred embodiment incorporates the use of image acquisition methods, including the use of spatial frequency filtering and image enhancement, taking advantage of the inherent regularity of the feature dimensions to impose a filtering algorithm (e.g. edge enhancement, convolution, etc.) that allows better contrast of noisy images.

Affymetrix CustomSeq protocol

In an embodiment of the present invention, sample processing is accomplished by employing the standard Affymetrix CustomSeq™ protocol. Generally, this method entails: (a) amplification of DNA probe-containing materials, (b) pooling and quantitation of amplified product, (c) fragmentation and labeling of the amplified product, (d) target hybridization, and (e) washing, staining, and scanning of the hybridized target. A detailed description of the Affymetrix CustomSeq™ protocol can be found in the product manual and protocol guide, which are available from the manufacturer.

In the standard Affymetrix CustomSeq™ protocol, step (a) entails either long-range PCR or short-range PCR, with long-range PCR being the preferred amplification strategy. For each of these amplification strategies, the manufacturer recommended PCR DNA polymerases are Taq variants, AmpliTaq Gold DNA polymerase (short-range PCR) and LA Taq DNA polymerase (long-range PCR). Although not specifically recommended by the manufacturer, any DNA polymerase may be employed for step (a) so long as the DNA polymerase used is a high fidelity DNA polymerase.

To facilitate DNA amplification step (a), the standard Affymetrix CustomSeq™ protocol employs specific PCR primers. However, the use of specific PCR primers significantly limits the broad application of the inventive technique due to the introduction of systemic bias flowing from the specific PCR based methods that have heretofore been employed. Accordingly, in a preferred embodiment of the present invention step (a) of the Affymetrix CustomSeq™ protocol is replaced with an alternate amplification strategy, such as multiplex PCR, total amplification (GenomiPhi™), or random RT/PCR. These alternate strategies are discussed hereinabove. Conditions for optimal PCR amplification for each of the manufacturer recommended PCR strategies, as well as the preferred strategies of the present invention, can be determined by routine experimentation by the skilled artisan.

Since variability exists between PCR reactions, the Affymetrix CustomSeq™ protocol states that assay performance may be compromised if amplicon concentration in the hybridization varies by more than two fold.

Therefore, step (b) of the Affymetrix CustomSeq™ protocol entails pooling PCR reactions and spectrophotometrically quantifying the same to ensure equimolar application of sample to the microarray.

However, the present invention poses several advantages over the SNP detection tailored protocols of the Affymetrix CustomSeq™ method. In particular, the use of the increased density chips with sequence length-independent similarity searches (BLASTN) in the present invention affords that fewer assumptions must be made in advance of selecting sequences for tiling. Furthermore, the use of length-independent similarity searches (BLASTN) removes the constraint that a particular known subsequence be successfully resequenced, making the approach more resistant to variations in target concentration and contributions from nonspecific binding leading to lost base calls. Accordingly, within the present invention step (b) of the Affymetrix CustomSeq™ protocol is optional and may be omitted.

Following DNA amplification, the DNA molecules obtained thereby are too long to hybridize with the short probes on the array surface. Accordingly, step (c) of the Affymetrix CustomSeq™ protocol involves fragmentation and subsequent labeling of the fragments with a fluorescent substrate. The method and reagents for fragmentation and labeling are not particularly limiting; however the label must be compatible with the detection apparatus for the resequencing microarray. To this end, the manufacturer recommended reagents and conditions may be employed.

Alternative variations of the Affymetrix protocols

Fluorescent labels that may serve to be advantageous for the methods described herein, as these are routinely used with automated instrumentation for simultaneous high throughput analysis of multiple samples, include the Cy fluorophores, the rhodamine based fluorophores: TARAM, ROX, JOE, and FAM; the BigDye™ fluorophores (Applied Biosystems, Inc.), the dansyl group, fluorescein and substituted fluorescein derivatives, acridine derivatives, coumarin derivatives, pthalocyanines, tetramethylrhodamine, Texas Red™, 9-(carboxyethyl)-3-hydroxy-6-oxo-6H-xanthenes, DABCYL™ ,BODIPY™, and ALEXA™ fluorophores (Molecular Probes, Eugene, Oregon)

Additionally, there are a variety of labels other than fluorophores that will be suitable and perhaps preferable for a variety of situations. These labels include, but are not limited to: resonance light scattering (RLS) particles (InVitrogen, Carlsbad, CA), quantum dots (Quantum Dot Corp.) and other nanoscale particles having desirable optical qualities.

The target hybridization (step (d)) may be performed as described in the Affymetrix CustomSeq™ protocol. The highlight of this step is that the sample containing the fragmented and labeled DNA is denatured by a high temperature (e.g., 85-100°C, preferably 95°C) incubation followed by a hybridization temperature (e.g., 45°C) equilibration. Once the DNA-containing sample has equilibrated the sample is applied to the resequencing array. The manufacturer recommends conducting the hybridization reaction for 16 hours; however, as stated above, the method of the present invention does not have its hands tied to enhance sensitivity to make the appropriate base calls. Therefore, shorter incubation times are appropriate for target hybridization. Within the context of the present invention, the target hybridization incubation time may range from a short time of 15 minutes to a long of 24 hours. Clearly, it is contemplated that this range of times embodies each of the intermediate times as if they were explicitly stated. Preferable times worth noting are 15 minutes, 30 minutes, 1 hour, 2 hours, 4 hours, 12, hours, and 16 hours.

The last step of the Affymetrix CustomSeq™ protocol entails washing the hybridized array using the Affymetrix Fluidics Station and scanned using the Agilent GeneArray™ Scanner. This instrument simply

automates what would otherwise be manually performable labeling and rinse steps. Thus, any instrument that would be capable of delivering and withdrawing milliliter quantities of labeling and rinse media on a timed basis would be a suitable alternative. The invention described herein will be amenable to any subsequent hardware variations offered by Affymetrix. In addition, data acquisition from the types of resequencing microarrays described herein may be obtained from any manufacturer of equipment for microarray processing.

Bioinformatics Issues Concerning Pathogen Detection-

Depending on the endpoints used for microarray-based detection of pathogens, the emphasis of bioinformatics issues is very different. Bioinformatic tools are indispensable for the efficient design and selection of specific complementary nucleic acid probe sequences for microarray development. For example, target pathogen genomic nucleic acid sequences are often amplified prior to microarray analysis and bioinformatics clearly has a role in the design of primers (assessing T_m/T_a, secondary structure, self-complementarity, and specificity issues) for assaying genes considered specific to an organism and strain (Kampke, Kieninger & Mecklenburg, 2001). These same assessments must also be made for microarray probe design.

During the initial stages of experimental design, it is assumed that primers and probes to genetic signatures associated with a target pathogen are specific to that pathogen or family of pathogens. It would follow that the generation of an amplicon or positive hybridization reaction using specifically designed primers or probe, respectively, would indicate the detection of the designated molecular trait from the target pathogen; however, this is not necessarily true. Bacterial and viral 'genetic promiscuity', the propensity of microorganisms to exchange genetic material, creates difficulties in developing single species or strain specific probes (Ochman, Lawrence & Groisman, 2000). Thus, preferred primer and probe design methodologies require the use of bioinformatic tools to: (a) perform multiple sequence alignments between different organisms or strains and design appropriate primers with the appropriate biochemical properties, (b) compare these sequences with those deposited in sequence databases to determine the present uniqueness of particular sequences and the potential for cross-reactivity, and (c) infer the probability of target specificity based on the level of genetic conservation and evolutionary relatedness with other pathogenic and non-pathogenic species whose primary genetic sequence has not yet been elucidated.

A very important bioinformatics aspect of the disclosed invention involves the assembly, annotation and selection of pathogen diagnostic targets into database(s) for incorporation into microarray design, as well as the concomitant task of relating detection events on the microarray to such database(s). An advantage of the present invention is that the information contained in the publicly available databases is ever increasing, thus further adding to the robust nature of the present invention. The present invention describes a process of manually selecting pathogen target sequences from the published literature (e.g. GenBank) and/or ascertaining an empirically determined diagnostic target sequence from published literature. The described approach has the advantage that a consortium of scientists, each possessing sufficient "domain expertise" for each of a large number of disparate pathogen species, can provide relevant, pathogen diagnostic sequence information that can be incorporated into an automated array design process without specific regard to specific probe, reagent, amplification, and sample preparation methods.

In one very preferred embodiment, the requisite domain expertise for each of a large number of unrelated pathogens will be maintained in an up-to-date fashion through a web-portal enabled database. Thus, an extended consortium, comprised of individual researchers of specific pathogens, would be able to provide the latest annotated target sequence information via a "pathogen page" formatted web portal, analogous to the "molecular page" model

adopted by the Alliance for Cellular Signaling (AfCS). The AfCS database then maintains an otherwise incomprehensible amount of specific information on thousands of molecules involved in intracellular signaling cascades. In this format, individual researchers without specific knowledge about individual signaling molecules can access detailed parameters that can be used in numerical simulations of signaling events. Thus, in another very preferable embodiment, the annotated target sequence data for individual pathogens is organized into an automated data pipeline in which will impose user-defined design constraints (e.g. number of probe features, number of pathogen targets, the levels of sensitivity and specificity required for array performance, etc.) upon the total information content of a pathogen database, allowing automated, optimal target selection and submission of those targets to a vendor in a format necessary for microarray fabrication.

In yet another very preferred embodiment, the selected target sequences determined by the previous process will be correlated with the data that is collected in actual use of the microarray, such that metrics for probability and quality can readily used for decision-making. Two preferable approaches for performing such automated pipelining of data and algorithms are VIBE (Visual Integrated Bioinformatics Environment) software (Incogen, Inc., Williamsburg, VA) and iNquiry (BioTeam, Boston, MA) which are representative of a class of integrated bioinformatics environments that could be used to equal effect for the intended purpose.

Data acquisition-

Raw sequence data from the resequencing microarray chips is provided by the Genetic Data Analysis Software version 2.0 (GDAS) packaged with the microarray reader from Affymetrix.

The Affymetrix resequencing array contains a defined number of probe cells or features. During scanning, the software divides each feature into subunit squares or pixels (3x3 μm). Each feature contains many copies of a unique 25-base oligonucleotide probe of defined sequence, while a series of eight features query a specific site in a known reference sequence. Four features interrogate the sense strand and contain probes that are identical except for the central base which is A, C, G, or T and four features interrogate the anti-sense strand and contain probes that are identical except for the central base which is A, C, G, or T.

GDAS uses the cell intensity data to make base calls for every base position represented on the resequencing array. Under the manufacturer setting for GDAS, the algorithm uses the intensity data from multiple samples to improve its calling accuracy and assigns a quality score for each call.

GDAS base calling is based on a previously described base-calling algorithm, ABACUS, detailed in (Cutler et al., 2001)). The model assumes that the pixel intensities of a feature are independently and normally distributed. The algorithm computes the estimated mean background and variance for the sense and anti-sense strand features. The base-calling algorithm also specifies models for the presence or absence of various genotypes in the sample (haploid or diploid). A variety of base calling algorithm parameters can be defined by the user (GDAS operator's manual/user's guide, Affymetrix) to obtain a trade-off between base calling percentage and accuracy.

Additional information regarding the GDAS algorithm and the parameters that can be modified is available in the GDAS user manual. A description of the parameters is found in the GDAS version 2.0 manual on pages 207-217. The recommended (default) settings for GDAS are "conservative" settings that focus on the highest level of accuracy. In contrast, the objective of the present invention is to increase the percentage of base calls. To achieve this objective, the present inventors adjusted the parameters to allow highly permissive base calls (increased percentage) as listed below:

"Permissive" Base Calling Algorithm Settings –

- Filter Conditions
  - No Signal threshold = 0.500 (default = 1.000000)
  - Weak Signal Fold threshold = 20000.000 (default = 20.000000)
  - Large SNR threshold = 20.000000 (default = 20.000000)
- Algorithm Parameters
  - Strand Quality Threshold = 0.000 (default = 0.000000)
  - Total Quality Threshold = 25.0000 (default = 75.000000)
  - Maximum Fraction of Heterozygote Calls = 0.99000 (default = 0.900000)
  - Model Type (0 = Heterozygote, 1 = Homozygote) = 0
  - Perfect Call Quality Threshold = 0.500 (default = 2.000000)
- Final Reliability Rules
  - Min Fraction of Calls in Neighboring Probes = 1.0000 (disables filter)
  - Min Fraction of Calls of Samples = 1.0000 (disables filter)

The settings above are significant in the present application because the base call algorithm is set up by default to sacrifice the number of base calls made in order to make the most accurate calls (i.e., for SNP detection). In the present application, the technique is less concerned about achieving the same degree of accuracy as required for SNP detection but instead expanding the number of calls made so that the longest possible stretches of contiguous sequence are produced by GDAS while maintaining necessary specificity.

It is to be understood that within the scope of the present invention, the above-listed permissive settings can be altered individually or *in toto* as desired by the practitioner to obtain an optimal sensitivity/specificity agreement. In addition, it is to be understood that the settings above are exemplary and that each setting may be altered by 10% or more (parameter dependent) without altering the desired result of the present invention.

Resequencing Pathogen Identifier (REPI) and alternatives, modifications, developments

Also according to the invention, it is the sequence information derived from a base-calling algorithm, as applied to the microarray hybridization pattern that is used to identify individual pathogens. Preferably, the sequence of target sequences determined by the resequencing probes is used to query a database using a similarity search algorithm. More preferably, the algorithm uses commonly used local alignment (e.g. Smith-Waterman, BLASTN) sequence alignment algorithms to statistically determine the probability that a given target sequence corresponds to a specific sequence in a database record (Korf, Yandell & Bedell, 2003). Even more preferably, a custom algorithm that determines subsequences that are most suitable for producing meaningful similarity searches against database records determines the set(s) of sequences that are submitted for similarity search automatically. Yet even more preferably, the automated subsequence-parsing algorithm is the Resequencing Pathogen Identifier (REPI) algorithm described in this invention and the sequence database records will be in both the public (e.g. GenBank) and private domain. Variants of nucleic acid sequence similarity search algorithms that are suitable for use in the intended invention include, but are not limited to: Washington University BLAST (WU-BLAST), NCBI-BLAST, FastA, MPsrch, Scanps, and BestFit (Korf et al., 2003).

REPI alternatives and variants

In the described invention, REPI (Resequencing Pathogen Identifier) software (see U.S. Application Serial No. 60/609,918 filed on September 15, 2004, and U.S. Application Serial No. 60/631,460, filed on November 29, 2004) was used to ascertain which base call subsequences from the CustomSeq / GCOS /GDAS process would likely return significant BLAST results through the use of a customized sliding window algorithm. Subsequently, REPI automatically returns BLAST outputs to the end user that allow probabilistic assignments to the likelihood that a given set of base calls correspond to a particular microbial sequence. This low-level software functionality is analogous to the "kernel" of UNIX or UNIX-derived computer operating system, in that all higher-level functions and user interfaces must pass though it for resequencing chip analysis.

The low-level functionality provided by REPI will be central to a number of higher bioinformatics tasks that will utilize discontinuous segments of nucleic acid, or even amino acid sequence. In the following examples, the present inventors provide data showing that sequence fragments can be linked automatically to individual pathogens. In several more preferred embodiments, this approach can be refined to better discriminate between mixtures of pathogens and genetic recombination between pathogens. In one very preferred embodiment, the analysis software would allow for automatic detection of overlapping or homologous sequence fragments on different tiled regions of the array, allowing inference of a mixture of pathogens. In an even more refined embodiment, the analysis software would determine that the sequence outputs from different tiled regions are not overlapping but correspond to contiguous sequence that may be used to infer a genetic recombination event.

For example, a co-infection of two strains of a virus may produce a recombinant with a gene that is homologous with one virus strain except for the 5' end, which has been substituted with the corresponding section of gene for the other virus strain. When this new recombinant virus genome is hybridized on a resequencing microarray, it produces signal from the corresponding pieces of both regions. One would need to have an assembly algorithm to construct a "model" of the pathogen showing which parts might fit together to form an entire target. If the two have significant overlap, one might conclude that there is probably a mixture. But if there were no overlap, there would remain a possibility that there is a recombinant. The degree of overlap (or lack of) could be affected by low concentrations of target with correspondingly smaller amounts of the tiles being filled in. This same principle can be applied even more readily, and with greater impact, on viruses where the recombination is a steady and recurring event, as in the case of influenza, where recombinations between viral segments result regularly in the formation of new viral strains. In fact, this described functionality in REPI will be essential for the distinction of pathogen mixtures versus recombination.

In another very preferred embodiment, REPI algorithms will allow for the analysis of transcriptional markers (e.g. RNA) that have been resequenced using the presently described type of microarray (via hybridization of RNA or complementary cDNA). In a method analogous to that described above for inference of genomic recombination events, transcriptional sequences may also be assembled to determine pathogen viability and transcriptional editing events that can serve as markers for infection.

Another REPI Alternative (estimating the amount of pathogen target in a sample)

Not only is the present inventive approach able to distinguish between mixtures of pathogens and recombination events within a given pathogen (described elsewhere herein) it would also be of great value to provide the end user with an estimate (quantitation) of the relative amount of pathogen that was detected in the resequencing microarray assay. In particular, this would be of great utility when the clinician (technician) attempts

to assign cause and effect when multiple pathogen genomic signatures are detected.

Two types of data may be used for this purpose. The first is the absolute intensity of the hybridization signals on the chip. A non-linear relationship exists between the amount of target in solution and the amount that actually hybridizes and the resulting signal. However, an estimate of the amount of target nucleic acid in the sample could be made by comparison with a standard curve prepared under control conditions. The signal intensity data is readily available from the .CEL file in the Affymetrix data hierarchy, and although the content of the .CEL files were not used in this disclosure, the output of REPI could easily be modified to include the intensity values of the .CEL files. Secondly, the percentage of base calls, both as a percentage of the total tile region size and as a percentage of base calls within a selected subsequence satisfying the sliding window algorithm, could be used as a measure of concentration. Our results show that both of these percentage metrics decrease with decreasing target concentration, although the correct pathogen can still be identified.

General utility for Pathogen detection

In a preferred embodiment, the invention described herein will be used for the routine diagnosis and surveillance of common respiratory pathogens in a clinical setting (at or near point-of-care). Readily obtainable samples (e.g. nasal wash, nasal swab, throat swab, sputum, or blood) will be processed in a simple manner to produce nucleic acid isolates that are obtained using an adsorptive process, enriched for pathogen-specific targets, amplified using a non-biased (e.g. total) amplification method or multiplexed PCR method, and hybridized on the resequencing microarray for a minimal amount of time prior to washing and imaging. The overall process will be sufficiently simple such that a skilled technician (medical technologist level) will be able to perform the assay without a significant interruption in their routine work pattern. Base calls will be made using the custom algorithms or using the steps specified by the vendor. REPI, or some variant thereof, will be used to automatically parse the base calls made by the microarray, and provide the end-user (e.g., physician, health care provider, public health officer, or other decision-makers) with decision-quality information for management (e.g., diagnostic, treatment, prognostic and outbreak control/containment measures) of the infectious pathogen(s) that are causative of the disease symptoms and complications. This analysis would occur locally through the use of an embedded sequence database that would be queried by REPI (e.g. local dedicated BLAST server). In addition to providing a routine diagnostic functionality, the microarray will also carry markers for highly improbable (i.e. bioterrorism) pathogens that would be cause for involvement of others, namely public health officials. However, it is understood that a nasal wash or throat swab may not be the optimal sample type for diagnosis of bioterrorism agents and that a separate sample type may be needed.

Also within the scope of the present invention, which further demonstrate the utility of the microarrays and methods of the present invention, include:

Scenario 1:

Patient arrives to medical facility with T> 100.5 and respiratory symptoms. Nasal wash and/or throat swab are taken. Pathogens which can be identified by this route include the commonly occurring pathogens including those listed in Table 1. The presence of fever has been found to be an important criteria for isolating respiratory pathogens by culture and literature demonstrates that pathogens are typically present at peak titer during febrile periods.

For the bioterrorism agents, little information is available in the literature on infectious titers in respiratory

secretions after intentional release of a biological agent. It is suspected that an aerosol release of an agent of bioterrorism would lead to detectable titers of organism in the first 24 hours post-exposure. In individuals presenting after the first 24 hours post-exposure, the microarray would serve the purpose of identifying common pathogens that might be otherwise erroneously suspected of being cases from the BT/BW agent. A proportion of individuals exposed to a significant aerosol release will develop symptoms rapidly and will retain the BT/BW agent in the nares for detection. For a disease, such as smallpox, the incubation period for onset of symptoms is much longer, but the virus can be isolated from throat culture for days.

Scenario 2:

The individual has been ill for days and did not initially present to a medical clinic, but chose to self-medicate. Patient may not have initially noted fever, but now has fever and respiratory symptoms and is concerned about lack of resolution. Health Care Practitioner (HCP) sees patient and determines appropriate clinical sample. If patient appears more ill, then chest X-ray may be acquired. Common organisms causing lower respiratory tract infection include, but are not limited to: *Mycoplasma pneumoniae, S. pneumoniae, C. pneumoniae, L. pneumophila, S. pyogenes*, Influenza A/B, RSV, Parainfluenza, *S. aureus*, SARS. Amongst the BT/BW agents of concern, an abnormal chest x-ray can be found with *B. anthracis*, Smallpox, *Y. pestis, F. tularensis*. For the common respiratory organisms, nasal wash/throat swab can still be appropriate sample techniques, although some practitioners will choose to send a sputum samples. For the BT/BW agents, sputum and blood can be appropriate sample techniques.

Scenario 3:

Ongoing outbreak of a known agent. The microarray can continue to be useful for detecting cases of other common pathogens, but may also be used to screen for known BT/BW agent using any type of appropriate specimen. Other assays may prove less expensive, but the microarray can provide forensic information and antibiotic resistance data at the time of pathogen identification.

Overall business model

The resequencing DNA microarray and associated devices (to include other types of lower content microarrays or alternative sequence detectors) will be but one class of elements of an integrated pathogen diagnostic / surveillance system. This system will be comprised of diagnostic, informatic, and epidemiologic components. At the diagnostic level, the RPM (and ancillary devices) will provide a rapid and cost-effective methodology for providing a diagnosis, patient-specific treatment information, and prognostic information (based on virulence and resistance markers) of infectious respiratory disease. This will represent a shift in diagnostic emphasis for the provider from clinical suspicion of one or a few pathogens (e.g., *Mycoplasma pneumoniae* and other pathogens with a presentation of "walking pneumonia" would be tested by obtaining bacterial cultures, presence of antibodies to that pathogen, etc.) to symptom-based and broad differential testing by multiplexed DNA microarrays based on the symptom(s) and the organ system or systems effected. The single highly multiplexed DNA arrays will additionally provide diagnostic information on which group of pathogens to treat (e.g., bacteria, viruses, parasitic, and fungal pathogens) producing substantial return on investment by reducing the number of prescriptions based on suspicion of causal agents (e.g., prescribing antibiotics for a viral respiratory infection will have no effect). Additional diagnostic applications can be created to cover all pathogens effecting an organ or organ systems (e.g., respiratory,

genitourinary, central nervous system, etc.), syndromes (e.g., fever of unknown origin evaluated in the hospital for two weeks without identifying the cause to rule out all potential infectious disease causes), symptoms (e.g., all pathogens causing a urticaria or rash that itches, or cough, etc.), around collections of pathogens or threats present in geographic locations, or functional categories (e.g., groupings based on all the organisms known to have antimicrobial resistance in hospital or other confined settings like prisons or nursing homes). This highly multiplexed differential diagnostic testing will be done by determining the causative agent(s) of infection, antimicrobial susceptibility of the agent(s), and genomic sequence-specific clues as to the nature of the agent such that the maximum number of opportunities is identified to increase the efficacy and efficiency of clinical management.

However, because of the high number of specific molecular queries that are being made, a large number of pathogens can be detected, each at previously unattainable levels of detail. As such, a large number of assays (culture, serotyping, and PCR confirmation) that are subsequently and infrequently performed as part of "surveillance" activities are now being performed simultaneously with diagnosis, obviating the need for burdensome and expensive tasks currently required at the clinical level for surveillance support. This would have great relevance to diagnosis and surveillance of variants of RNA viruses (e.g. Influenza and SARS) in a manner that would be prohibitively complicated when relying on specific oligonucleotide probe sets.

In the specific embodiment described here, it will be highly advantageous to have diagnostic microarrays, the fabrication of which will not rely on the availability of a large number of target sequences and a means to fabricate arrays using them. More importantly, it will be critical not to be restricted to the assumption that the target sequences are invariant. Diagnostic DNA microarrays will identify specific but unanticipated genomic variants of a model pathogen, without requiring re-design of specific oligonucleotide probes and array re-fabrication. This will be critical to the ability to characterize the cause(s) of infectious disease outbreaks in a time-effective manner. For example, such microarrays could be used to rapidly detect new variations of influenza or SARS virus without requiring that the pathogens be isolated, cultured, and sequenced using conventional approaches; a process that would require weeks to months if the pathogen were readily cultivable.

The present invention also embraces applications for detecting a mixture of pathogens, especially when there is no preliminary evidence to suggest that the mixture might be interrogated by specific reagents (e.g. PCR primers). Thus, the present invention provides a means to impact the ability to determine the complementary roles of interacting pathogens in disease etiology. However, in applications such as viral or bacterial stock quality control and assessment of viral vaccine production, which involves the intentional mixture of field strain and cultivable viruses to produce recombinants that culture well. Thereby, the present invention enables the presentation of the correct the appropriate epitope(s) for vaccine efficacy.

The informatics component of the system will provide the necessary components to allow local (point-of-care), automatic microarray data analysis as well as coordinate multi-directional information transfer. "Upward" flow of information will entail the transfer of specific sequence base calls from the resequencing chip, preferably in FASTA format, and all associated local processing results, to local, regional, national and international levels. "Lateral" flow of information will involve the exchange of specific sequence base calls and associated local processing results to other local point-of-care medical facilities. "Downward" flow of information is defined as a provision of national level data integration to regional and local health officials.

Like clinical samples, environmental samples may contain small amounts of target nucleic acids in a high genomic background of unknown origin. But unlike clinical samples of a given type, the background found in an

environmental sample (e.g. soil, water, or collected from an aerosol particle collector) might show a more heterogeneous composition depending on the geographical location, season, and environmental conditions. Accordingly, the aforementioned amplification, enrichment and/or subtraction strategies may be employed to obtain reliable base calling.

Forensic and environmental applications

The amount of detailed sequence information provided by the RPM will be enabling for various applications other than medical diagnosis and surveillance. Thus, the capability of the apparatus extends to forensic fingerprinting of specific pathogen strains. The capability enables preemptive diagnosis of etiologies of infectious disease, as alternative to conventional practice of corroborative diagnostic analysis. In the case of an intentional infection, poisoning, or bioterrorism event, the resequencing pathogen detection microarray would allow for detailed strain identification that could be used to determine the possible originator of the event and to allow for rapid mitigation of the event (e.g. determination of infectious capacity, antimicrobial resistance, or engineered modifications to an organism) by implementing targeted public health containment measures directed by having the pathogen identified to the strain as the completed first step in the outbreak investigation process.

The present invention further suggests methods and processes to automate and optimize the iterative and adaptive design, fabrication and validation of arrays, including derivative sub-arrays. In a very preferable embodiment, an enterprise level, a consortium of experts on individual pathogens would maintain a web portal-enabled database. The consortium would maintain pathogen target sequences for identification and virulence.

The same technology described in the present invention can be used for non-clinical samples, including those collected from air, water, soil or surface swabs. The only modifications necessary to those described in the present invention will be those necessary for nucleic acid extraction and background nucleic acid removal, if a subtractive approach followed by generic amplification is a desired approach.

Multiple Pathogen Surveillance in a Population

The invention further provides a specific implementation that validates its capabilities in a real world operational setting. This implementation relates to epidemic outbreaks of acute respiratory disease involving common and less common etiologies, while simultaneously evaluating the possible presentation of hostile pathogenic agents (rare if ever) in individual encounters. Thus, the invention provides a means to perform near real time surveillance of a plurality of infectious pathogens involved in an infectious outbreak. Such surveillance may be validated and eventually become operational in a "real world testbed". In a preferred embodiment, the real world testbed is a human population that regularly encounters a variety of respiratory pathogens. In a preferred embodiment, the population is comprised of military personnel at an installation or base. In a very preferred embodiment, the population is comprised of active duty military personnel.

End user-specified applications

The integrated process of microarray design and assay will require only that sequences be provided to a microarray manufacturer and not involve the design of ancillary reagents (e.g. for specific PCR). Thus, an end user who has no detailed knowledge of genomics or would be capable of defining qualitative attributes of a microarray-based assay, and an automated bioinformatics pipeline would be used to select suitable target gene subsequences for submission to a resequencing microarray manufacturer. This would allow rapid deployment of a new micorarray

design for a specific geographic location, theater of operations. Thus, the integrated design/analysis capability that is enabled by the present invention will generalize to other envisioned applications besides those listed herein.

Adenovirus Sequences-

In an additional embodiment of the present invention are the genomic sequences of thirteen adenovirus strains, which were not known as of the date of the present invention. The thirteen adenovirus strains are: Ad3, Ad3FS_navy, Ad4, Ad4vaccine, Ad4FS_navy, Ad4FS_AF, Ad5FS, Ad7, Ad7FS_navy, Ad7 vaccine, Ad16, Ad1, and Ad21. These genomic sequences have been assigned the GenBank accession numbers shown in Table 6 appearing in the Examples. The full GenBank records, including partial annotation, for each of these sequences are found in the Sequence Listing attached herewith.

A "polypeptide" as used herein is understood to mean a sequence of several amino acid residues linked by peptide bonds. Such amino acids are known in the art and encompass the unmodified and modified amino acids. In addition, one or more modifications known in the art such as glycosylation, phosphorylation, etc may modify the polypeptide.

The term "isolated" means separated from its natural environment. This term is intended to also embrace the terms "purified" (100% pure) and "substantially purified" (at least 90% pure).

The term "polynucleotide" refers in general to polyribonucleotides and polydeoxyribonucleotides, and can denote an unmodified RNA or DNA or a modified RNA or DNA.

The term "homologous" as used herein is understood to mean sequence similarity between two or more polynucleotides or proteins from the same species or from a different species. Within the meaning of this term, said two or more polynucleotides (or proteins) are homologous when at least 70%, preferably at least 80%, most preferably at least 90% of the nucleotide base (amino acid) composition of a candidate sequence corresponds to the sequence according to the invention. According to the invention, a "homologous protein" is to be understood to retain at least 50%, preferably at least 75%, more preferably at least 85%, most preferably at least 95%, of the activity of the activity of the sequence of the present invention. As used herein "corresponds" is to be understood to mean that the corresponding amino acids are either identical or are mutually homologous amino acids. The expression "homologous amino acids" denotes those that have corresponding properties, particularly with regard to their charge, hydrophobic character, steric properties, etc. The same terminology can be used to describe DNA or RNA sequence homology for gene sequences that encode the corresponding proteins.

The term "homologous fragment" as used herein is understood to mean two or more polynucleotides or proteins from the same species or from a different species. In this context, it is contemplated that a fragment is homologous when it shares at least 40% identity to a fragment having at least 50 amino acids. Preferably, homologous fragments share at least 50% identity to a fragment having at least 50 amino acids. More preferably, homologous fragments share at least 60% identity, at least 70% identity, at least 80% identity, at least 90% identity, or at least 95% identity to a fragment having at least 50 amino acids. Accordingly, homologous fragments are included within the scope of the present invention. For homologous polynucleotides, it is understood that that the same homology ranges are envisioned in the present inventions but over a range of up to 1000 nucleotides, inclusive of all integers (i.e., 150, 250, 300, 500, 750, etc.).

Homology, sequence similarity or sequence identity of nucleotide or amino acid sequences may be determined conventionally by using known software or computer programs such as the *BestFit* or *Gap* pairwise comparison programs (GCG Wisconsin Package, Genetics Computer Group, 575 Science Drive, Madison,

Wisconsin 53711). *BestFit* uses the local homology algorithm of Smith and Waterman, Advances in Applied Mathematics 2: 482-489 (1981), to find the best segment of identity or similarity between two sequences. *Gap* performs global alignments: all of one sequence with all of another similar sequence using the method of Needleman and Wunsch, J. Mol. Biol. 48:443-453 (1970). When using a sequence alignment program such as *BestFit*, to determine the degree of sequence homology, similarity or identity, the default setting may be used, or an appropriate scoring matrix may be selected to optimize identity, similarity or homology scores. Similarly, when using a program such as *BestFit* to determine sequence identity, similarity or homology between two different amino acid sequences, the default settings may be used, or an appropriate scoring matrix, such as *blosum45* or *blosum80*, may be selected to optimize identity, similarity or homology scores.

The present invention also relates to polynucleotides that contain complete genes that are identified by open reading frames. Examples of the preferred genes embraced by the present invention include *E1A*, *hexon*, and *fiber*. The sequences of *E1A*, *hexon*, and *fiber*, as well as other preferred polynucleotide sequences within the scope of the present invention are found in the attached Sequence Listing. The present invention also embraces fragments of said genes and polynucleotides and fragments thereof that can be obtained by screening by means of the hybridization of a corresponding gene bank with a probe which contains the sequence of said polynucleotide or a fragment thereof, and isolation of said DNA sequence.

The present invention also relates to coding DNA sequences that result from degeneration of the genetic code. Moreover, one skilled in the art is also aware of conservative amino acid replacements such as the replacement of glycine by alanine or of aspartic acid by glutamic acid in proteins as "sense mutations" that do not result in any fundamental change in the activity of the protein, i.e. which are functionally neutral. It is also known that changes at the N- and/or C-terminus of a protein do not substantially impair the function thereof, and may even stabilize said function.

Polynucleotide sequences according to the invention are suitable as hybridization probes for RNA, cDNA and DNA, in order to isolate those cDNAs or genes, which exhibit a high degree of similarity to the probe sequence.

Polynucleotide sequences according to the invention are also suitable as primers for polymerase chain reaction (PCR) for the production of DNA that encodes an active enzyme.

Oligonucleotides such as these, which serve as probes or primers, can contain more than 30, preferably up to 30, more preferably up to 20, even more preferably at least 15, and most preferably at least 13 successive nucleotides. Oligonucleotides with a length of at least 40 or 50 nucleotides are also suitable.

Hybridization protocols are known in the art and are disclosed, for example, in Sambrook et al., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, New York (1989). However, as used herein, stringent hybridization conditions are those conditions which allow hybridization between polynucleotides that are 75%, 80%, 85%, 90%, 95%, or 98% homologous as determined using conventional homology programs, an example of which is UWGCG sequence analysis program available from the University of Wisconsin (Devereux, Haeberli & Smithies, 1984). Typically, stringent conditions will be those in which the salt concentration is less than about 1.5 M Na ion, typically about 0.01 to 1.0 M Na ion concentration (or other salts) at pH 7.0 to 8.3 and the temperature is at least about 30°C for short probes (e.g., 10 to 50 nucleotides) and at least about 60°C for long probes (e.g., greater than 50 nucleotides). Stringent conditions may also be achieved with the addition of destabilizing agents such as formamide. Exemplary low stringency conditions include hybridization with a buffer solution of 30 to 35% formamide, 1 M NaCl, 1% SDS (sodium dodecyl sulphate) at 37°C, and a wash in 1X to 2X SSC (20X SSC=3.0 M NaCl/0.3 M trisodium citrate) at 50 to 55°C. Exemplary moderate stringency conditions

include hybridization in 40 to 45% formamide, 1 M NaCl, 1% SDS at 37°C, and a wash in 0.5X to 1X SSC at 55 to 60°C. Exemplary high stringency conditions include hybridization in 50% formamide, 1 M NaCl, 1% SDS at 37°C, and a wash in 0.1X SSC at 60 to 65°C.

Specificity is typically the function of post-hybridization washes, the critical factors being the ionic strength and temperature of the final wash solution. For DNA--DNA hybrids, the Tm can be approximated from the equation of Meinkoth and Wahl, (Meinkoth & Wahl, 1984): Tm =81.5°C +16.6 (log M)+0.41 (%GC)-0.61 (% form)-500/L; where M is the molarity of monovalent cations, %GC is the percentage of guanosine and cytosine nucleotides in the DNA, % form is the percentage of formamide in the hybridization solution, and L is the length of the hybrid in base pairs. The Tm is the temperature (under defined ionic strength and pH) at which 50% of a complementary target sequence hybridizes to a perfectly matched probe. Tm is reduced by about 1°C for each 1% of mismatching; thus, Tm, hybridization and/or wash conditions can be adjusted to hybridize to sequences of the desired identity. For example, if sequences with approximately 90% identity are sought, the Tm can be decreased 10°C. Generally, stringent conditions are selected to be about 5°C lower than the thermal melting point (Tm) for the specific sequence and its complement at a defined ionic strength and pH. However, severely stringent conditions can utilize a hybridization and/or wash at 1, 2, 3, or 4°C lower than the thermal melting point (Tm); moderately stringent conditions can utilize a hybridization and/or wash at 6, 7, 8, 9, or 10°C lower than the thermal melting point (Tm); low stringency conditions can utilize a hybridization and/or wash at 11, 12, 13, 14, 15, or 20°C lower than the thermal melting point (Tm). Using the equation, hybridization and wash compositions, and desired Tm, those of ordinary skill will understand that variations in the stringency of hybridization and/or wash solutions are inherently described. If the desired degree of mismatching results in a Tm of less than 45°C (aqueous solution) or 32°C (formamide solution) it is preferred to increase the SSC concentration so that a higher temperature can be used. An extensive guide to the hybridization of nucleic acids is found in Current Protocols in Molecular Biology, Chapter 2, Ausubel, et al., Eds., Greene Publishing and Wiley-Interscience, New York (2000).

In this invention "primer" or "probe" means a polynucleotide, especially an oligonucleotide, that is produced synthetically or biologically and includes a specific nucleotide sequence and permits hybridization to a section containing the target nucleotide sequence.

Defined primers or probes, as well as all other oligonucleotides and polynucleotide of the present invention, may be produced by any of several well-known methods, including automated solid-phase chemical synthesis using cyanoethyl-phosphoramidite precursors. Other well-known methods for construction of synthetic primers/oligonucleotides may, of course, be employed. J. Sambrook, E. F. Fritsch and T. Maniatis, Molecular Cloning 11 (2d ed. 1989).

The primers used to amplify the sample nucleic acids may be coupled to a detectable moiety. A preferred example of such a detectable moiety is fluorescein, which is a standard label used in nucleic acid sequencing systems using laser light as a detection system. Other detectable labels can also be employed, however, including other fluorophores, radio labels, chemical couplers such as biotin which can be detected with streptavidin-linked enzymes, and epitope tags such as digoxigenin detected using antibodies. The primers may be modified whereby another nucleotide is added to, removed from, or substituted for at least one nucleotide in the oligonucleotide. Introduction of known labels such as radioactive substances, enzymes, fluorescence substances, etc. after synthesis of oligonucleotide is also included therein.

Similarly, the probes/oligonucleotides used to hybridize with the polynucleotides coding for the polypeptides of the invention, for example for the purpose of detection of such a polynucleotide, may be coupled to

a detectable moiety.

As used herein, the term "enhancement" means increasing the intracellular activity of one or more enzymes in a plant cell and/or plant that are encoded by the corresponding DNA. Enhancement can be achieved with the aid of various manipulations of the bacterial cell. In order to achieve enhancement, particularly over-expression, the number of copies of the corresponding gene can be increased, a strong promoter can be used, or the promoter- and regulation region or the ribosome binding site which is situated upstream of the structural gene can be mutated. Expression cassettes that are incorporated upstream of the structural gene act in the same manner. In addition, it is possible to increase expression by employing inducible promoters. A gene can also be used which encodes a corresponding enzyme with a high activity. Expression can also be improved by measures for extending the life of the mRNA. Furthermore, preventing the degradation of the enzyme increases enzyme activity as a whole. Moreover, these measures can optionally be combined in any desired manner.

A gene can also be used that encodes a corresponding or variant enzyme with a high activity. Preferably the corresponding enzyme has a greater activity than the native form of the enzyme, more preferably at least in the range of 5, 10, 25% or 50% more activity, most preferably more than twice the activity of the native enzyme.

The above written description of the invention provides a manner and process of making and using it such that any person skilled in this art is enabled to make and use the same, this enablement being provided in particular for the subject matter of the appended claims, which make up a part of the original description.

As used herein, the phrases "selected from the group consisting of," "chosen from," and the like include mixtures of the specified materials.

Where a numerical limit or range is stated herein, the endpoints are included. Also, all values and sub-ranges within a numerical limit or range are specifically included as if explicitly written out.

The above description is presented to enable a person skilled in the art to make and use the invention, and is provided in the context of a particular application and its requirements. Various modifications to the preferred embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments and applications without departing from the spirit and scope of the invention. Thus, this invention is not intended to be limited to the embodiments shown, but is to be accorded the widest scope consistent with the principles and features disclosed herein.

Having generally described this invention, a further understanding can be obtained by reference to certain specific examples, which are provided herein for purposes of illustration only, and are not intended to be limiting unless otherwise specified.

EXAMPLES

Materials and Methods -

Table 6 (below) lists the adenovirus strains cited in the following examples. GenBank accession numbers refer to the genomic sequence numbers assigned to each strain. These sequences were not available to the public at the time of invention and form an embodiment of the present invention, as well as fragments of the same.

Table 6:

GenBank name	Accession no.	Genome size	Origin
Ad3	AY599834	35,345	ATCC#VR-3, strain GB

Ad3FS_navy	AY599836	35,265	Ad3FS NHRC#1276 from NTC Great Lakes, IL 11/07/97
Ad4	AY594253	35,990	ATCC#VR-4, strain RI-67
Ad4vaccine	AY594254	35,994	Calif. Public Health (via Kevin Russell/NHRC)
Ad4FS_navy	AY599835	35,965	Ad4FS NHRC#42606 from Ft Jackson, SC 04/02/03
Ad4FS_AF	AY599837	35,964	Linda Canas, Brooks AFB, Lackland AFB AF#3 2002
Ad5FS	AY601635	35,931	Ad5FS NHRC#7151 from Ft Jackson, SC 01/06/98
Ad7	AY594255	35,305	ATCC#AV-HAD7_AFIP, strain Gomen
Ad7FS_navy	AY601634	35,198	Ad7FS NHRC#1315 from NTC Great Lakes, IL 11/19/97
Ad7vaccine	AY594256	35,236	NHRC vaccine tablet (Margaret Ryan, Kevin Russell/NHRC)
Ad16	AY601636	35,522	ATCC#VR-17, strain ch.79
Ad1	AF534906	36,001	ATCC#VR-1, strain Adenoid 71 1953
Ad21	AY601633	35,382	ATCC#NIAID V-221-002-014, NIH Research Reagent, prepared in Nov. 1963

ATCC = American Type Culture Collection (Manassas, VA)
NHRC = Naval Health Research Center (San Diego, CA)
NIH = National Institutes of Health (Bethesda, MD)

The full GenBank records, including partial annotation, for each of these are found in the Sequence Listing attached herewith.

Influenza Content

The prototype influenza types represented by tiles on RPMV1 are:

Influenza A virus (A/New Caledonia/20/99) H1 HA gene for hemagglutinin 1
FluAHA3 Influenza A virus (A/Fujian/411/02) H3N2 gene for hemagglutinin 3
FluAHA5 Influenza A virus (A/HongKong/156/97/H5N1), hemagglutinin 5
FluANA1 Influenza (A/Chile/1/83), neuraminidase 1
FluANA2 Influenza A virus (A/Panama/2007/99/H3N2) NA gene for neuraminidase 2
FluAMATRIX Influenza virus A/NWS/33/H1N1 matrix protein (M)
FluBNA Influenza B virus (B/Yamagata/16/88), neuraminidase glycoprotein genes
FluBHA Influenza B virus (B/Yamanashi/166/98) hemagglutinin 1 subunit (HA)
FluBMATRIX Influenza B virus (B/Yamagata/16/88) M1 matrix protein (M)

The Accession numbers for each of the foregoing sequences, as well as the remaining pathogen target

sequences, obtained from the public domain and personal communications, are listed in Table 9.

Preparation Example 1: RPM Version 1 Chip Design

DNA sequences were provided to Affymetrix for creation of the resequencing microarray chip (RPM Version 1 chip) utilized in the following examples. Submission of the DNA sequence and instruction files to Affymetrix were in accordance with the manufacturer instructions CustomSeq™ Array Protocol and product literature. Probe lengths were nominally 25-nucleotides long and contained a variable (interrogation point) central nucleotide for each of four possible variants (A, C, T or G) in both the sense and antisense directions.

The target genes selected for the RPMV1 pathogens listed above are described in the version 1 layout shown in Table 8 and the Sequence Listing along with the respective PCR primers used for amplification of the same. The sequences submitted for tiling and chip fabrication were based on the Affymetrix instruction file summarized in Table 7, which corresponds to the sequences appearing as SEQ ID NOs: 1-58. The corresponding "instruction file" lists the alias designator (e.g. FluAHA5) for each tile region and provides a "FASTA" formatted target gene sequence (this can be all or part of the complete target gene).

Table 7: RPMV1 Affymetrix instructions file for tiling and chip fabrication

Name	Alias	Start	End	SEQ ID NO:	StartSeq	EndSeq	Design
FluAHA1	FluAHA1	1	699	1	TTGAGAAG	ATGGTATG	1
FluAHA3	FluAHA3	1	794	2	GATAGTGA	AAGCATTC	1
FluAHA5	FluAHA5	1	524	3	AATCCACT	GCTCCAAT	1
FluANA1	FluANA1	1	1360	4	AAAAGCAG	TTTTGTGG	1
FluANA2	FluANA2	1	1449	5	GCAAAAGC	TAGAAAAA	1
FluAMATRIX	FluAMATRIX	1	923	6	AGCAAAAG	TGCCAGAG	1
FluBHA	FluBHA	1	684	7	TTACATCC	AGCCATAG	1
FluBNA	FluBNA	1	896	8	ATGAACAA	CAGTTACA	1
FluBMATRIX	FluBMATRIX	1	362	9	ATGTCGCT	CATGAAAG	1
Ad4HEXON	Ad4HEXON-1	1	1096	10	GTGGCGCC	TAAAGTTA	1
Ad4HEXON	Ad4HEXON-2	2226	2504	10	CGAGGTTA	GCCCACGC	1
Ad4FIBER	Ad4FIBER	1	1258	11	CGACCCCG	ACCCTGCA	1
Ad4E1A	Ad4E1A	1	1326	12	GCGGGGCA	CCCAGGCA	1
Ad5HEXON	Ad5HEXON-1	1	843	13	GTGGCGCC	ATTGCTTT	1
Ad5HEXON	Ad5HEXON-2	1655	1846	13	GACCTAAG	CCAACGTG	1
Ad5FIBER	Ad5FIBER	1	2012	14	TTCTGTCC	AGATCACC	1
Ad5E1A	Ad5E1A	1	616	15	AGCCGGAG	CTGTGGAA	1
Ad7HEXON	Ad7HEXON-1	1	807	16	GTGGCGCC	ATTGGCTT	1
Ad7HEXON	Ad7HEXON-2	1652	2245	16	TCTGTATG	AATTACAC	1
Ad7FIBER	Ad7FIBER	1	712	17	CCTTCAAC	AATGTTAA	1
Ad7E1A	Ad7E1A	1	615	18	AAGAGTTT	ACTGCCAC	1
PIVIHN	PIVIHN	1	204	19	TAGACCCA	TATAGGGA	1
PIVIIIHN	PIVIIIHN	1	213	20	CAAATCTA	TGAAAGAT	1
PIVIIINCFP	PIVIII5NCFP	1	230	21	ACTTAGGA	TTACAACC	1
HRV5NT	HRV5NT	1	412	22	GTCAAAGG	TCCTGTTT	1
RSVABL	RSVABL	1	379	23	AAGTGCTC	AAGCAAAC	1
RSVAN	RSVAN	1	106	24	AATACAAA	AGATAGTA	1

RSVBN	RSVBN	1	128	25	GGCAAATA	CAATTATG	1
WNVCPRM	WNVCPRM	1	432	26	GGCCAATA	TGATCCAG	1
WNVE	WNVE	1	94	27	ATTTGGCT	TTTGTGTG	1
WNVNS1	WNVNS1	1	153	28	GAAGCTTG	GGGTACAA	1
HCV229EMG	HCV229EMG	1	598	29	TAGAACAG	TAACCTAC	1
HCVOC43MG	HCVOC43MG	1	358	30	TGATTATT	TATATGAC	1
SPNLYTA	SPNLYTA	1	125	31	TATCGAAC	CTCAGACC	1
SPNPLY	SPNPLY	1	99	32	GGTTTGGC	ATCAAGAT	1
SPYSPEB	SPYSPEB	1	281	33	AATCTTTT	TAGACATG	1
SPYMEFAE	SPYMEFAE	1	370	34	GGCAGGGC	TTACGAAA	1
SPYERMB	SPYERMB	1	248	35	AACTGATT	TAGAATCC	1
SPYERMTR	SPYERMTR	1	176	36	CAACGGGT	GATATTGT	1
MPP1	MPP1	1	369	37	AGGGGGTT	ACTATGTT	1
NMCTRA	NMCTRA	1	135	38	TTGGATGC	TTTTGCTG	1
NMCRGA	NMCRGA	1	254	39	GGTGCTGC	TGCCGGTC	1
BPPTXP	BPPTXP	1	305	40	GAAGTAGC	CAAACCGC	1
BPPTXS1	BPPTXS1	1	222	41	CGGCGCAT	AGGCCGAA	1
CPMOMPVD4	CPMOMPVD4	1	150	42	ATGCTGAT	TCAGATCA	1
CPMOMPVD2	CPMOMPVD2	1	133	43	AGCGTTCA	TAGGCGCT	1
CPRPOB	CPRPOB	1	346	44	AAGGACTT	CTGCAGGC	1
BARPOB	BARPOB	1	199	45	CGTCCTGG	GGCAGAAG	1
BAPAGA	BAPAG	1	354	46	TAGCGGCG	TAATTCGT	1
BACAPB	BACAPB	1	246	47	TTACACGT	ACCTATTA	1
VMVHA	VMVHA	1	510	48	AACTATTA	TCACCAAC	1
VMVCRMB	VMVCRMB	1	291	49	TCGGGAAC	CGTCTGTT	1
ZEVL	ZEVL	1	443	50	TACTACCA	TCACACTG	1
LVGPC	LVGPC	1	351	51	GCGCACCG	GTGGGCAA	1
FTLP	FTLP	1	431	52	ATCGTAAT	TAAGTATG	1
FTFOPA	FTFOPA	1	111	53	CAGATATA	GATACTAC	1

YPCVE	YPCVE	1	265	54	ATAAAGGG	AGGCGGGG	1
YPCAF1	YPCAF1	1	525	55	TATGAAAA	ATATAGAT	1
ATTIM	ATTIM	1	523	56	ACATCGAC	GAGCTTGC	1
ATNAC1	ATNAC1	1	543	57	TATATGTA	ATTGTACA	1
Ad7HEXVAC	Ad7HEXVAC	168	383	58	GGTGCTTG	AAGCCCAT	1

Table 8: RPMV1 layout, along with the respective PCR primers used for amplification of the same

Organism	Gene Name	Amplicon	Probe	Gene found in SEQ ID NO:	Forward Primer (SEQ ID NO:)	Size	%GC	Tm	Reverse Primer (SEQ ID NO:)	Size	%GC	Tm	Taqman Probe (SEQ ID NO:)	Size	%GC	Tm
Influenza A	Hemaglutinin 1	675	699	1	439	23	47.8	54.8	505	24	33.3	55.6				
Influenza A	Hemaglutinin 3	770	794	2	440	24	33.3	57.6	506	22	36.4	55.9				
Influenza A	Hemaglutinin 5	500	524	3	441	26	42.3	59.8	507	26	42.3	58.7				
Influenza A	Hemaglutinin 5	219			442	26	30.8	58.9	508	24	45.8	58.5				
Influenza A	Neuraminidase 1	1336	1360	4	443	22	22.7	54.2	509	18	55.6	53.5				
Influenza A	Neuraminidase 2	1434	1449	5	444	22	45.5	57.9	510	23	39.1	57.8				
Influenza A	Matrix Gene	911	923	6	445	20	40	55	511				571	20	55	62
Influenza B	Hemaglutinin	660	684	7	446	22	45.5	55.5	512	24	47.9	57.5				
Influenza B	Neuraminidase	881	896	8	447	25	32	56.3	513	22	45.5	56				
Influenza B	Matrix Gene	338	362	9	448	24	45.8	59.9	514	25	36	59.6	572	22	54.5	63.4
Adenovirus 5	Hexon	819	843	13	449				515							
Adenovirus 5	Hexon	168	192	13	450	24	45.8	57.6	516	24	54.2	58.5				
Adenovirus 5	Fiber	1988	2012	14	451	22	45.5	55.9	517	20	60	61				
Adenovirus 5	E1A	171			452	24	54.2	61.5	518	21	66.7	61.3				
Adenovirus 5	E1A	431	616	15	453	23	56.5	59.7	519	21	57.1	57.3				
Adenovirus 4	Hexon	764	1096	10	454				520							
Adenovirus 4	Hexon	255	279	10	455	18	61.1	63	521	18	66.7	62				
Adenovirus 4	Hexon	511			456	19	57.1	66	522	18	50	64				
Adenovirus 4	Fiber	967			457	20	55	57.8	523	21	47.6	54.9				
Adenovirus 4	Fiber	435	1258	11	458				524							
Adenovirus 4	E1A	844			459	22	45.5	57.1	525	19	59.9	59.6				
Adenovirus 4	E1A	878			460	23	56.5	61.2	526	25	48	60.6				
Adenovirus 4	E1A	409	1326	12	461											
Adenovirus 7	Hexon	774	798	16	462				527							
Adenovirus 7	Hexon	570	594	16	463	24	61.6	60.5	528	24	50	60.3				
Adenovirus 7	Fiber	688	712	17	464	23	41.3	54.7	529	23	47.8	58.2				
Adenovirus 7	E1A	205			465	20	65	62	530	23	60.9	61.3				
Adenovirus 7	E1A	428	615	18	466				531							
Adenovirus 7	Hexon															
Parainfluenza Virus 1	HN	180	204	19	467	27	48.1	62.8	532	28	35.7	58.2				
Parainfluenza Virus	HN	189	213	20	468	21	47.6	48.5	533	21	42.9	49.5				

III												
Parainfluenza Virus III	5' noncoding region of fusion protein	206	230	21	469	21	38.1	46.3	534	20	40	48
Human rhinovirus	5' noncoding region	388	412	22	470	16	56.2	44.9	535	16	56.2	43.8
RSV (A, B)	L-polymerase	355	379	23	471	19	36.8	43.9	536	19	36.8	42.9
RSV (A)	major nucleocapsid, N	82	106	24	472	26	38.5	57.3	537	21	47.6	54.3
RSV (B)	major nucleocapsid, N	104	128	25	473	26	38.5	58	538	30	33.3	59.1
West Nile virus	C and prM	408	432	26	474	25	48	62.6	539	25	56	64.9
West Nile virus	E	70	94	27	475	21	52.4	53.8	540	21	52.4	53.8
West Nile virus	NS1	129	153	28	476	21	52.4	53.2	541	21	47.6	54.3
Human coronavirus (229E)	membrane glycoprotein	574	598	29	477	20	40	53.7	542	20	50	51.9
Human coronavirus (OC43)	membrane glycoprotein	334	358	30		20	55	55	543	20	45	53.7
Streptococcus pneumoniae	Autolysin, lytA	101	125	31	478	21	47.6	52.7	544	21	42.9	53.2
Streptococcus pneumoniae	pneumolysin, ply	75	99	32	479	22	50	56.3	545	23	43.5	58
Mycoplasma pneumoniae	Cytadhesin P1 protein	345	369	37	480	24	58.3	63.8	546	25	52	60.8
Neisseria meningitidis	capsular transport protein (ctrA) gene	111	135	38	481	19	57.9	53.2	547	20	45	54.4
Neisseria meningitidis	regulatory protein, crgA	230	254	39	482	25	60	73.6	548	24	62.5	69.4
Bordetella pertussis	Pertussis toxin promoter region	281	305	40	483	22	72.7	69.6	549	20	55	59.1
Bordetella pertussis	Pertussis toxin S1 subunit ptxS1	198	222	41	484	18	61.1	56.2	550	19	63.2	58.6
Chlamydia pneumoniae	major outer membrane protein (MOMP) VD4	126	150	42	485	16	62.5	50.3	551	25	32	55.5
Chlamydia pneumoniae	DNA directed RNA polymerase (rpoB)	322	346	44	486	21	42.9	52	552	20	50	49.2

Chlamydia pneumoniae	major outer membrane protein (MOMP) VD2	109	133	43	487	20	40	50.6	553	21	47.6	48.7
Streptococcus pyogenes	pyrogenic exotoxin B (speB)	257	281	33	488	20	50	48.1	554	20	40	48.7
Streptococcus pyogenes	macrolide-efflux determinant (mefA, mefE)	346	370	34	489	21	33.3	43	555	21	38.1	47.2
Streptococcus pyogenes	erythromycin resistance methylase (ermB)	224	248	35	490	23	39.1	50.7	556	20	50	51.7
Streptococcus pyogenes	erm(TR)	152	176	36	491	20	40	45.2	557	23	30.4	48.7
Bacillus anthracis	RNA polymerase beta-subunit (rpoB)	175	199	45	492	21	47.6	52.5	558	23	34.8	53.2
Bacillus anthracis	protective antigen (pag)	330	354	46	493	25	40	54.9	559	27	44.4	57.1
Bacillus anthracis	Poly(D-glutamic acid) capsule (capB)	222	246	47	494	19	52.6	49	560	19	42.1	51.7
Variola Major Virus	hemagglutinin (HA)	486	510	48	495	18	27.8	48	561	23	34.8	48.3
Variola Major Virus	cytokine response modifier B (crmB)	267	291	49	496	28	39.3	59.1	562	24	50	59.8
Ebola Virus	L Gene	419	443	50	497	22	27.3	50.1	563	30	33.3	60.1
Lassa Virus	GPC Gene	335	351	51	498	20	55	59.5	564	29	31	57.6
Francisella tularensis	13-kDa lipoprotein	407	431	52	499	27	55	59.5	565	24	31	57.6
Francisella tularensis	FopA	87	111	53	500	27	37	59.9	566	23	43.5	56
Yersinia pestis	ove2155 sequence	242	265	54	501	22	54.5	60.1	567	20	65	61.8
Yersinia pestis	Caf1	501	525	55	502	21	52.4	57.4	568	23	39.1	53.6
Arabisopsis thaliana	TIM	499	523	56	503	20	45	47.7	569	20	50	49.9
Arabisopsis thaliana	NAC1	519	543	57	504	20	45	51.1	570	20	50	53.3
			29344									

The instruction file references the same alias designators, but further specifies the actual subsequences that are actually to be tiled onto the array. In most cases, this represents the entire sequence from the sequence file but in others (e.g. FluBMATRIX) only nucleotides 1-362 of the total sequence were used for tiling. Table 9 provides the information presented in the instructions file.

Table 9 (below): Instruction file (specific file) of the RPM V1 design specification. The alias designator is a name assigned to each discrete "tile" region (e.g. a geometric region of the microarray containing all probe combinations required for resequencing of a stretch of pathogen genome sequence). The pathogen, sequence accession number, and tile size for each tile region are shown. The instructions, which were processed in Affymetrix submission format, appear in Table 7. The instruction file references complete or partial sequence of the complete target genes that are found in SEQ ID NOs: 1-58 appearing in the attached Sequence Listing.

Table 9: RPMV1 Chip Table

ALIAS	NAME	GENE_NAME	ACCESSION_NO	LENGTH
ATNAC1	Arabidopsis thaliana	NAC1		543
ATTIM	Arabidopsis thaliana	TIM		523
Ad4E1A	Adenovirus 4	E1A	AF594253(draft)	1326
Ad4FIBER	Adenovirus 4	Fiber	AF594253(draft)	1258
Ad4HEXON-1	Adenovirus 4	Hexon	AF594253(draft)	1096
Ad4HEXON-2	Adenovirus 4	Hexon	AF594253(draft)	279
Ad5E1A	Adenovirus 5	E1A	AY147066	616
Ad5FIBER	Adenovirus 5	Fiber	M18369	2012
Ad5HEXON-1	Adenovirus 5	Hexon	AF542130	843
Ad5HEXON-2	Adenovirus 5	Hexon	AF542130	192
Ad7E1A	Adenovirus 7	E1A	AY594255(draft)	615
Ad7FIBER	Adenovirus 7	Fiber	AY594255(draft)	712
Ad7HEXON-1	Adenovirus 7	Hexon	AY594255(draft)	807
Ad7HEXON-2	Adenovirus 7	Hexon	AY594255(draft)	584
Ad7HEXVAC	Adenovirus 7	Hexon	AY594256(draft)	216
BACAPB	Bacillus anthracis	Poly(D-glutamic acid) capsule (capB)	M24150	246
BAPAG	Bacillus anthracis	protective antigen (pag)	M22589	354
BARPOB	Bacillus anthracis	RNA polymerase beta-subunit (rpoB)	AF205323	199
BPPTXP	Bordetella pertussis	Pertussis toxin promoter region	M13223	305
BPPTXS1	Bordetella pertussis	Pertussis toxin S1 subunit pbxS1	M13223.1	222
CPMOMPVD2	Chlamydia pneumoniae	major outer membrane protein (MOMP) VD2	CP0694	133
CPMOMPVD4	Chlamydia pneumoniae	major outer membrane protein (MOMP) VD4	M69230	150
CPRPOB	Chlamydia pneumoniae	DNA directed RNA polymerase (rpoB)	NT01CP0714	346

FluAHA1	Influenza A	Hemaglutinin 1	AJ344014	699
FluAHA3	Influenza A	Hemaglutinin 3	privale communication	794
FluAHA5	Influenza A	Hemaglutinin 5	AF028709	524
FluAMATRIX	Influenza A	Matrix Gene	L25814	923
FluANA1	Influenza A	Neuraminidase 1	M24783	1360
FluANA2	Influenza A	Neuraminidase 2	AJ457937	1449
FluBHA	Influenza B	Hemaglutinin	AF100355	684
FluBMATRIX	Influenza B	Matrix Gene	AF100378	362
FluBNA	Influenza B	Neuraminidase	AY139081	896
FTFOPA	Francisella tularensis	FopA	AF097542	111
FTLP	Francisella tularensis	13-kDa lipoprotein	M32059	431
HCV229EMG	Human coronavirus (229E)	membrane glycoprotein	AF304460	598
HCVOC43MG	Human coronavirus (OC43)	membrane glycoprotein	M93390	358
HRV5NT	Human rhinovirus	5' noncoding region	NC_001617	412
LVGPC	Lassa Virus	GPC Gene	M15076	351
MPP1	Mycoplasma pneumoniae	Cytadhesin P1 protei	M18639	369
NMCRGA	Neisseria meningitidis	regularoty protein, crgA	AF190471	254
NMCTRA	Neisseria meningitidis	capsular transport potein (ctrA)	NMB0071	135
PIVIHN	Parainfluenza Virus I	HN	U70948	204
PIVIII5NCFP	Parainfluenza Virus III	5' noncoding region	Z11575	213
PIVIIIHN	Parainfluenza Virus III	HN	M18764	230
RSVABL	RSV	L-polymerase	AF254574	379
RSVAN	RSV A	major nucleocapsid,	M11486	106
RSVBN	RSV B	major nucleocapsid,	D00736	128
SPNLYTA	Streptococcus pneumoniae	Autolysin, lytA	SP1937	125
SPNPLY	Streptococcus pneumoniae	pneumolysin, ply	SP1923	99
SPYERMB	Streptococcus pyogenes	erythromycin resistance methylase (ermB)	X52632	248
SPYERMTR	Streptococcus pyogenes	erm(TR)	AF002716	176
SPYMEFAE	Streptococcus pyogenes	macrolide-efflux determinant (mefA, mefE)	U70055	370
SPYSPEB	Streptococcus pyogenes	pyrogenic exotoxin B (speB)	NT01SP1804	281
VMVCRMB	Variola Major Virus	cytokine response mo	U88145	291
VMVHA	Variola Major Virus	hemagglutinin (HA)	X65516	510
WNVCPRM	West Nile virus	C and prM	AF196835	432
WNVE	West Nile virus	E	AF196835	94
WNVNS1	West Nile virus	NS1	AF196835	153
YPCAF1	Yersinia pestis	Caf1	X61996	525
YPCVE	Yersinia pestis	cve2155 sequance	AF350077	265
ZEVL	Ebola Virus	L Gene	AF086833	443
				29569

The chip design team at Affymetrix used the combination of the information above and the corresponding sequence file information to generate the layout of the chip. FIG. 1 shows an overview of the chip layout as a function of where the gene sequences for any given pathogen are clustered on the resequencing microarray chip (RPM Version 1 chip) utilized in the following examples. This figure and chip layout is only for illustration of the

"real estate" allocation to various pathogens for the RPMV1 and is not intended to be limiting in any way. The skilled artisan would readily appreciate that the relative order and amounts of sequence dedicated to each of the pathogen clusters on this chip can be altered without intrinsic deleterious effects on the utility of the chip.

It is important to note that the tiling strategy dictates that the first 12 and last 12 sequences from each discrete tile region are not queried by the tiling strategy of the resequencing microarray, since they are used as components of the first and last 25-mer probes that are varied at the number 13 position.

The sequences used for the adenovirus regions (Ad4, Ad5, Ad7 and Ad7 vaccine) of the chip were all derived from early drafts of genomes sequenced by the present inventors. The GenBank submission files that correspond to the genomes used for tiled regions are listed in Table 6. Because the sequences submitted to Affymetrix for the prototypes were based on early drafts of the genomes, there were discrepancies observed between those early sequences and the final sequences submitted to Genbank. A list of those discrepancies is given in the Table 10:

Table 10: Discrepancies observed between the RPMV1 tiled sequences and the final sequences submitted to Genbank appearing in Table 6

Contig for Ad4

	Length of target	Sequence Base #	Target	Sequence
E1A	2004	554	missing	A
		658	C	T
		697	G	A
		698	A	G
		851	C	T
		1480	C	T
		1675	C	T
		1777	A	G
		2002	missing	T
Hexon	2813	18319	C	G
		18330	missing	T
		18331	missing	G
		18332	missing	G
		18385	A	G
		18451	C	T
		18523	T	C
		18547	T	C
		18571	C	T
		18586	T	C
		18617	T	C
		18640	T	C
		18659	G	T
		18662	A	G
		18687	T	C
		18700	A	C
		18843	A	G
		18889	T	A
		18901	C	T
		18940	G	T
		18965	A	C
		18997	T	C
		19013	G	A

19020	A	C
19113	A	C
19237	A	G
19325	T	C
19327	A	G
19330	C	T
19447	A	G
19542	C	A
19714	T	C
19732	A	C
19759	C	T
19762	A	G
19765	A	G
19795	C	A
19796	T	A
19798	C	T
19816	T	C
19819	C	T
19881	A	missing
19897	C	T
19906	C	T
19911	A	G
19915	T	C
19916	T	C
19936	T	C
19976	T	C
20038	C	T
20050	C	T
20128	C	C
20149	A	C
20158	A	C
20176	T	C
20206	C	G
20210	G	A
20239	missing	C
20245	C	missing
20246	T	A
20285	T	C
20297	T	C
20338	T	C
20363	T	C
20366	A	C
20429	T	C
20435	T	C
20447	G	C
20459	G	A
20499	T	C
20511	T	C
20519	T	C
20528	T	C
20570	T	C
20579	T	C
20658	C	G
20660	T	C
20663	T	C
20666	G	A

		20684	T	C
		20687	C	T
		20690	T	A
		20713	G	A
		20753	T	C
		20759	A	G
		20768	C	T
		20819	T	C
		20864	T	C
		20939	T	C
		21008	C	T
		21038	G	A
Fiber	1386	31602	missing	C
		31611	missing	C
		31616	missing	C
		31652	missing	A
		31672	G	missing
		31714	missing	C
		31746	T	missing
		31790	missing	C
		31798	C	missing
		31799	C	missing
		31816	missing	C
		31923	T	missing
		31943	C	missing
		32003	G	missing
		32047	T	missing
		32051	missing	T
		32260	T	missing
		32262	G	T
		32266	missing	G
		32473	A	T
		32475	T	A
		32618	T	C
		32619	C	T
		32934	missing	C
Contig for Ad5_canJI				
E1A	60	none		
Hexon	60	19020	G	missing
		19023	A	missing
		19024	C	missing
		19025	A	missing
Fiber	60	none		
Contig for Ad7				
E1A	60	none		
Hexon	60	none		
Fiber	60	none		
Contig for Ad7_Navy				
E1A	60	590	C	T
Hexon	60	18109	A	G
Fiber	60	none		
Contig for Ad7_Vaccine				

E1A	60	559	C	G
		586	C	T
Hexon	60	18142	A	G
Fiber	60	none		

This relatively small number of discordances did not interfere with the ability of the chip to make base calls that could be associated with the correct organism, except in one specific case of adenovirus type 4, described in the Examples. Overall, the resequencing microarray technique of the present invention corroborated the accurate (refined) final sequence of the tiled genes with respect to base substitutions, validating the unanticipated robustness of our method.

Preparation Example 2: PCR primer design and Amplification Protocols

Degenerate PCR Primers Design -

The objective of primer selection to support conserved (degenerate) multiplex PCR is to design primers that target the conserved regions flanking species-specific variable regions of *E1A*, *fiber*, and *hexon* genes. In general, this method may be applied to any organism, as conserved sequences within a species are a ubiquitous in nature. These target genes were selected based on their function and location within the linear adenoviral genome. *E1A* is located at the 5' end of the adenoviruses genome and encodes a *trans*-acting transcriptional regulatory factor that is necessary for transcriptional activation of early genes. The *hexon* and *fiber* genes, which are located in the middle and 3' end of the adenovirus genome, encode antigenic determinants ε and γ respectively, which determine the viral serotype. Thus, detection and serotyping of ARD-causing adenoviruses can be effectuated by targeting the nucleic acid determinants that give rise to the serotype. Thereby, the primers provided specific amplification within the adenovirus while the variable regions supplied serotype-specific characters for proper species identification.

The primers used for conserved (degenerate) multiplex PCR in the following examples are based on a global alignment of *E1A*, *fiber*, and *hexon* gene sequences, respectively, available from GenBank (GenBank accession numbers are given in parentheses): *E1A*-AdB (NC_004001), AdC (NC_001405), Ad3 (AF492352), Ad4 (M14918), Ad7 (X03000); *fiber*-Ad2 (AJ278921), Ad5 (M18369), Ad3 (X01998), Ad4 (X76547), Ad7 (M23696), Ad16 (U06106), Ad21 (U06107); *hexon*-Ad3 (X76549), Ad4 (X84646), Ad6 (AF161560, X67710, Y17245), Ad7 (AF053087, X76551), Ad16 (X74662), Ad21 (AB053166). The global sequence alignment for primer design of the *E1A* gene used the *E1A* gene sequences from Ad3, Ad4, Ad7, Ad21, AdB, and AdC serotypes. The global sequence alignment for primer design of the *fiber* gene used *fiber* gene sequences from Ad2, Ad3, Ad4, Ad5, Ad7, Ad16, and Ad21 serotypes. The global sequence alignment for primer design of the *hexon* gene used the *hexon* gene sequences from Ad3, Ad4, Ad6, Ad7, Ad16, and Ad21 serotypes.

Subsequent to the global sequence alignment, primer pairs were selected based on their ability to amplify *E1A*, *fiber*, and *hexon* genes of serotype 3, 4, 6, 7, 16 and 21 (data not shown). Table 11 shows the primer pairs employed in the following Examples.

Table 11:

Primer	Gene	Sequence (5' → 3')	Amplicon size (bp)
AdE1A-F	E1A	CGC TGC ACG ATC TGT ATG AT (SEQ ID NO: 421)	

AdE1A-R	E1A	TCT CAT ATA GCA AAG CGC ACA (SEQ ID NO: 422)	409-446
AdB1*	Fiber	TST ACC CYT ATG AAG ATG AAA GC (SEQ ID NO: 423)	
AdB2*	Fiber	GGA TAA GCT GTA GTR CTK GGC AT (SEQ ID NO: 424)	670-772
AdFib-F3	Fiber	ACT GTA KCW GYT TTG GYT GT (SEQ ID NO: 425)	
AdFib-R3	Fiber	TTA TTS YTG GGC WAT GTA KGA (SEQ ID NO: 426)	430-437
AdHex-F7	Hexon	CAC GAY GTG ACC ACM GAC CG (SEQ ID NO: 427)	
AdHex-R5	Hexon	TTK GGT CTG TTW GGC ATK GCY TG (SEQ ID NO: 428)	770-815

Multiplex Degenerate Primer PCR protocol –

The primers pairs (Lin et al., 2004) were evaluated in various multiplex combinations to obtain amplification of adenovirus serotype 3, 4, 6, 7, 16, and 21. PCR was performed in 50 µl volumes containing 20 mM Tris-HCl (pH 8.4), 50 mM KCl, 200 µM each of dNTPs, 200 nM AdB1, AdB2 primers; 300 nM AdE1A-F, AdE1A-R primers; 400 nM Adfib-F3, Adfib-R3 primers; 500 nM Adhex-F7, Adhex-R5 primers, 2 U of Platinum *Taq* DNA polymerase (Invitrogen), and 10^6 copies of DNA templates. The amplification reaction was performed using a Peltier Thermal Cycler-PTC225 (MJ Research) with preliminary denaturation at 94°C for 3 minutes, then followed by 40 cycles of denaturation at 94°C for 30 seconds, annealing at 50°C for 30 seconds, the extension at 72°C for 40 seconds, and a final extension at 72°C for 10 minutes. The generic multiplex PCR assay could amplify all three genes of all six ARD causing adenoviruses even though the *hexon* gene of Ad4 showed very weak band on agarose gel.

Total Amplification protocol –

Total amplification was conducted using the commercially available GenomiPhi™ DNA Amplification Kit (Amersham Biosciences) to representatively amplify linear genomic DNA (hereinafter referred to as "GenomiPhi total amplification"). The amplification method employed in the GenomiPhi total amplification method utilizes bacteriophage Phi29 DNA polymerase enzyme to exponentially amplify single- or double-stranded linear DNA templates by strand displacement amplification. The starting sample was not quantified, but rather was used directly.

Preparation Example 3: REPI software

Raw sequence data from the resequencing microarray chips is provided by the Genetic Data Analysis Software version 2.0 (GDAS) packaged with the microarray reader from Affymetrix. GDAS base calling is based on a previously described base-calling algorithm (Cutler et al., 2001). Each of the FASTA output files containing the base calls obtained from the GDAS software was analyzed using specialized software (REPI) that the present inventors developed.

In the case of the present invention, the sequence output of GDAS is most often a scattered mixture of contiguous sequence calls (A, T, C or G) that are interspersed with varying amounts of no-calls (n's) where the GDAS software does not make a base call due to lack of amplification, weak hybridization signal on the chip and/or high background hybridization caused by non-specific binding (Cutler et al., 2001). An example output of the

GDAS output for the Adenovirus 4 prototype sample for the Ad4FIBER tile region is shown below (SEQ ID NO: 429):

>Ad4FIBER:CustomSeq-Adenovirus 4 Start=12 End=1245

nnnnnnnnnnnnnnnncnnncncngaccgngnnnttcannaacnctcccntcgnnctcttcagatg
natttnnaagaaaagccccctgggggtgttgtccnnannnnnnngccgaccctgtcncnnnaagaat
gnnnaaattannnnnaagctgngngaggggtnnnnnttgacgactcgggaaaactcnttgcaan
cacagtaaacaaggccattgcnnctcttcagnttttnccaacaacaccatttnnnnttaacatgga
tacccctttatacaccaaagntggaaaactancttacaagtttctnccaccattaagtatatta
aaatcaacaattttgaatacnnnnnnnnnnagcttttggntcaggtttnggactcagtnnnngcgc
ccnngcagtananttagnctcnccacttacatttgntgataaagggaatanaaagattacccnaa
anagnnnnttgcatgttanaacaggagntgcaattgaaagcaacatcagttgggctaaaggtnta
aaattngaagatggtgccatagctacaaacattggtaannnnnnnnnnnnntnnnaaccagnngtnc
agaannannagnnannaangcttatccaatccaannnnnnnnntgncnctggtctcagctttgaca
gcacaggagccataatgnctggcaataaagnctatgataaattaactttgtggacaacgcctgac
ccatcaccaaactgncaaatncttgcagaaaatgntgcaaaactaacactttgnnnnnnnnanng
nnacagncaaatactggccactgtancngntttggntgttagaagnggaaacttaaacccaatta
ctggcacagtaagcagtgctcaagnttttcnncgntttgatgcaaatggtgnncntntnacagaa
cactctanncnnaaaaaatnntggggcnanaagcaangagatagnatagatggcactccatacac
caatgctgttggttttatgccaaattcaacagcttntnnaaagacncaaagttctnctnctaaaa
ataatntagtgggtcaagtatacatgantnnagntgtttnanannncatgnttcttnctataact
cttaatggtnctgatgacaccaccngtgcatnctcaatgncattttcatacacctggactaacgg
aagctatatcggagcaacatttggagctaactcatacacttctcntacatngcccannannnn

Similarity search algorithms such as BLAST (Korf et al., 2003) allow the use of n's (analogously to a wildcard) but the inclusion of too many n's results in an unacceptable degree of ambiguity. In that case, no meaningful BLAST results will be returned.

The REPI software was designed to parse the output of the FASTA file selecting and editing to mold sequence data into a format suitable for sequence similarity searches using the NCBI BLASTN algorithm. To accomplish this objective, REPI functions through a series of filters modifying the data as little as possible while extracting usable, "BLASTable" data from the FASTA files. Due to the nature of the resequencing microarray the sequences often contain large amounts of non-base calls (n's). BLAST is unable to return significant similarity for sequences with a large amount of non-base calls. Therefore the original sequences must be filtered to extract those portions that are most likely to return a significant similarity.

The first filter that a prospective sequence encounters is a control check. The control sequence incorporated into the microarray is specifically designed to be a nonsense sequence; therefore, it will never return a significant similarity. Next the sequence is evaluated for "BLASTable" data. Here a sliding window algorithm is used, the window-size parameter is entered by the user and represents the number of base calls the algorithm will evaluate at one time. The sequence is evaluated starting from the first base-call the window slides along the sequence searching for the first area containing relevant data, this is evaluated using a scoring method where all valid bases are given a score of one and all n's are given a score of zero. If the score is greater than or equal to a predetermined threshold (here 25% is used) the program marks the start of this window as the beginning of usable

data. Once the start of usable data is determined the program reverses its parameters and begins searching for the end of the useable data, the score must now be less than or equal to the threshold. For each sequence REPI searches for the largest continuous string(s) of usable data, which will represent that sequence's initial subsequence.

This subsequence is then trimmed for beginning and trailing n's. Trimming is necessary because the previous filter uses the starting position of the starting window as the beginning of the subsequence and the last position of the ending window as the end of the subsequence, therefore all though that window's score was acceptable there may be n's leading or trailing the subsequence. The next filter the subsequence goes through is a length evaluation. Subsequences longer than 50 nucleotides are allowed to continue, subsequences shorter than 20 nucleotides are discarded, and subsequences between 20 and 50 nucleotides are re-evaluated as follows. Due to the length of these subsequences they are rescored using the same scoring system described earlier. Subsequences with greater than 60% non-base calls are discarded; all others are allowed to continue to be searched with the BLAST algorithm against GenBank, or one's own modified database.

Once the similarity search is complete REPI computes a number of statistics on the subsequence including the subsequence percentage of the target sequence, the subsequence length, the number of subsequence base calls, and the percentage of subsequence base calls. The subsequence percentage of the target sequence and the subsequence length shows what portion of the target pathogen gene was identified. The subsequence length and percentage of subsequence base calls allow us to monitor the filtering algorithm filters as well as the GDAS threshold parameters. REPI saves all statistical results returned from the BLASTN algorithm allowing the user to manipulate which results are displayed in the graphical user interface.

In the examples provided, REPI was interfaced to a local BLAST (NCBI GenBank) database (contained on an Apple G5 single processor (1.8 Ghz) computer with 4.5 GB of random access memory) via a CGI (Perl) interface. Displayed results included all database sequences within an expect value (E-value) threshold of 1.0e-9. The E-value represents the number of alignments expected at random given the size of the search space, the scoring matrix, and the gap penalties; the lower the E-value the less likely the database sequence similarity matches was in fact a random identification. By definition e = 2.71828182845904523536028747135.

The REPI output is comprised of the (BLASTable) subsequence names, lengths, E-values, and bits scores are displayed for each subsequence in descending order of bit scores. The name is reported as the GenBank record's FASTA definition line and includes the sequence length. The score is the normalized score computed from the scoring matrix and gap penalties, the higher the score the greater the similarity.

The REPI output of the example listed above is shown below. For each "BLASTable" subsequence, REPI returns (in descending order of bit score ranking) all GenBank data records having expect values of < 1.0 e-9. The highest bit score is achieved for the adenovirus 4 prototype (AY594253), which is genetically indistinguishable from the Ad4 vaccine strain (AY594254) across this stretch, while lower bit scores suitably distinguish field strains from Air Force and Navy training sites (SEQ ID NO: 430).

>Ad4FIBER:CustemSeq-Adenovirus 4 Start=12 End=1245
Subsequence:
cnnncncngaccgngnnnttcannaacnctcccntcgnnctcttcagatgnattnnaagaaaagcc
cctgggggtgttgtccnnannnnnnngccgaccctgtcncnnnaagaatgnnnaaattannnnnaa
gctgngngagggggtnnnncttgacgactcgggaaaactcnttgcaancacagtaaacaaggccat
tgcnnctctcagnttttnccaacaacaccatttnnnnttaacatggataccccttttatacaccaaa
gntggaaaactancottacaagtttctnccaccattaagtatattaaaatcaacaattttgaatac

nnnnnnnnnagcttttggntcaggtttnggactcagtnnnngcgcccnngcagtanantttagnctc
nccacttacatttgntgataaagggaatanaaagattacccnaaanagnnnnttgcatgttanaac
aggagntgcaattgaaagcaacatcagttgggctaaaggtntaaaattngaagatggtgccatagc
tacaaacattggtaannnnnnnnnnnntnnnaaccagnngtncagaannannagnnannaangctta
tccaatccaannnnnnnnntgncnctggtctcagctttgacagcacaggagccataatgnctggcaa
taaagnctatgataaattaactttgtggacaacgcctgacccatcaccaaactgncaaatncttgc
agaaaatgntgcaaaactaacactttgnnnnnnnnnanngnnacagncaaatactggccactgtanc
ngttttggntgttagaagnggaaacttaaacccaattactggcacagtaagcagtgctcaagnttt
tcnncgntttgatgcaaatggtgnncntntnacagaacactctannennaaaaaatnntggggcna
naagcaangagatagnatagatggcactccatacaccaatgctgttggttttatgccaaattcaac
agcttntnnaaagacncaaagttctnctnctaaaaataatntagtgggtcaagtatacatgantnn
agntgtttnanannncatgnttcttnctataactcttaatggtnctgatgacaccaccngtgcatn
ctcaatgncattttcatacacctggactaacggaagctatatcggagcaacatttggagctaactc
atacaccttctcntacatngcccanna

Subsequence Percentage of Target: 98%

Subsequence Length: 1215

Number of Subsequence Base Calls: 1020

Percentage of Subsequence Base Calls: 84%

lcl|AY594254 | Human Adenovirus serotype 4, vaccine strain#| 35,994bp; Length = 35994

evalue: 0.0, score: 751.806 for Ad4FIBER

lcl|AY594253 |Human Adenovirus Serotype 4| 35,990bp; Length = 35990

evalue: 0.0, score: 751.806 for Ad4FIBER

gi|303967|gb|L19194.1|ADRFIBERX Mastadenovirus h4 fiber protein, complete cds; Length = 1346

evalue: 0.0, score: 743.877 for Ad4FIBER

gi|22796371|emb|AJ315930.1|HAD315930 Human adenovirus type 4 DNA; Length = 12718

evalue: 0.0, score: 735.947 for Ad4FIBER

lcl|AY599837 | Human Adenovirus serotype 4, USAF Field Strain | 35,964bp; Length = 35964

evalue: 0.0, score: 704.23 for Ad4FIBER

lcl|AY599835 | Human Adenovirus serotype 4, US Navy Field Strain | 35,965bp; Length = 35965

evalue: 0.0, score: 696.3 for Ad4FIBER

gi|434913|emb|X76547.1|AV4FIB1 Adenovirus type 4 gene for fiber protein; Length = 1375

evalue: 2.32306E-154, score: 553.571 for Ad4FIBER

gi|17105037|gb|AF394196.1|AF394196 Simian adenovirus 25, complete genome; Length = 36521

evalue: 6.5072E-53, score: 216.57 for Ad4FIBER

gi|33694802|tpg|BK000413.1| TPA: Simian adenovirus 25, complete genome; Length = 36519

evalue: 6.5072E-53, score: 216.57 for Ad4FIBER

The application Java Archive (.jar) files for the REPI program are generated and processed in accordance with the description provided in U.S. Application Serial No. 60/609,918 filed on September 15, 2004, and U.S. Application Serial No. 60/631,460, filed on November 29, 2004.

Example 1 – Base calling algorithm settings and BLAST analysis of base calls for Adenovirus 4 using conserved (degenerate) PCR primers and GenomiPhi total amplification

Raw sequence data from the resequencing microarray chips is provided by the Genetic Data Analysis Software version 2.0 (GDAS) packaged with the microarray reader from Affymetrix. GDAS base calling is based on a previously described base-calling algorithm, ABACUS, detailed previously (Cutler et al., 2001). A variety of base-calling algorithm parameters can be defined by the user (GDAS operators manual) to obtain a trade-off between base calling percentage and accuracy.

A description of the parameters is found in the GDAS manual on pages 207-217. The recommended (default) settings for GDAS are "conservative" settings that focus on the highest level of accuracy. In contrast, the objective of the present invention is to increase the percentage of base calls. To achieve this objective, the present inventors adjusted the parameters to allow highly permissive base calls (increased percentage) as listed below:

"Permissive" Base Calling Algorithm Settings –

- Filter Conditions
  - No Signal threshold = 0.500 (default = 1.000000)
  - Weak Signal Fold threshold = 20000.000 (default = 20.000000)
  - Large SNR threshold = 20.000000 (default = 20.000000)
- Algorithm Parameters
  - Strand Quality Threshold = 0.000 (default = 0.000000)
  - Total Quality Threshold = 25.0000 (default = 75.000000)
  - Maximum Fraction of Heterozygote Calls = 0.99000 (default = 0.900000)
  - Model Type (0 = Heterozygote, 1 = Homozygote) = 0
  - Perfect Call Quality Threshold = 0.500 (default = 2.000000)
- Final Reliability Rules
  - Min Fraction of Calls in Neighboring Probes = 1.0000 (disables filter)
  - Min Fraction of Calls of Samples = 1.0000 (disables filter)

The settings above are significant in the present application because the base call algorithm is set up by default to sacrifice the number of base calls made in order to make the most accurate calls (i.e., for SNP detection). In the present application, the technique is less concerned about achieving the same degree of accuracy as required for SNP detection but instead expanding the number of calls made so that the longest possible stretches of contiguous sequence are produced by GDAS, while maintaining specificity.

In a comparative approach to sample preparation for analysis by the RPM V1 microarray, a starting concentration of 10^6 genomic copies of Adenovirus 4 prototype (AY594253) per microliter were amplified using either degenerate adenovirus PCR primers (Lin et al., 2004) or GenomiPhi isothermal methods. For the total amplification experiments, DNA was isolated from cultured adenoviruses and aliquoted at concentrations of 10^6 copies per microliter. DNA was amplified using a total amplification strategy (GenomiPhi, Amersham), then processed in accordance with the standard Affymetrix CustomSeq™ protocol (available from manufacturer).

Images of the hybridized microarrays are shown in FIG. 2. GenomiPhi total amplification allowed the entire tiled region (increased sensitivity) to be resequenced compared to the more limited region resulting from conserved (degenerate) multiplex PCR. This result arises due to the fact that GenomiPhi total amplification does not rely on specific primer sequences within the tiled fragment. However, it is also important to note that irrespective of which amplification strategy was employed, i.e., conserved (degenerate) multiplex PCR or GenomiPhi total amplification, the proper Ad4 calls were made. The consistency between these methods is important as the conserved primers may have a more direct application to serotyping members of the same family of pathogens from complex samples without the need for selective enrichment.

Based on the corresponding GDAS outputs (using "permissive" settings), REPI identified the following list of top-ranked returns for the conserved PCR amplification strategy for the E1A, Fiber, and Hexon-1 tile regions of the V1 RPM microarray (note: omitted from this list are several adenovirus type 4 GenBank records having nearly identical sequences as the Ad4 prototype and Ad4 vaccine strain).

Table 12: Ad4E1A:CustomSeq-Adenovirus 4

Accession #	Name	E value:	Bit Score:
AY594254	Human Adenovirus serotype 4, vaccine strain	1.04808E-107	396.964
AY594253	Human Adenovirus Serotype 4	1.04808E-107	396.964
AY599837	Human Adenovirus serotype 4, USAF Field Strain	8.34268E-53	214.587
AY599835	Human Adenovirus serotype 4, US Navy Field Strain	8.34268E-53	214.587

Table 13: Ad4FIBER:CustomSeq-Adenovirus 4

Accession #	Name	E value:	Bit Score:
AY594254	Human Adenovirus serotype 4, vaccine strain	0.0	751.806
AY594253	Human Adenovirus Serotype 4	0.0	751.806
AY599837	Human Adenovirus serotype 4, USAF Field Strain	0.0	704.23
AY599835	Human Adenovirus serotype 4, US Navy Field Strain	0.0	696.3

Table 14:Ad4HEXON-1:CustomSeq-Adenovirus 4

Accession #	Name	E value:	Bit Score:
AY594254	Human Adenovirus serotype 4, vaccine strain	0.0	751.806
AY594253	Human Adenovirus Serotype 4	0.0	751.806
AY599835	Human Adenovirus serotype 4, US Navy Field Strain	1.73046E-169	603.13
AY599837	Human Adenovirus serotype 4, USAF Field Strain	4.2185E-167	595.2

In each case shown above, the adenovirus type 4 prototype (AY594253) and vaccine strain (AY594254) returned the highest expect values and bit scores for hybridization of the adenovirus type 4 prototype amplicons obtained by conserved PCR amplification. This is expected because the prototype strain was used for vaccine production and the sequences were determined to be identical. In each case, the returns were distinguished in order of similarity from the closely related Air Force (AY599837) and Navy (AY599835) adenovirus 4 field strains.

Listed below are the corresponding outputs following GenomiPhi amplification of the adenovirus type 4 prototype instead of conserved PCR (note: not shown are several closely-related adenoviruses with bit scores higher than the Air Force and navy field strains):

Table 15: Ad4E1A: Adenovirus 4 GenomiPhi3

Accession #	Name	E value:	Bit Score:
AY594253	Human Adenovirus Serotype 4	0.0	868.765
AY594254	Human Adenovirus serotype 4, vaccine strain	0.0	868.765
gi|209874|gb|M14918.1	ADRDB1AA Adenovirus type 4 E1A region	0.0	860.836

Table 16: Ad4FIBER: Adenovirus 4 GenomiPhi3

Accession #	Name	E value:	Bit Score:
gi|434913|emb|X76547.1	AV4FIB1 Adenovirus type 4 gene for fiber protein	0.0	1031.32
AY594254	Human Adenovirus serotype 4, vaccine strain	0.0	926.254
AY594253	Human Adenovirus Serotype 4	0.0	926.254
AY599837	Human Adenovirus serotype 4, USAF Field Strain	0.0	743.877

Table 17: Ad4HEXON-1: Adenovirus 4 GenomiPhi3

Accession #	Name	E value:	Bit Score:
AY594254	Human Adenovirus serotype 4, vaccine strain	0.0	1065.02
AY594253	Human Adenovirus Serotype 4	0.0	1065.02
gi|11693508|gb|AF065062.2|AF065062	Human adenovirus type 4 strain RI-67 pVI core protein	0.0	1065.02
AY599835	Human Adenovirus serotype 4, US Navy Field Strain	2.96209E-147	529.782

Based on the results evidenced by FIG. 2, GenomiPhi total amplification allowed the entire tiled region (increased sensitivity) to be resequenced compared to the more limited region resulting from conserved (degenerate) multiplex PCR. This result arises due to the fact that GenomiPhi total amplification does not rely on primer sequences within the tiled fragment. REPI listed the appropriate adenovirus type (AY594254 or AY594253) as the highest scoring return for each tile region with the exception of Ad4FIBER. This discrepancy was later resolved by observing that the early draft sequence of the adenovirus type 4 prototype (AY594253) contained errors that gave rise to a slightly higher homology between the sequence used to define Ad4FIBER and a GenBank record for a different adenovirus type 4 strain (gi|11693508|gb|AF065062.2|AF065062).

With this one exception, it is also important to note that irrespective of which amplification strategy was employed, *i.e.*, conserved (degenerate) multiplex PCR or GenomiPhi total amplification, the proper Ad4 calls were made (except in case of Ad4FIBER with GenomiPhi due to tile sequence errors). The consistency between these methods is important as the conserved primers may have a more direct application to serotyping members of the same family of pathogens from complex samples without the need for selective enrichment.

Example 2 - Ad4 dilution series

In the present example, hybridization and base calling was assayed as a function of the initial concentration of the target subsequent to conserved (degenerate) multiplex PCR. In addition, this example also compares two different base-calling strategies within the GDAS software: (a) "permissive" (described in Specification) and (b) "conservative" (default) settings. The biological sample utilized in this example was the adenovirus 4 prototype.

Hybridization and base calling were assayed as a function of the initial concentration of the target subsequent to conserved (degenerate) multiplex PCR. A dilution series of the adenovirus 4 prototype (ATCC) was prepared having 10^5, 10^3, and 10^1 genomic copies per microliter. To this end, the Affymetrix CustomSeq protocol was followed, except that samples aliquoted from the aforementioned dilutions were amplified using the conserved (degenerate) multiplex adenovirus primer strategy for *E1A*, *fiber*, and *hexon* genes.

Tables 18-20 demonstrate the ability of the RPMV1 chip with REPI analysis to detect the appropriate Adenovirus type 4 target (not specific to strain) depending on whether "Conservative" (default GDAS) or "Permissive" (from Example 1) base call settings were used. A positive detection was counted when REPI returned one or more GenBank (or local) database record(s) for an Adenovirus type 4 target as the highest BLAST bit score value(s). In each case, "length" corresponds to the number of base pairs in the subsequence selected by REPI as

having satisfied the conditions of the sliding window algorithm.

Table 18:

Dilutions	Ad4 Fiber									
	Conservative					Permissive				
	Expt.	Score	Eval	name	length	Expt.	Score	Eval	name	length
10^5	1	835.065	E-0.0	Ad4 Fiber Protein	1227	1	1623.97	0.0	Ad4 Fiber Protein	1227
	1-2	1015.46	E-0.0	Ad4 Fiber Protein	990	1-2	1447.89	0.0	Ad 4 Fiber Protein	997
	1-3	297.846	E-78	Ad4 Fiber Protein	451	1-3	703.626	0.0	Ad4 Fiber Protein	512
	1-4	839.03	0.0	Ad4 Fiber Protein	1059	1-4	1605.08	0.0	Ad4 Fiber Protein	1215
10^3	2	488.153	E-134	Ad4 Fiber Protein	1208	2	1559.2	0.0	Ad4 Fiber Protein	1220
	2-2*		n/d	-	-	2-2		n/d	-	-
	2-3	232.429	E-58	Ad4 Fiber Protein	421	2-3	405.389	E-110	Ad4 Fiber Protein	444
	2-4		n/d	-	-	2-4		n/d	-	-
10^1	3	172.958	E-40	Ad4 Fiber Protein	294	3	301.101	E-79	Ad4 Fiber Protein	442
	3-2*		n/d	-	-	3-2		n/d	-	-
	3-3		n/d	-	-	3-3	118.758	E-24	Ad4 Fiber Protein	279
	3-4	99.61	E-19	Ad4 Fiber Protein	93	3-4	116.39	E-24	Ad4 Fiber Protein	95

* indicates degraded template; n/d indicates "not determined" due to insufficient base calls

Table 19:

Dilutions	Ad4 E1A									
	Conservative					Permissive				
	Expt.	Score	E-val	name	length	Expt.	Score	Eval	name	length
10^5	1	448.5	E-123	Ad4 E1A region	553	1	775.595	E-0.0	Ad4 E1A region	556
	1-2	420.8	E-115	Ad4 E1A region	422	1-2	691.471	E-0.0	Ad4 E1A region	444
	1-3		n/d	-	-	1-3	561.5	E-157	Ad4 E1A region	413
	1-4	353.4	E-94	Ad4 E1A region	424	1-4	589.253	E-165	Ad4 E1A region	424
10^3	2	341.5	E-91	Ad4 E1A region	399	2	607.1	E-171	Ad4 E1A region	412
	2-2*		n/d	-	-	2-2		n/d	-	-
	2-3	194.8	E-47	Ad4 E1A region	404	2-3	470.774	E-130	Ad4 E1A region	421
	2-4		n/d	-	-	2-4		n/d	-	-
10^1	3		n/d	-	-	3	385.836	E-104	Ad4 E1A region	405
	3-2*		n/d	-	-	3-2		n/d	-	-
	3-3		n/d	-	-	3-3	199.58	E-48	Ad4 E1A region	403
	3-4	412.8	E-112	Ad4 E1A region	397	3-4	640.794	E-0.0	Ad4 E1A region	398

Table 20:

Dilutions	Ad4 Hexon									
	Conservative					Permissive				
	Expt.	Score	Eval	name	length	Expt.	Score	Eval	name	length
10^5	1	377.1	E-101	Ad4 Hexon gene	760	1	893.45	0.0	Ad4 Hexon gene	769
	1-2	603.13	E-0.0	Ad4 Hexon gene	760	1-2	941.874	E-0.0	Ad4 Hexon gene	768
	1-3	107.5	E-21	Ad4 Hexon gene	262	1-3	246.762	E-62	Ad4 Hexon gene	497
	1-4	498.1	E-138	Ad4 Hexon gene	760	1-4	920.916	E-0.0	Ad4 Hexon gene	762
10^3	2	383.1	E-103	Ad4 Hexon gene	759	2	826.865	E-0.0	Ad4 Hexon gene	759
	2-2*		n/d	-	-	2-2		n/d	-	-
	2-3		n/d	-	-	2-3		n/d	-	-
	2-4		n/d	-	-	2-4		n/d	-	-
10^1	3		n/d	-	-	3	78.8677	E-12	Ad4 Hexon gene	143
	3-2*	71.86	E-11	Ad4 Hexon gene	65	3-2	107.54	E-21	Ad4 Hexon gene	72
	3-3		n/d	-	-	3-3		n/d	-	-
	3-4		n/d	-	-	3-4	149.17	E-33	Ad4 Hexon gene	209

* indicates degraded template; n/d indicates "not determined" due to insufficient base calls

Across the range of dilutions, the "Permissive" base call settings produced GDAS outputs that were used by REPI to consistently yield higher subsequence lengths and bit scores than those outputs using the default GDAS base call settings for SNP detection. In several cases, the "Permissive" base call settings resulted in a sufficient number of base calls for REPI to detect the target whereas the default settings did not. This example demonstrates that by lowering the restrictions on base calling by GDAS and coupling the output to the REPI algorithm, higher sensitivity and discriminatory power (strain identification) among pathogens is achieved.

Of particular note here is that in some cases, there was evidence contained in the image, GDAS output, and REPI analyses, of unintentional contamination of the degenerate primer cocktail with trace amounts of Adenovirus 7 and Adenovirus 5 (confirmed by specific real-time PCR). Because there was no significant cross-hybridization between the tile regions for the prototype adenoviruses, this contamination did not result in a perturbation of the base calling or results in the Adenovirus 4 tile regions. This demonstrates the robustness of the methods described herein to perform quantitative separation of mixtures of closely related pathogens.

It is noteworthy that the Andersen group at Lawrence Livermore National Laboratory (Wilson et al., 2002b) described the use of an Affymetrix resequencing chip that could detect a low concentration (~10^1 copies) following specific PCR amplification. However, it was not disclosed or suggested how this sensitivity was defined or to what extent those results were influenced by hybridization of closely related microbial species. Rather, the emphasis in that paper was the percentage of probe pairs that could be used, not the actual sequences as they were called by the chip. Therefore, the artisan would not have any expectation resulting from the disclosure. Nor would the skilled artisan have inferred this possibility from the previous patent (US Patent 6,228,575) or related publication (Gingeras et al., 1998) since these references fail to disclose or suggest robustness of the prescribed methods of pattern recognition to concentration differences, errors in the definition of tile region sequences, or other forms of interference.

Example 3 –Base calling algorithm settings and BLAST analysis of base calls for Adenovirus 5 field strain (Ad5FS; AY601635) and adenovirus 7 prototype (Ad7; AY594255) using conserved (degenerate) PCR primers and

GenomiPhi total amplification

This example is the same as Example 1, except the resequencing microarray chip (RPMV1) described above in Preparation Example 1 was probed with adenovirus type 5 field strain (Ad5FS; AY601635) or adenovirus type 7 prototype (AY594255) using either (a) conserved (degenerate) multiplex PCR or (b) GenomiPhi total amplification (FIG. 3). Based on the GDAS outputs (using "permissive" settings), REPI identified the following 3 top "hits" for the conserved PCR and total amplification strategies with each of the Ad5 prototype and the Ad7 prototype. Without exception, each subsequence called by the adenovirus type 5 tile regions (Ad5E1A, Ad5FIBER, Ad5FIBER, Ad5HEXON-1 and Ad5HEXON-2) listed the top "hit" (highest BLAST bit score) as the correct prototype strain for adenovirus type 5 (Ad5FS; Accession number AY601635) using either conserved PCR amplification or total (GenomiPhi) amplification.

Also, without exception, each subsequence for the adenovirus type 7 tile regions (Ad7E1A, Ad7FIBER, Ad5HEXON-1 and Ad5HEXON-2) listed the top "hit" (highest BLAST bit score) as the correct prototype strain for adenovirus type 7 (Ad7; Accession number AY594255) when using either conserved PCR or total (GenomiPhi) amplification. In addition, GenomiPhi amplification led to base calls from both the Ad4E1A regions and the Ad7vaccine regions, both resulting in top bit scores assigned to the correct Ad7 prototype strain.

The results obtained for the adenovirus type 5 and adenovirus type 7 prototypes confirmed those for adenovirus type 4. Specifically, the results shown in Figures 3A-D show that GenomiPhi total amplification allowed the entire tiled region (increased sensitivity) to be resequenced compared to the more limited region resulting from conserved (degenerate) multiplex PCR. More importantly, these results confirm that irrespective of which amplification strategy was employed, i.e., conserved (degenerate) multiplex PCR or GenomiPhi total amplification, the proper Ad5 or Ad7 calls were made.

Example 4 - Ad4-5 Breakthrough Strain as a model of mixed infection detectable by resequencing microarray assay

The sample for this example was provided by the Naval Health Research Center (San Diego). The archived sample was a nasal wash from a basic trainee who had previously been immunized for adenovirus (using the Ad4/Ad7 vaccine) and who subsequently was diagnosed with adenovirus infection and febrile respiratory illness. Strains associated with infection in spite of previous vaccination are broadly referred to as "breakthrough strains". In this case, the presumption was that a single variant form of adenovirus was the causative agent. The sample described here is referred to as Ad4-5 Breakthrough because of inconclusive culture and serological assays that indicated properties of both adenovirus types 4, while sequencing of the *hexon* gene (one of antigenic determinants of adenovirus serotype) indicated properties of adenovirus type 5.

The sample was processed according to the multiplex degenerate primer PCR protocol described in Preparation Example 1. This approach was demonstrated to (Lin et al 2004) successfully amplify hypervariable regions on hexon and fiber genes (as well as a relatively variable E1A region) for all adenoviruses associated with febrile respiratory infection. Otherwise, the standard Affymetrix CustomSeq protocol was used.

The resultant hybridization pattern is shown is FIG. 4. Based on the GDAS outputs (using "permissive" settings), REPI identified the following 3 top "hits" for total amplification strategies by multiplex PCR (See Tables 21-24).

Table 21: Ad5FIBER:Ad 4-5 Breakthrough Strain

Accession #	Name	E value:	Bit Score:
lcl|AY601635	Human Adenovirus Serotype 5, Field Strain	5.01036E-76	291.899
gi|33694637|tpg|BK000408.1	TPA: Human adenovirus type 5	5.01036E-76	291.899
gi|32127287|gb|AY224398.1	Human adenovirus type 5 strain KNIH 99/5 fiber gene	5.01036E-76	291.899

Table 22: Ad5HEXON-1:Ad 4-5 Breakthrough Strain

Accession #	Name	E value:	Bit Score:
lcl|AY601635	Human Adenovirus Serotype 5, Field Strain	0.0	644.759
gi|33694637|tpg|BK000408.1	TPA: Human adenovirus type 5	1.81596E-172	613.041
gi|32127287|gb|AY224398.1	Human adenovirus type 5 strain KNIH 99/5 fiber gene	2.63084E-165	589.253

Table 23: Ad7E1A:Ad 4-5 Breakthrough Strain

Accession #	Name	E value:	Bit Score:
gi|4127293|emb|AJ005536.1|ACA005536	Adenovirus clinical isolate, clone B44 from genomic DNA	3.18875E-83	315.688
lcl|AY601633	Human Adenovirus Serotype 21	4.97873E-82	311.723
gi|21311720|gb|AF492353.1	Human adenovirus type 21 E1A 13S protein gene	1.21371E-79	303.794
lcl|AY601634	Human Adenovirus Serotype 7, US Navy Field Strain	2.95877E-77	295.864

Table 24: Ad7HEXON-1:Ad 4-5 Breakthrough Strain

Accession #	Name	E value:	Bit Score:
lcl|AY601633	Human Adenovirus Serotype 21	6.98074E-24	117.452
gi|13919592|gb|AY008279.1	Human adenovirus type 21 hexon protein gene	6.98074E-24	117.452
gi|21311720|gb|AF492353.1	Human adenovirus type 50	6.98074E-24	117.452
lcl|AY594255	Human Adenovirus Serotype 7	6.0101E-12	77.8048
lcl|AY601634	Human Adenovirus Serotype 7, US Navy Field Strain	6.0101E-12	77.8048

Selected REPI return values for Adenovirus 4,5 Breakthrough Strain on RPMV1. This "strain" was determined by several independent means to be a mixture of adenovirus type 5 and a B subgroup member, most likely being adenovirus type 21. This was borne out in the combined hybridization results and REPI analysis, with adenovirus type 5 being confirmed on all adenovirus 5 tiles, while the B subgroup prototype (adenovirus 7; AY594255) tiles returned the highest bit scores for a adenovirus type 21, a different member of the B subgroup.

Conventional DNA sequencing revealed that the complete adenovirus 5 genome was recovered and that other sequences were present that could not be assembled because an Adenovirus 5 model assumption was required. However, a significant amount of corroborating evidence was amassed to support the conclusion of an Ad5 / Ad 21 co-infection, including similar results obtained in parallel experiments with 70-mer oligonucleotide arrays (Lin et al 2004) showing evidence of an Ad 5 / Ad 21 mixture or co-infection, and sequencing of amplicons using conventional approaches that supported the presence of both Ad5 and Ad 21. An extended study conducted subsequently of adenovirus breakthrough strains (in collaboration with NHRC San Diego) showed that a variety of such strains were actually comprised of mixtures of lesser adenoviruses (manuscript in preparation).

There are several significant aspects and advantages implicit in this discovery:

1. demonstration that a prototype region (Ad 7 for B subgroup) could be used to successfully identify a different B subgroup member (Ad 21) without specific *a priori* design or anticipation of discovering Ad 21 in a sample.
2. demonstration of a microarray to distinguish mixed pathogens due to spatial resolution. This mixture confounded a conventional DNA sequencing approach that relied on assembly of contiguous fragments based on assumption of a single organism.

Example 5 – Influenza A strain identification using prototype regions

Influenza A positive clinical samples of unknown serotype were collected during the 2002-2003 and 2003-2004 flu seasons and provided to Dr. Zheng Wang as frozen nasal washes by Dr. Elizabeth Walter.

Samples were processed for pathogen chip analysis as follows:

EPICENTRE MasterPure™ DNA Purification Kits (Madison, Wisconsin) were used to extract total nucleic acids from 50 µl of nasal wash (sample NW20031114-05-02) without RNase treatment. Sample NW20031114-05-02 was collected on November 14, 2003 at Lackland Air Force Base (San Antonio, TX). The patient was vaccinated on November 10, 2003. The total nucleic acids were suspended in 20 µl nuclease free H_2O. Two-step RT-PCR was employed to amplify each of the viral gene segments.

Briefly, the RNA in 4 µl total nucleic acids was transcribed into cDNA by using SuperScript™III Reverse Transcriptase (Invitrogen, Carlsbad, CA) according to the protocol provided by the manufacturer and 100 pmol Uni3 primer in 20 µl. The RT (reverse transcription) reaction was performed at 42° C for 1 hr and then was inactivated at 70° C for 15 min. 2 µl of the RT-reaction was used for cDNA amplification. The cDNA was amplified by using TaqPlus Long System (Stratagene, La Jolla, CA) according to protocol provided. Two different PCR conditions were used for amplification. For universal PCR, universal primers uni3 and uni5 were used to amplify all eight segments of hemagglutinin (HA), neuraminidase (NA) and matrix (M) (see Hoffman et al, 2001). For multiplex PCR, segments were amplified by mixing three segment specific primer pairs (Bm-HA-1/Bm-NS-890R, BA-Na-1/Ba-Na-1413R and Bm-M-1/Bm-M-1027R). The final concentration of Mg^{2+}-ions was 2 mM and final primer concentration was 1 µM. PCR condition for universal amplification was: 94° C for 2 min followed by 29 cycles of 94° C for 1 min, 40° C for 2 min, 72° C for 3 min, and final extension at 72° C for 10 min. The

multiplex PCR condition was basically same except that the annealing temperature was raised to 58° C. PCR products were purified by Qiagen PCR Purification kit. 500 ng of universally amplified PCR products and 1000 ng of multiplex PCR products were applied to two V1 Pathogen chips for hybridization according to Affymetrix protocol, respectively.

Primer sequences (from Hoffman et al, 2001) –

Uni3:	AGCAAAAAGCAGG (SEQ ID NO : 431)
Uni5:	AGTAGAAACAAG (SEQ ID NO : 432)
Bm-HA-1:	TATTCGTCTCAGGGAGCAAAAGCAGGGG (SEQ ID NO : 433)
Bm-NS-890R:	ATATCGTCTCGTATTAGTAGAAACAAGGGTGTTTT (SEQ ID NO : 434)
Ba-Na-1:	TATTGGTCTCAGGGAGCAAAAGCAGGAGT (SEQ ID NO : 435)
Ba-Na-1413R:	ATATGGTCTCGTATTAGTAGAAACAAGGAGTTTTTT (SEQ ID NO : 436)
Bm-M-1:	TATTCGTCTCAGGGAGCAAAAGCAGGTAG (SEQ ID NO : 437)
Bm-M-1027R:	ATATCGTCTCGTATTAGTAGAAACAAGGTAGTTTTT (SEQ ID NO : 438)

The chip scan results are shown for each of the two amplification protocols: (a) universal primer PCR and (b) multiplex PCR (FIG. 5). Based on the GDAS outputs (using "permissive" settings), REPI identified the following 3 top "hits" for the universal primer (Hoffman et al, 2001) amplification method and total amplification strategies with each of the Ad5 prototype and specific multiplex PCR method (See Table 25).

For this experiment, the present inventors obtained sequence for the HA gene of the Flu strain that evaded the 2003-2004 vaccine and caused widespread illness, namely Fujian/411/2002 (note: only the HA sequence was available for Fujian/411/2002) and incorporated that into the database searched by REPI. Each of the two amplification methods produced effectively the same results, although bit scores varied slightly. Specifically, Fujian 411/2002 returned the highest bit score for FluAHA3 in the REPI output files. Moscow 10/99, the strain used for vaccination in 2003, did not return a REPI output for FluAHA3.

Table 25: FluAHA3:NW20031114-05-02 ACID04 -B2

Accession #	Name	E value:	Bit Score:
lcl|ISDN38157	InfluenzaA/Fujian/411/2002_ Hemagglutinin_104	0.0	1431.75
gi|37530025|gb|AY389356.1	Influenza A virus (A/Middleburg/41/03(H3N2)) hemagglutinin (HA) gene	0.0	1431.75
gi|37530033|gb|AY389360.1	Influenza A virus (A/Pretoria/17/03(H3N2)) hemagglutinin (HA) gene	0.0	1423.83
gi|37530031|gb|AY389359.1	Influenza A virus (A/Pretoria/16/03(H3N2)) hemagglutinin (HA) gene	0.0	1423.83

The highest BLAST bit score for HA3 was achieved for (InfluenzaA/Fujian/411/2002_Hemagglutinin_104), the H3N2 etiologic agent of the 2003-2004 Influenza outbreak in the United States that evaded protection by vaccination. An indistinguishable viral sequence for HA3 also achieved the same bit score. Over 500 GenBank records were returned for HA3, all having expect values of 0.0 and bit scores ranging from those shown above to 995.636. The vaccine strain, (A/Panama/2007/99(H3N2)), was not in the list of returned Influenza A strains in the HA3 region. Note: sequence for InfluenzaA/Fujian/411/2002_Hemagglutinin_104 was only available for HA, so other regions are not compared here.

Although not shown, the present inventors have been able to identify the H1N1 outbreak strain from the 2002-2003 flu season.

Example 6 -- Reduced hybridization times

The Affymetrix CustomSeq protocol specifies that the hybridization step be at least 16 hours to facilitate maximum hybridization. For the intended purpose of a diagnostic capability, this could be prohibitively long. Therefore, the applicability and efficiency of the present methodologies to short hybridization times was assessed.

In the present example hybridization and base calling were performed, using samples that were amplified by specific PCR reagents and then hybridized for periods of either 1 hour, 30 minutes, or 15 minutes on the resequencing microarray chip (RPMV1) described above in Preparation Example 1. For this comparative study the Affymetrix CustomSeq protocol was followed with the exception of varying hybridization time. In the example data shown (FIG. 6), a nasal wash that was negative for all targets probed by the microarray except the erythromycin resistance markers SPYERMB, SPYERMTR, and SPYMEFAE was subjected to specific PCR for each of those markers. The amplicons were then hybridized to separate microarrays for either 16 hours or 15 minutes, and then processed otherwise as prescribed by the Affymetrix protocol.

The results appear in FIG. 6A [16 hours; ex-6a]) and FIG. 6B [2 hours; ex-6b]. Based on the GDAS outputs (using "permissive" settings), REPI identified the following 3 top "hits" for the 16 hour hybridization and the 15 minute hybridization, respectively.

The corresponding GDAS and REPI analyses show that the number of base calls resulting is fewer in the case of the 15 minute hybridization compared to that for the 16 hour hybridization (See Tables 26-31). For example, the SPYERMB tile region produced a subsequence length of 219 bp (98% of tile region, 95% base calls made within the subsequence) for a 16 hour hybridization, while discontinuities in the hybridization pattern from a

15 minute hybridization resulted in fragmentation of the tile into two subsequences of lengths 100 bp (45% of tile region, 99% base calls made within subsequence) and 87 bp (39% of tile region, 99% base calls made in subsequence).

Table 26: SPYERMB:BL_JMS_020604_TW_3c (16 hour hybridization)

Accession #	Name	E value:	Bit Score:
gi|21886737|gb|AF516335.1	Enterococcus faecium plasmid pUW786 multiple antibiotic resistance gene cluster	1.90377E-98	365.247

Table 27: SPYERMB:BL_JMS_020604_TW_3b (15 minute hybridization)

Accession #	Name	E value:	Bit Score:
gi|21886737|gb|AF516335.1	Enterococcus faecium plasmid pUW786 multiple antibiotic resistance gene cluster	1.6409E-47	194.764

Table 28: SPYERMTR:BL_JMS_020604_TW_3c (16 hour hybridization)

Accession #	Name	E value:	Bit Score:
gi|2190969|gb|AF002716.1|AF002716	Streptococcus pyogenes leader peptides 1 (lpg1) and 2 (lpg2), and erythromycin resistance methylase (ermTR) gene	3.18989E-13	79.787

Table 29: SPYERMTR:BL_JMS_020604_TW_3b (15 minute hybridization)

Accession #	Name	E value:	Bit Score:
No calls	N/A	N/A	N/A

Table 30: SPYMEFAE:BL_JMS_020604_TW_3c (16 hour hybridization)

Accession #	Name	E value:	Bit Score:
gi|22121182|gb|AY071836.1	Streptococcus sp. 6 macrolide-efflux protein (mefA) gene	1.01677E-60	240.358

Table 31: SPYMEFAE:BL_JMS_020604_TW_3b (15 minute hybridization)

Accession #	Name	E value:	Bit Score:
gi|22121182|gb|AY071836.1	Streptococcus sp. 6 macrolide-efflux protein (mefA) gene	3.331E-36	159.081

The tables above show the comparative top rankings for the three different antibiotic resistance markers described in Example 6 for 16 hour versus 15 minute hybridization times. Although the SPYERMTR tile region did not produce a sufficient number of base calls to allow identification following a 15-minute hybridization, both the SPYERMB and SPYMEFAE returned high bit scores for the same variants of the antibiotic resistance markers comprising the tile regions (identified in Table 9).

However, the REPI output for each of the three tile regions showed that the highest bit scores in each

region were the same (except for SPYERRMTR which lacked sufficient base calls for the 15 minute hybridization), although both the bit scores and expect values were different in each case. Similar results were obtained for 30 minute and 1 hour hybridizations, with an increase in the number of base calls made with increasing hybridization times. Further, this example clearly illustrates the robustness of the method to make fine scale discrimination between targets with a range of different hybridization patterns.

Example 7 - Subtractive hybridization

A variety of methods might be employed to reduce the amount of background human DNA in clinical samples when using total amplification. One method is direct subtraction of the background genomic DNA from amplified products in hybridization solution with COT-1 fraction human genomic DNA that consists largely of rapidly annealing repetitive elements. Another method is bead-based subtraction of background genomic DNA from clinical sample prior to total amplification. A third method is the combination of the above methods, the genomic background DNA from clinical sample were subtracted using bead-based subtraction prior to total amplification, subsequently, the background DNA might be further subtracted from the clinical sample in hybridization solution with COT-1 human DNA.

Methods for FIG. 7A and 7B

A nasal wash was collected from one clinical sample and the total nucleic acid was isolated using MasterPure™ DNA purification kit (Epicentre). The nucleic acid was predigested with McrBc (an endonuclease that cleaves DNA containing methylcytosine on one or both strands) at 37° C for one hour, and then heated to 65° C to denature the enzyme. Subsequently, the sample was split to two aliquots and amplified with GenomiPhi DNA amplification kit (Amersham Biosciences). The amplified products were fragmented and labeled according to Affymetrix CustomSeq protocol.

For this comparative study the Affymetrix CustomSeq protocol was followed except for the following changes. The clinical sample was hybridized to the resequencing microarray chips (RPMV1) either with standard hybridization solution according to Affymetrix CustomSeq protocol (FIG. 7A) or with hybridization mixture containing 12 μg Herring Sperm DNA and 10 μg COT-1 human DNA (Roche, Indianapolis, IN) instead of 22 μg Herring sperm DNA as Affymetrix recommended (FIG. 7B).

Methods for FIG. 7C and 7D

The present example describes bead-base subtraction and the combination of bead-base subtraction with subtractive hybridization methods for increasing the pathogen specific signal-to-noise ratio when using total amplification.

COT-1 human DNA, consisting largely of rapidly annealing repetitive elements, was biotinylated at 3'-end using terminal transferase (Tdt) (NEB) to generate Biotinylated Subtraction Probes (BSPs). An aliquot of ~400 ng of BSPs was incubated at 95°C for 10 minutes in 4xSSC and 0.2% SDS with nucleic acid extract of clinical nasal wash (diagnosed as Ad4 positive clinical sample) predigested with McrBC at 37°C for one hour, then slowly cooled to 65°C to allow co-hybridization with the HMB for one hour. After hybridization, the BSP-HMB complexes were incubated at room temperature for 30 minutes at 1xPBS, 0.1% BSA with BcMag.Streptavidin Magnetic Beads (SMBs, Bioclone). The beads were separated from supernatant using a magnetic separator. The supernatant was then transferred to a new tube and the magnetic beads were washed once with 1xPBS, 0.1% BSA. The supernatants

were combined and precipitated with ethanol. The DNA pellet was resuspended with nuclease free water (Ambion) then split to two aliquots and amplified with GenomiPhi DNA amplification kit (Amersham Biosciences) according to the manufacture recommended protocol. Briefly, 1ml DNA template was denatured with 9 µl of sample buffer at 95°C for 3 minutes, the cooled down to 4°C. In a separate tube, 1 µl of enzyme was mixed with 9 µl of reaction buffer, and then the mixture was added to the denatured DNA template. The reaction was then performed at 30°C for 18 hours at Thermal Cycler-PTC225 (MJ Research Inc., Reno, NV).

For this comparative study, the amplified products were hybridized to the resequencing microarray chips (RPMV1) either with standard hybridization solution according to Affymetrix CustomSeq protocol (FIG. 7C) or with hybridization mixture containing 12 µg Herring Sperm DNA and 10 µg COT-1 human DNA instead of 22 µg Herring sperm DNA as Affymetrix recommended (FIG. 7D).

Methods for FIG. 7E

The combination of bead-base subtraction and subtractive hybridization procedure was repeated with double amount of initial material and the result appearing in FIG. 7E evidenced that the present inventors were able to subtract human background from clinical sample for the resequencing microarray chip (RPM Version 1 chip) described above in Preparation Example 1 to resolve the presence and identification of Ad4 hexon and fiber genes in the clinical sample.

Subtractive Hybridization Results

The results of the subtractive hybridization approaches are shown in FIG. 7. As shown in FIG. 7A, total amplification of the isolated nucleic acids resulted in significant background hybridization to the RPMV1 microarray. Although the adenovirus type 4 region showed a discernibly higher signal than that of the overall background, GDAS was unable to make enough base calls to satisfy the sliding window condition in REPI, so no attempts to BLAST the data were made. Co-hybridizing the same set of total amplicons with COT-1 human genomic DNA did little to improve this (FIG. 7B) and no base calls were made. FIG. 7C shows that the use of a magnetic bead-based subtraction alone, prior to total amplification, again did not result in a sufficient number of base calls to allow similarity searching.

However, through the combined use of a bead-based subtraction prior to amplification and co-hybridization with COT-1 human DNA, enough base calls could be made to identify and rank the adenovirus 4 field strains (Navy and Air Force without discrimination) higher than those of the vaccine and prototype adenovirus 4 strains in each of three subsequences identified in the Ad4HEXON-1 tile region (FIG. 7D and Table 32).

Table 32: Ad4HEXON-1:BL_818141_030503_NW_4

Accession #	Name	E value:	Bit Score:
lcl|AY599837	Human Adenovirus serotype 4, USAF Field Strain	6.14232E-37	161.064
lcl|AY599835	Human Adenovirus serotype 4, US Navy Field Strain	6.14232E-37	161.064
lcl|AY594254	Human Adenovirus serotype 4, vaccine strain	1.49737E-34	153.134
lcl|AY594253	Human Adenovirus Serotype 4	1.49737E-34	153.134

Moreover, by performing the same set of combined steps using 2 microliters of starting sample material instead of 1 microliter (FIG. 7E), base calling was extended into the Ad4FIBER tile region (see Table 33) in addition to Ad4HEXON-1 (see Table 34), allowing unambiguous high bit-score ranking for Ad4 Field Strain (though not distinguishing between Air Force and Navy field strains) versus prototype (AY594253) or vaccine strain (AY594254) in several Ad4FIBER subsequences. However, the Ad4 Air Force Field Strain (Accession No. AY599837) was distinguishable from the Navy field strain (AY599835) in the Ad4HEXON-1 tile because an increased number of base calls allowed for a more complete sequence comparison and increased bit score resolution.

Table 33: Ad4FIBER:BL_818141_030503_NW_9b

Accession #	Name	E value:	Bit Score:
lcl|AY599837	Human Adenovirus serotype 4, USAF Field Strain	3.51948E-22	111.505
lcl|AY599835	Human Adenovirus serotype 4, US Navy Field Strain	3.51948E-22	111.505
lcl|AY594254	Human Adenovirus serotype 4, vaccine strain	8.57976E-20	103.575
lcl|AY594253	Human Adenovirus Serotype 4	8.57976E-20	103.575

Table 34: Ad4HEXON-1:BL_818141_030503_NW_9b

Accession #	Name	E value:	Bit Score:
lcl|AY599837	Human Adenovirus serotype 4, USAF Field Strain	1.59752E-70	274.058
lcl|AY599835	Human Adenovirus serotype 4, US Navy Field Strain	9.49375E-66	258.199
lcl|AY594254	Human Adenovirus serotype 4, vaccine strain	5.64196E-61	242.34
lcl|AY594253	Human Adenovirus Serotype 4	5.64196E-61	242.34

Example 8 – RPMV2 chip and design thereof

A listing of the sequence tiles for the RPM V2 chip is listed below in (Table 35). This represented an approximate 10-fold increase in the content of the RPM V1 chip.

Table 35: RPMV2 Chip Table

Alias	Organism	Gene Name	Accession Number: Seq Num	Length	SEQ ID NO:
ATTIM1	Arabidopsis thaliana(1)	triosephosphate isomerase (TIM)		528	59
Ad3E1A	Adenovirus 3	E1A	AY599834:576-1455	879	60
Ad3HEXON	Adenovirus 3	Hexon	AY599834:18420-21254	595	61
Ad3FIBER	Adenovirus 3	Fiber	AY599834:31370-32329	746	62
Ad7E1A	Adenovirus 7	E1A	AY594255:577-1445	868	63
Ad7HEXON	Adenovirus 7	Hexon	AY594255:18419-21232	513	64
Ad7FIBER	Adenovirus 7	Fiber	AY594255:31320-32297	977	65
Ad7NAVYE1A	Adenovirus 7 FS Navy	E1A	AY601634:575-1454	879	66
Ad7NAVYHEXON	Adenovirus 7 FS Navy	Hexon	AY601634:18408-21210	504	67
Ad7NAVYFIBER	Adenovirus 7 FS Navy	Fiber	AY601634:31320-32295	975	68
Ad16E1A	Adenovirus 16	E1A	AY601636:574-1452	878	69
Ad16HEXON	Adenovirus 16	Hexon	AY601636:18450-21272	667	70
Ad16FIBER	Adenovirus 16	Fiber	AY601636:31448-32509	852	71
Ad21E1A	Adenovirus 21	E1A	AY601633:574-1452	878	72
Ad21HEXON	Adenovirus 21	Hexon	AY601633:18454-21303	807	73
Ad21FIBER	Adenovirus 21	Fiber	AY601633:31406-32377	685	74
Ad11E1A	Adenovirus 11	E1A	AY163756:568-1440	872	75
Ad11HEXON	Adenovirus 11	Hexon	AY163756:18254-21100	677	76
Ad11FIBER	Adenovirus 11	Fiber	AY163756:30911-31788	977	77
Ad35E1A	Adenovirus 35	E1A	AY271307:569-1441	872	78
Ad35HEXON	Adenovirus 35	Hexon	AY271307:18257-21115	859	79
Ad35FIBER	Adenovirus 35	Fiber	AY271307:30827-31798	971	80
Ad1E1A	Adenovirus 1	E1A	33330439:560-1546	986	81
Ad1HEXON	Adenovirus 1	Hexon	33330439:18861-21755	715	82
Ad1FIBER	Adenovirus 1	Fiber	33330439:31101-32649	760	83
Ad2E1A	Adenovirus 2	E1A	33694600:559-1542	983	84
Ad2HEXON	Adenovirus 2	Hexon	33694600:18838-21744	837	85
Ad2FIBER	Adenovirus 2	Fiber	33694600:31030-32778	750	86
Ad5E1A	Adenovirus 5	E1A	33465630:560-1545	986	87
Ad5HEXON	Adenovirus 5	Hexon	33465630:18642-21700	732	88
Ad5FIBER	Adenovirus 5	Fiber	33465630:31037-32782	747	89
Ad6E1A	Adenovirus 6	E1A	CB|	985	90

Ad6HEXON	Adenovirus 6	Hexon	X67710	833	91
Ad6FIBER	Adenovirus 6	Fiber	AB108424	750	92
Ad4E1A	Adenovirus 4	E1A	AY594253:576-1441	865	93
Ad4HEXON	Adenovirus 4	Hexon	AY594253:18248-21059	2810	94
Ad4FIBER	Adenovirus 4	Fiber	AY594253:31645-32922	1277	95
Ad4AFE1A	Adenovirus 4 FS AF	E1A	AY599837:575-1407	832	96
Ad4AFHEXON	Adenovirus 4 FS AF	Hexon	AY599837:18179-20989	2810	97
Ad4AFFIBER	Adenovirus 4 FS AF	Fiber	AY599837:31453-32740	1277	98
Ad12E1A	Adenovirus 12	E1A	9626621:503-1099	597	99
Ad12HEXON	Adenovirus 12	Hexon	9626621:17740-20499	884	100
Ad12FIBER	Adenovirus 12	Fiber	9626621:29368-31131	908	101
Ad17E1A	Adenovirus 17	E1A	9632407:560-1138	579	102
Ad17HEXON	Adenovirus 17	Hexon	9632407:17754-20617	692	103
Ad17FIBER	Adenovirus 17	Fiber	9632407:30935-32035	829	104
Ad40E1A	Adenovirus 40	E1A	9626553:418-1326	824	105
Ad40HEXON	Adenovirus 40	Hexon	9626553:17643-20414	878	106
Ad40FIBER	Adenovirus 40	Fiber	9626553:28751-29914	707	107
FluAHA1	Influenza A H1N1 (New Caledonia Like)	Hemagglutinin 1	AJ344014	1692	108
FluAHA2	Influenza A H2N2 (berkley)	Hemagglutinin 2	L11125	805	109
FluAHA3	Influenza A H3N2 (Fujian)	Hemagglutinin 3	ISDN38157	1042	110
FluAHA4	Influenza A H4N6 (Swine: Ontario)	Hemagglutinin 4	AF285665	1371	111
FluAHA5	Influenza A H5N1 (Vietnam)	Hemagglutinin 5	AY526745	303	112
FluAHA6	Influenza A H6N2 (Turkey; Germany)	Hemagglutinin 6	AJ507203	867	113
FluAHA7	Influenza A H7N7 (Netherlands)	Hemagglutinin 7	AY338459	816	114
FluAHA8	Influenza A H8N4 (Duck; Alberta)	Hemagglutinin 8	AF310986	897	115
FluAHA9	Influenza A H9N2 (Swine: China)	Hemagglutinin 9	AY294658	801	116
FluAHA10	Influenza A H10 (Shorebird)	Hemagglutinin 10	AF311750	775	117
FluAHA11	Influenza A H11 (Duck; Taiwan)	Hemagglutinin 11	AF310986	728	118
FluAHA12	Influenza A H12N4 (Ruddy Turnstone; Delaware)	Hemagglutinin 12	AF310990	736	119
FluAHA13	Influenza A H13N6 (Gull; Astrakan)	Hemagglutinin 13	M26089	1765	120
FluAHA14	Influenza A H14 (mallard; Gurjev)	Hemagglutinin 14	M35997	763	121
FluAHA15	Influenza A H15N8 (Duck; Australia)	Hemagglutinin 15	L43916	793	122
FluANA1-1	Influenza A H1N1 (New Caledonia Like)	Neuraminidase 1	AJ518092	1459	123
FluANA1-2	Influenza A H5N1 (Vietnam)	Neuraminidase 1	AY526746	575	124

FluANA2	Influenza A H3N2 (Ireland)	Neuraminidase 2	AJ457947	1062	125
FluANA3	Influenza A H5N3 (chicken: TX)	Neuraminidase 3	AY300947	852	126
FluANA4	Influenza A H8N4 (Duck Alberta)	Neuraminidase 4	K01030	257	127
FluANA5	Influenza A H6N5 (Shearwater)	Neuraminidase 5	M24740	913	128
FluANA6	Influenza A H4N6 (Swine: Ontario)	Neuraminidase 6	AF285887	739	129
FluANA7	Influenza A H7N7 (Netherlands)	Neuraminidase 7	AY340079	894	130
FluANA8	Influenza A H5N8 (Duck: NY)	Neuraminidase 8	AY300948	843	131
FluANA9	Influenza A H2N9 (Duck: Nanchang)	Neuraminidase 9	AY180830	444	132
FluAH1N1MATRIX	Influenza A H1N1 (New Caledonia Like)	Matrix	AJ458301	734	133
FluAH5N1MATRIX	Influenza A H5N1 (Vietnam)	Matrix	AY526748	657	134
FluBHA	Influenza B	Hemagglutinin B	AB126838	785	135
FluBNA	Influenza B	Neuraminidase B	AY139074	809	136
FluBMATRIX	Influenza B	Matrix	AB036877	763	137
FluCHA	Influenza C	Hemagglutinin-esterase	AB093473	401	138
FluCMATRIX	Influenza C	Matrix	AB088809	662	139
PIV1HN	Parainfluenza 1	Hemagglutinin-neuraminidase	19718363:6903-8630	1728	140
PIV1MATRIX	Parainfluenza 1	Matrix	19718363:3837-4609	958	141
PIV1NC	Parainfluenza 1	Nucleocapsid	19718363:56-1797	1682	142
PIV2HN	Parainfluenza 2	Hemagglutinin-neuraminidasegi	19525721:6817-8532	1716	143
PIV2MATRIX	Parainfluenza 2	Matrix	19525721:3411-4742	741	144
PIV2NC	Parainfluenza 2	Nucleocapsid	19525721:71-1919	1849	145
PIV3HN	Parainfluenza 3	Hemagglutinin-neuraminidase	10937870:6806-8530	1725	146
PIV3MATRIX	Parainfluenza 3	Matrix	10937870:3753-4814	544	147
PIV3NC	Parainfluenza 3	Nucleocapsid	10937870:111-1658	1546	148
PIV4HN	Parainfluenza 4	Hemagglutinin-neuraminidase	E02727	666	149
PIV4MATRIX	Parainfluenza 4	Matrix	E03809	855	150
HRV14NCR	Rhinovirus 14	5' NCR	AF108166	520	151
HRV1ANCR	Rhinovirus 1A	5' NCR	AF108179	511	152
HRV21NCR	Rhinovirus 21	5' NCR	AF108160	499	153
HRV29NCR	Rhinovirus 29	5' NCR	AF542420	676	154
HRV58NCR	Rhinovirus 58	5' NCR	AF108183	504	155
HRV62NCR	Rhinovirus 62	5' NCR	AF108184	501	156
HRV87NCR	Rhinovirus 87	5' NCR	AF108187	606	157
HRV95NCR	Rhinovirus 95-01468	5' NCR	AF108164	508	158
RSVABL	RSV A&B	polymerase L	AF254574	379	159

RSVAMATRIX	RSV A	Matrix	3069371:3253-4210	958	160
RSVANC	RSV A	Nucleocapsid	3069371:1126-2398	955	161
RSVBMATRIX	RSV B	Matrix	2582022:3263-4033	770	162
RSVBNC	RSV B	Nucleocapsid	2582022:1140-2315	602	163
HCV229ESPIKE	Coronavirus 229E	Spike	12175745:20570-24091	1534	164
HCV229EMEM	Coronavirus 229E	Membrane protein	12175745:24095-25672	676	165
HCV229ENC	Coronavirus 229E	Nucleocapsid	12175745:25686-26855	824	166
HCVOC43SPIKE	Coronavirus OC43	Spike	30018022:23644-27729	1456	167
HCVOC43MEM	Coronavirus OC43	Membrane protein	30018022:28402-29094	693	168
HCVOC43NC	Coronavirus OC43	Nucleocapsid	30018022:29104-30450	968	169
SARSSPIKE	Coronavirus SARS(Urbani)	Spike	30027617:21492-25259	1438	170
SARSMEM	Coronavirus SARS(Urbani)	Membrane Glycoprotein	30027617:26398-27063	666	171
SARSNC	Coronavirus SARS(Urbani)	Nucleocapsid	30027617:28120-29366	932	172
HCVNL63SPIKE	Coronavirus NL63	Spike	AY567487:20472-24542	1534	173
HCVNL63ORF3	Coronavirus NL63	ORF3	AY567487:24542-25219	678	174
HCVNL63MEM	Coronavirus NL63	Membrane protein	AY567487:25442-26122	681	175
HCVNL63NC	Coronavirus NL63	Nucleocapsid	AY567487:26133-27266	879	176
MPVMATRIX	Metapneumovirus	Matrix	AY145271	765	177
MPVNC	Metapneumovirus	Nucleocapsid	AY145272	1185	178
HHV1L	Human herpesvirus 1 (Simplex)	DNA polymerase	9629376:62807-66514	1061	179
HHV1CAPSID	Human herpesvirus 1 (Simplex)	major capsid protein	9629376:c40528-36404	993	180
HHV3L	Human herpesvirus 3 (VZV)	DNA polymerase	9625875:c50636-47052	1061	181
HHV3CAPSID	Human herpesvirus 3 (VZV)	major capsid protein	9625875:71540-75730	993	182
HHV4L	Human herpesvirus 4 (EBV)	DNA polymerase	9625578:c156746-153699	1067	183
HHV4CAPSID	Human herpesvirus 4 (EBV)	major capsid protein	9625578:c137466-133321	992	184
HHV5L	Human herpesvirus 5 (CMV)	DNA polymerase	9628290:c59566-56550	1138	185
HHV5CAPSID	Human herpesvirus 5 (CMV)	major capsid protein	9628290:c129228-125114	998	186
HHV6L	Human herpesvirus 6 (Roleola)	DNA polymerase	9628290:c59566-56550	1058	187
HHV6CAPSID	Human herpesvirus 6 (Roleola)	major capsid protein	9628290:c93912-89875	1001	188
ENTEROVIRUS	Enterovirus (genus)	Enterovirus	NC_001612	1758	189
COXSACKIEVIRUS	Human coxsackievirus	unknown	AF499635	920	190
ECHO	Echo (subgroup)	Echovirus	NC_003988	1277	191
POLIO	Polio (subgroup)	Poliovirus	NC_002058	1226	192
POLIO1NCR	Polio type 1 Sabin	5'NCR	AY184219:162-597	436	193
POLIO2NCR	Polio type 2 Sabin	5'NCR	AY184220:162-598	437	194

POLIO3NCR	Polio type 3 Sabin	5'NCR	AY184221:164-600	437	195
MEASLESHA	Paramyxoviridae morbillivirus (Rubeola)	Hemagglutinin	AY523561	1854	196
MEASLESMATRIX	Paramyxoviridae morbillivirus (Rubeola)	Matrix	9626945:3438-4445	1008	197
NEWCASTLEHN	Newcastle	Hemagglutinin-Neuraminidase	AY510092	1734	198
NEWCASTLEMATRIX	Newcastle disease	Matrix	11545722:3256-4487	1232	199
WNE	West Nile Virus	Envelope	AF346319	1504	200
WNNS	West Nile Virus	Nonstructural protein 5	AF206017	917	201
WNCM	West Nile virus	C and prM		432	202
YFE	Yellow Fever	Envelope	AY359908	1547	203
YFNS	Yellow Fever	Nonstructural protein 5	AF013417	1035	204
VMVG3R	Variola major virus	G3R	623595:163809-164570	762	205
VMVHA	Variola major virus	hemagglutinin	623595:151032-151973	942	206
VMVSOD	Variola major virus	SOD	623595:144137-144514	378	207
VMVCRMB	Variola major virus	CrmB		291	208
MONKEYPOX	Monkeypox virus	Inclusion body protein	U84603	612	209
EBOLAL	Reston Ebola	L	22769222:11464-18868	600	210
EBOLANP	Reston Ebola	NP	22769222:56-3013	806	211
EBOLAMATRIX	Reston Ebola	Matrix	22769222:4396-5893	1498	212
MARBURGL	Marburg virus	L protein	13489275:11479-18474	1216	213
MARBURGNP	Marburg virus	NP	13489275:103-2190	647	214
LASSAL	Lassa virus	L	23343512:c7122-466	1021	215
LASSANP	Lassa virus	Nucleoprotein	23343509:101-1610	751	216
LASSAGP	Lassa virus	Glycoprotein	23343509:c3347-1872	1476	217
MACHUPOL	Machupo virus	L polymerase	34365535:c7094-465	1568	218
MACHUPONP	Machupo virus	Nucleoprotein	34365532:c3364-1570	763	219
MACHUPOG	Machupo virus	Glycoprotein	34365532:89-1579	1491	220
VEEVNS	Venezuelan equine encephalitis virus	NS	9626526:1-7526	923	221
VEEVNC	Venezuelan equine encephalitis virus	Structrual protein	9626526:7532-11444	1512	222
EEEVNS	Eastern equine encephalitis virus	NS	21216484:47-5683	1312	223
EEEVNC	Eastern equine encephalitis virus	Nucleocapsid	21216484:7592-11317	975	224
WEEVNS	Western equine encephalitis virus	NS	21238454:25-7428	678	225
WEEVNC	Western equine encephalitis virus	Structrual protein	21238454:7473-11183	802	226
NIPAHMATRIX	Nipah virus	Matrix	13559806:5006-6366	1359	227
NIPAHN	Nipah virus	N	13559806:56-2297	856	228
SINNOMBREGP	Sin Nombre	Glycoprotein	556060:52-3474	1293	229

SINNOMBRENC	Sin Nombre	Nucleocapsid	38371725:43-1329	639	230
NORWALKL	Norwalk virus	RNA-dependent RNA polymerase	9630803:3646-5371	739	231
NORWALKCAPSID	Norwalk virus	capsid protein	9630803:5358-6950	760	232
DENGUECAPSID	Dengue virus	capsid protein	9626681:97-396	300	233
DENGUEM	Dengue virus	pre-M protein	9626681:439-936	498	234
DENGUE1NCR	Dengue type 1	3'NCR	AF309641:10501-10657	157	235
DENGUE2NCR	Dengue type 2	3'NCR	AF359579:10501-10659	159	236
DENGUE3NCR	Dengue type 3	3'NCR	AF317645:10477-10632	156	237
DENGUE5NCR	Dengue type 4	3'NCR	AF326573:10424-10585	162	238
FMDVVP1	Foot and mouth disease virus	VP1	21426907:3231-3863	633	239
FMDV3D	Foot and mouth disease virus	3D	21426907:6615-8024	846	240
SLEVNS5	Saint Louis encephalitis virus	NS5	AF013416	1035	241
SLEVPP	Saint Louis encephalitis virus	polyprotein precursor	AY289616	727	242
RVFVN	Rift Valley fever virus	N	61828:c1652-915	738	243
RVFVNS	Rift Valley fever virus	NS	61828:35-832	798	244
USUTUPP	Usutu virus	polyprotein	AF452643	1035	245
JEVPP	Japanese encephalitis virus	polyprotein	M18370:9052-10097	1035	246
CHANDIPURAMATRIX	Chandipura virus	Matrix	4583436:97-851	755	247
CHANDIPURAGP	Chandipura virus	glycoprotein	J04350	752	248
ATTIM2	Arabidopsis thaliana(2)	triosephosphate isomerase (TIM)		523	249
ATTIM3	Arabidopsis thaliana(3)	triosephosphate isomerase (TIM)		523	250
SPYEMM1	Streptococcus pyogenes	emm1	CDC	398	251
SPYEMM2	Streptococcus pyogenes	emm2	CDC	360	252
SPYEMM3	Streptococcus pyogenes	emm3	CDC	391	253
SPYEMM4	Streptococcus pyogenes	emm4	CDC	337	254
SPYEMM5	Streptococcus pyogenes	emm5	CDC	490	255
SPYEMM6	Streptococcus pyogenes	emm6	CDC	437	256
SPYEMM9	Streptococcus pyogenes	emm9	CDC	509	257
SPYEMM11	Streptococcus pyogenes	emm11	CDC	500	258
SPYEMM12	Streptococcus pyogenes	emm12	CDC	364	259
SPYEMM13L	Streptococcus pyogenes	emm13L	CDC	325	260
SPYEMM18	Streptococcus pyogenes	emm18	CDC	524	261
SPYEMM22	Streptococcus pyogenes	emm22	CDC	620	262
SPYEMM28	Streptococcus pyogenes	emm28	CDC	333	263
SPYEMM29	Streptococcus pyogenes	emm29	CDC	328	264

SPYEMM44	Streptococcus pyogenes	emm44	CDC	391	265
SPYEMM81	Streptococcus pyogenes	emm81	CDC	325	266
SPYEMM75	Streptococcus pyogenes	emm75	CDC	451	267
SPYEMM77	Streptococcus pyogenes	emm77	CDC	450	268
SPYEMM89	Streptococcus pyogenes	emm89	CDC	378	269
SPYEMM94	Streptococcus pyogenes	emm94	CDC	516	270
SPYCSR	Streptococcus pyogenes	Csr R & Csr S	AF095713	952	271
SPYSFB1	Streptococcus pyogenes	sfb1	AJ347842	615	272
SPYSPEB	Streptococcus pyogenes	SpeB	AB051298	729	273
SPNGYRA	Streptococcus pneumoniae	GyrA	AY157689	815	274
SPNLYTA	Streptococcus pneumoniae	Autolysin lytA		125	275
SPNPLY	Streptococcus pneumoniae	pneumolysin ply		99	276
SAUGYRA	Staphylococcus aureus	GyrA	D10489	821	277
SAUTST	Staphylococcus aureus	tst	18266750:2118-2822	705	278
SAUENTK	Staphylococcus aureus	EntK	18266750:13059-13787	729	279
SAUENTQ	Staphylococcus aureus	EntQ	18266750:12265-13035	771	280
CPNGYRA	Chlamydia pneumoniae	GyrA	28415636:2451-4955	824	281
CPNOMPB	Chlamydia pneumoniae	OmpB	X53511	1030	282
CPNMOMPVD4	Chlamydia pneumoniae	MOMP VD4	M69230	150	283
CPNMOMPVD2	Chlamydia pneumoniae	major outer membrane protein (MOMP)VD2		133	284
CPNRPOB	Chlamydia pneumoniae	PstI fragment (rpoB)	NT01CP0714	346	285
CPSOMPA	Chlamydia psittaci	OmpA	AF269281	991	286
CPSSIGA	Chlamydia psittaci	SigA	U04442	883	287
CDIDTX	Corynebacterium diphtheriae	Dtx gene	A04646	813	288
CDIGYRA	Corynebacterium diphtheriae	GyrA	38198900:8792-11362	816	289
CDIDTXR	Corynebacterium diphtheriae	dtxR gene	M60936	1124	290
HINGYRA	Haemophilus influenzae	GyrA	1574717:c7221-4579	896	291
HINOMPA	Haemophilus influenzae	OmpP5 (OmpA-family)	L20309	937	292
LPNGYRA	Legionella pneumophilla	GyrA	AY091594	236	293
LPNMOMPS	Legionella pneumophilla	MompS	AF078136	1157	294
MCAGYRA	Moraxella catarrhalis	GyrA	AF056196	321	295
MCAHA	Moraxella catarrhalis	hemagglutinin	AY077637	653	296
MTUGYRA	Mycobacterium tuberculosis	GyrA	13879041:7302-9818	818	297
MTUOMPA	Mycobacterium tuberculosis	OmpA	38490207:318539-319519	932	298

MTURPOB	Mycobacterium tuberculosis	RpoB	468333:1065-4598	411	299
MPNGYRA	Mycoplasma pneumoniae	GyrA	11379479:4821-7340	809	300
MPNP1	Mycoplasma pneumoniae	P1 gene	AF290002	2570	301
NMEGYRA	Neisseria meningitidis	GyrA	7413486:89-2639	941	302
NMEMVIN	Neisseria meningitidis	MviN	7225498:c5929-4368	904	303
NMECTRA	Neisseria meningitidis	capsular transport protein (ctrA)		135	304
NMECRGA	Neisseria meningitidis	CrgA	AF190471	254	305
AHE16S	Arcanobacterium hemolyticum	16S rRNA	X73952	1469	306
AHEPLD	Arcanobacterium hemolyticum	pld	L16583	1111	307
BANGYRA	Bacillus anthracis	GyrA	AY291534	732	308
BANLEF	Bacillus anthracis	lethal factor	M29081	685	309
BANPAG	Bacillus anthracis	protective antigen	AF306783	599	310
BANRPOB	Bacillus anthracis	rpoB	AF205335	777	311
BANCYA	Bacillus anthracis	Cya	142812:544-2946	545	312
BANCAPB	Bacillus anthracis	encapsulation protein gene B(capB)		246	313
BCERPOB	Bacillus cereus	rpoB	AF205342	777	314
BSUGYRA	Bacillus subtilius	GyrA	40012:7769-10234	812	315
BSURPOB	Bacillus subtilius	rpoB	AF205356	780	316
BTHCRY	Bacillus thuringensis	cry	AF276797	659	317
BTHRPOB	Bacillus thuringensis	rpoB	AF205349	777	318
BPEGYRA	Bordetella pertussis	GyrA	33571514:266253-268934	815	319
BPEPRNA	Bordetella pertussis	PrnA	AJ507642	777	320
BMEGYRA	Brucella melitensis (F6145)	GyrA	AE009529:4650-7356	895	321
BABRB51	Brucella abortus (RB51)	WbqA with insert Consensus Sequence	AF107768	1339	322
BABOMP25	Brucella abortus (2308 B37)	Omp25	X79284	530	323
BABOMP2	Brucella abortus (2308 B37)	Omp2	U26438	1434	324
BCAOMP2	Brucella canis	Omp2	U26439	1434	325
BMEOMP2	Brucella melitensis (F6145)	Omp2	U26440	1434	326
BNEOMP2	Brucella neotoma	Omp2	U26441	1434	327
BOVOMP2	Brucella ovis	Omp2	U26442	1449	328
BSUIOMP2	Brucella suis (A44)	Omp2	U26443	1434	329
BMAPENA	Burkholderia mallei (Glanders)	PenA	AY032868	1117	330
BMAWAAF	Burkholderia mallei (Glanders)	WaaF	AY124769	1015	331
BPSPENA	Burkholderia pseudomallei (Melidosis)	PenA	AY032869	1117	332
BPSWAAF	Burkholderia pseudomallei (Melidosis)	WaaF	AF097748	1100	333

BCEPRECA	Burkholderia cepacia	RecA	U70431	811	334
CPEGYRA	Clostridium perfringens	GyrA	18143657:7100-9391	810	335
CPETMPC	Clostridium perfringens	TmpC	18146729:c45993-44881	1113	336
CBUGYRA	Coxiella burnetii	GyrA	29540947:165494-168040	812	337
CBUTOLC	Coxiella burnetii	TolC	29540626:51830-53680	745	338
FTURD1A	Francisella tularensis subsp. tularensis strain	RD1-A	32469331:c985-455	531	339
FTURD1B	Francisella tularensis subsp. tularensis strain	RD1-B	32469331:c1338-1054	265	340
FTUTUL4	Francisella tularensis	TUL4	M32059	834	341
FTUMDH	Francisella tularensis	mdh	AF513319	960	342
FTU13KD	Francisella tularensis	13-kDa protein	M32059	431	343
FTUFOPA	Francisella tularensis	outer membrane protein FopA		111	344
OTSGROEL	Orientia tsutsugamushi	GroEL	AY191589	546	345
OTSSTA56	Orientia tsutsugamushi	sta56	AY283160	1059	346
RPRGYRA	Rickettsia prowazekii	GyrA	3860572:260672-259369	968	347
RPROMP1	Rickettsia prowazekii	Omp1	3860572:c191770-189464	986	348
YPEGYRA	Yersinia pestis	GyrA	21959674:c10908-8233	812	349
YPEOMPA	Yersinia pestis	OmpA	16120353:c1628253-1627192	813	350
YPECVE	Yersinia pestis	cve2155 sequence	AF350077	517	351
YPECAF1	Yersinia pestis	caf1	X61996	525	352
ACAHAG	Ajellomyces capsulatus	H antigen	U20346	1082	353
ACAMAG	Ajellomyces capsulatus	M antigen	AF026266	919	354
ACAGH17	Ajellomyces capsulatus	GH17	U27588	810	355
BDEWI-1	Blastomyces dermatitidis	WI-1	S63772	942	356
BDEBYS1	Blastomyces dermatitidis	bys1	AF277079	912	357
CIMAG2	Coccidioides immitis	Ag2	U32518	1234	358
CIMBG12	Coccidioides immitis	bg12	AF022693	965	359
CPACP2	Cryptosporidium parvum	CP2	AY471868	735	360
CPASOD	Cryptosporidium parvum	Sod	AF528280	975	361
ECOGYRA	E. coli 0157:H7	GyrA	15445223:c3136459-3133832	812	362
ECOOMPA	E. coli 0157:H7	OmpA	12518283:3562-4221	660	363
SENGYRA	Salmonella enterica	GyrA	29136667:70224-72860	812	364
SENOMPA	Salmonella enterica	OmpA	16502231:c18055-17003	904	365
SDYOMPA	Shigella dysenteriae	OmpA	46949:668-1623	907	366
SFLGYRA	Shigella flexneri	GyrA	30041916:c2708-81	812	367
SFLOMPA	Shigella flexneri	OmpA	24051234:c1458-3340	898	368

VCHGYRA	Vibrio cholerae	GyrA	15640032:1330207-1332891	687	369
VCHOMPA	Vibrio cholerae	OmpA	6031221:1022-1987	942	370
MSRA	Staphylococcus aureus	MSR(A)	AF467080	400	371
MECR1	Staphylococcus aureus	mecR1	AF142100	652	372
MEFA	Streptococcus pyogenes	MefA	U70055	611	373
ERMTR	Streptococcus pyogenes	Erm(TR)	2190969:211-942	732	374
ERMB	Streptococcus pyogenes	ErmB	38707161:8545-9307	763	375
EMRB	Rickettsia prowazekii	EmrB	3860572:c167837-166278	1560	376
GYRB	Streptococcus pneumoniae	GyrB	X83917	1947	377
PARC	Streptococcus pneumoniae	ParC	AF503577	2637	378
PARE	Streptococcus pneumoniae	parE	6851036:1255-3198	2008	379
PBP1	Streptococcus pneumoniae	ponA (Pbp1A)	AF445215	1282	380
PBP5	Enterococcus faecium	pbp5	AF375986	668	381
MECA	Staphylococcus aureus pUB110	mecA	9181834:<1-729	729	382
BLAZ	Staphylococcus aureus plasmid pLW043	blaz	33390917:c41681-41136	646	383
DFRA	Staphylococcus aureus plasmid pLW043	dfrA	33390917:c2802-2317	486	384
VANA	Staphylococcus aureus plasmid pLW043	vanA	33390917:34299-35330	1032	385
QACC	Staphylococcus aureus plasmid pLW043	qacC	33390917:c21313-20990	324	386
RMTB	Escherichia coli	rmtB	AB117036	756	387
STRA	Escherichia coli pMBSF1 plasmid	strA	25815144:723-1526	804	388
STRB	Escherichia coli pMBSF1 plasmid	strB	25815144:1526-2362	837	389
AADA1	Escherichia coli plasmid p541	aadA1	40287459:10966-11777	792	390
SULII	Escherichia coli plasmid pSTOJO1	sulII	17129524:449-1264	816	391
CTXM	Escherichia coli strain EU2657	ctx-M	AY517475	436	392
KPC2	Klebsiella pneumoniae	carbapenemase (KPC-2)	AY034847	918	393
AMPC	Klebsiella pneumoniae plasmid	AmpC	40546851:1310-2449	1140	394
BLACMY2	Klebsiella pneumoniae plasmid	bla CMY-2	1212997:1924-3069	1146	395
AMPR	Klebsiella pneumoniae plasmid pKP3	AmpR	40546851:c1199-324	876	396
SULI	Plasmid R388	sulI	45795:860-1719	840	397
AACAAPHD	Staphylococcus aureus plasmid pLW043	aacA-aphD	33390917:23440-24879	1440	398
FLOR	Vibrio cholerae	floR	32469306:11605-12819	1215	399
TETM	Enterococcus faecalis	tet(M)	M85225	536	400
TETC	Escherichia coli partial plasmid	(tetC)	Y19114	602	401
TETS	Listeria monocytogenes	tet(S)	L09756	555	402
TETA	Pseudomonas aeruginosa plasmid RP4	tet(A)	X75761	494	403

TETG	Pseudomonas sp. plasmid pPSTG2	tet(G)	AF133140	550	404
TETL	Staphylococcus hyicus (plasmid pSTE1)	tet(L)	X60628	548	405
TETB	Transposon Tn10	tet(B)	V00611	571	406
PTX	Bordetella pertussis	Pertussis toxin	M13223	672	407
BONT	Clostridium botulinum	bonT	3805779:7268-11143	792	408
NTNH	Clostridium botulinum	ntnh	3805779:3649-7242	496	409
BOTE	Clostridium botulinum	botE	X62683	1000	410
EPSILON	Clostridium perfringens plasmid	epsilon-toxin	X60684	820	411
TETANUS	Clostridium tetani	tetanus toxin	40789:281-4228	1165	412
STX1A	E. coli 0157:H7	stx1A	32400301:1-948	948	413
STX2A	E. coli 0157:H7	stx2A	13359151:1-960	960	414
RICINUSTOXIN	Ricinus communis	Ricinus communis toxin	X52908	1133	415
CTXAB	Vibrio cholerae	ctxA+ctxB	Gary	984	416
PBLUEVEC	pBluescript II KS(+)			236	417
PGEMVEC	pGEM-9Zf(-)		X65312	226	418
PUCVEC	pUC4KAN		X06404	252	419
ATTIM4	Arabidopsis thaliana(4)	triosephosphate isomerase (TIM)		523	420
				309034	

Example 9 – Influenza A strain identification with random RT-PCR approach

This example is to present application of newly modified random RT-PCR protocol on isolated Influenza A (Fujan/411/2002 strain) nucleic acids spiked into normal nasal wash samples. A random RT-PCR protocol has been applied by DeRisi's lab to amplify viral pathogens for microarray interrogation (Wang et al., 2003). Modification to this protocol was recently reported for amplifying cultured influenza viruses (Kessler et al., 2004). However, the modified protocol was not reported to amplify viral targets in clinical samples.

The Influenza A virus cultures (H1N1 & H3N2) were provided by the Air Force Institute for Operational Health (AFIOH) and sent to Virapure, LLC for amplification and quantification prior to the study. According to the *Certificate of Analysis*, the virus was amplified for two rounds on early passage MDCK cells purchased from ATCC exclusively for this project, followed by virus amplification in the presence of 1 µg/ml TPCK treated trypsin. At 48 hours after infection, the virus supernatants were collected and adjusted to contain 3% sucrose, 20mM Tris pH 7.1 and pH stabilizer. Prior to delivery, Corning screw top cryovials were filled with 200-300µl aliquots of supernatant. The titration of each sample vial was performed according to procedure *AMI10, Plaque Forming Assay of Influenza Virus*. A titer of 1.2 X 10^7 PFU/ml was obtained for Influenza A H3N2, K0717 SV5/SV40 RMK and 5 X 10^6 PFU/ml for Influenza A/California/2935/03/H1N1.

To generate a clinical collection control, a nasal wash (0.9% Normal Saline) was obtained from an asymptomatic member of the Clinical Division of the Advanced Diagnostic Laboratory at Lackland AFB. From each Virapure pre-quantified titer, a 10-fold/6-series dilution of Influenza-spiked nasal aspirate was generated beginning with and including the Virapure stock of each strain. A total of 100µl of each influenza-spiked nasal wash were processed from the dilution using the MasterPure Total Nucleic Acid Extraction distributed by EPICENTRE. During the protocol, 150 µl of *2X T and C Lysis Solution* containing Proteinase K was added to each 100µl dilution of the spiked nasal wash, vortex thoroughly and incubated at 65°C for 15 minutes. Next, the samples were placed on ice for 5 minutes followed by the addition of 150 µl of *MPC Protein Precipitation Reagent*. The samples were vortex mixed vigorously for 10 seconds. The mixture was then precipitated by centrifugation at 10,000 x g for 10 minutes and the supernatant transferred to a microcentrifuge tube. To the recovered supernatant, 500 µl of isopropanol wer added and the tube inverted (30-40) times.

The mixture was centrifuged at 4°C for 10 minutes and the isopropanol decanted without dislodging pellet. Following, the pellet was rinsed twice with 75% ethanol and dried at room temperature. Once dried, the nucleic acid pellet was resuspended in 35 µl of TE Buffer. Each sample was properly labeled and placed in dry ice prior to shipment to the Naval Research Laboratory.

Each of three 100 µl normal nasal wash aliquots was spiked with a serial of dilution (ranging from 10^5 pfu to 10^1) of influenza A H3N2 viral cultures. Total nucleic acids were extracted with EPICENTRE MasterPure™ DNA Purification Kits (Madison, Wisconsin), as in Example 5, and suspended in 40 µl H_2O. Random RT-PCR was applied as follows, according to that described (Kessler et al., 2004):

2 µl of total nucleic acid was reverse transcribed by using 1 µl primer D (40 pmol/µl; 5' –GTT TCC CAG TCA CGA TCN NNN NNN NN; SEQ ID NO: 573) and 1 µl SuperScript™III Reverse Transcriptase (50 units/µl; Invitrogen, Carlsbad, CA) in 20 µl. The RT (reverse transcription) reaction was performed at 42° C for 1 hr and then was inactivated at 70° C for 15 min. Then 10 µl RT products were amplified with 1 µl primer B (100

pmol/μl; 5' –GTT TCC CAG TCA CGA TC; SEQ ID NO: 574) and 2.5 units TaqPlus Long polymerase (5 units/μl, Stratagene, La Jolla, CA) in 50 μL. PCR was conducted with 35 cycles of 94° C for 30 s, 40° C for 30 s, 50° C for 30 s, and 72° C for 160 s, followed by an additional 7 minutes at 72° C. PCR products from 10^5, 10^3 and 10^1 pfu flu spiking samples were applied to three different V1RPM pathogen microarrays for hybridization according to Affymetrix Customseq protocol.

The V1RPM chip scans for the three spike-in samples, 10^5, 10^3, and 10^1 pfu, amplified by this random RT-PCR method, are shown in FIG. 8 A-C, respectively. All samples resulted in clear sequence calls in at least some of the Influenza A tile regions, indicating that the random RT-PCR protocol successfully amplified flu genomes in the spiking samples even without interference of human genomic DNA. Based on the GDAS outputs (using "permissive" settings), REPI identified the following 4 top "hits" from each sample (Tables 36-38). The top four hits for 10^5 (Table 36) and 10^3 pfu (Table 37) samples corresponded to the top ranking being assigned to the correct Fujian/411/2002 strain and were exactly same as those obtained for the Fujian/411/2002 (+) clinical sample NW20031114-05-02 ACID04 -B2, amplified by influenza universal primers (shown in Table 25). This result indicates that random RT-PCR has similar amplification power to the Influenza A-specific PCR with relatively high titer of viruses in the sample. With low titer of flu viruses (10^1 pfu), the percentage of tile region that hybridized and the percentage of base calls decreased. This resulted in a slight skewing of the rankings, making Fujian 411/2002 tied for the second highest-ranking strain. However, the V1RPM was still able to read the spiked virus as H3N2 Pretoria strain, which originally derived from and is almost identical to Fujian/411/2002 strain.

Because of success of random RT-PCR in this experiment, it is believed that this protocol will work in flu clinical samples and other pathogenic viruses.

Table 36: FluAHA3:Influenza A H3N2 spiked samples (10^5 pfu)

Accession #	Name	E value:	Bit Score:
lcl|ISDN38157	InfluenzaA/Fujian/411/2002_ Hemagglutinin_104	0.0	1400.04
gi|37530025|gb|AY389356.1	Influenza A virus (A/Middleburg/41/03(H3N2)) hemagglutinin (HA) gene	0.0	1400.04
gi|37530033|gb|AY389360.1	Influenza A virus (A/Pretoria/17/03(H3N2)) hemagglutinin (HA) gene	0.0	1392.11
gi|37530031|gb|AY389359.1	Influenza A virus (A/Pretoria/16/03(H3N2)) hemagglutinin (HA) gene	0.0	1392.11

Table 37: FluAHA-Influenza A H3N2 spiked samples (10^3 pfu)

Accession #	Name	E value:	Bit Score:
lcl|ISDN38157	InfluenzaA/Fujian/411/2002_ Hemagglutinin_104	0.0	1471.4
gi|37530025|gb|AY389356.1	Influenza A virus (A/Middleburg/41/03(H3N2)) hemagglutinin (HA) gene	0.0	1471.4
gi|37530033|gb|AY389360.1	Influenza A virus (A/Pretoria/17/03(H3N2)) hemagglutinin (HA) gene	0.0	1463.47
gi|37530031|gb|AY389359.1	Influenza A virus (A/Pretoria/16/03(H3N2)) hemagglutinin (HA) gene	0.0	1463.47

Table 38: FluAHA3:Influenza A H3N2 spiked samples (10^1 pfu)

Accession #	Name	E value:	Bit Score:
gi|37530033|gb|AY389360.1	Influenza A virus (A/Pretoria/17/03(H3N2)) hemagglutinin (HA) gene	0.0	686.389
gi|37530031|gb|AY389359.1	Influenza A virus (A/Pretoria/16/03(H3N2)) hemagglutinin (HA) gene	0.0	686.389
gi|37530029|gb|AY389358.1|	Influenza A virus (A/Pretoria/2/03(H3N2)) hemagglutinin (HA) gene	0.0	686.389
gi|37530025|gb|AY389356.1|	Influenza A virus (A/Middleburg/41/03(H3N2)) hemagglutinin (HA) gene	0.0	686.389
lcl|ISDN38157	InfluenzaA/Fujian/411/2002_ Hemagglutinin_104	0.0	678.459

This example is significant because it shows that a completely non-biased amplification method, derived from a June 2001 public domain protocol may be used as a preparative step for resequencing microarrays, resulting in PCR-level sensitivity (10^1 target copies). Although this amplification protocol has been used for several published examples of long oligomer (70-mer) microarray-based assays, it is not obvious that it would suffice for resequencing microarray approaches. Numerous modifications and variations on the present invention are possible in light of the above teachings. It is, therefore, to be understood that within the scope of the accompanying claims, the invention may be practiced otherwise than as specifically described herein.

Example 10: Other Pathogen Tests:

In summary, the following pathogens were detected / discriminated from laboratory and/or clinical samples on RPMV1, (in aggregate representing > 180 chips tested) with 100% concordance of identification and input identity, and with no type cross-hybridizations, except to parts of sequence tiles representing homologous sequences between type variant strains, in:

Human adenoviruses group C — Ad5 prototype — Ad5 USA field strain

Human adenoviruses group E — Ad4 prototype — Ad4 AF field strain
Ad4 vaccine — Ad4 USN field strain

Human adenoviruses group B	Ad3 prototype	Ad3 USN field strain
	Ad7 prototype	Ad7 USN field strain
	Ad7 vaccine	
	Ad16 prototype	
	Ad21 prototype	Ad21 field strain
Influenza A	H1N1	H3N2

Variola Major (smallpox)
Lassa Virus
Ebola Virus
Streptococcus pneumonia
Streptococcus pyogenes
Chlamydia pneumonia
Mycoplasma pneumonia
Neisseria meningitides
Bacillus anthracis
Yersinia pestis
Francisella tularensis

Selected examples of RPMV1 microarray results for prepared non-infectious laboratory samples of Variola Major (smallpox), Ebola Virus, *B. anthracis*, *Y. pestis*, and *F. tularensis* have been performed, but not shown here. Variola Major (smallpox), Ebola Virus, and *F. tularensis* samples were prepared using specific PCR primers. *B. anthracis* and *Y. pestis* samples were amplified using GenomiPhi reagents (as described in Example 3).

Example 11: Features of Sequences Adenoviruses

The following tables present the sequence features and putative gene products for the sequenced adenoviruses appearing in Table 6 and SEQ ID NOs: 575-587.

Table 39: Ad3 (Accession No. AY599834; SEQ ID NO: 575) Sequence Features and putative gene products

Feature Type	Location	Comment or Gene Locus	Product
repeat_region	1..134		
promoter	480..485	"TATA box for the E1A genes"	
CDS	Join (576..662, 1250..1351)	gene="E1A"	"6KD protein"
CDS	Join (576..1155, 1250..1455)	gene="E1A"	"29.1kD protein"
CDS	Join (576..1062, 1250..1455)	gene="E1A"	"25K protein"
polyA_site	1494..1499	"polyA site for E1A"	
promoter	1549..1554	"TATA box for the E1B genes"	
CDS	1603..2139	gene="E1B"	"19kD small T antigen"
CDS	1908..3386	gene="E1B"	55K protein
Promoter	3384..3389	"TATA box for pIX"	
polyA_site	3450..3455	"polyA site for E1B"	
CDS	3480..3896	gene="protein IX"	"protein IX"
polyA_site	3913..3918	"polyA site for pIX"	
polyA_site	Complement (3925..3930)	"polyA site for E2B"	
CDS	Complement (join (3948..5281, 5560..5572))	gene="E2B"	"IVA2 maturation protein"
CDS	Complement (5051..8419)	gene="E2B"	"DNA polymerase"
CDS	5123..5692	gene="hypothetical"	"hypothetical 20.6KD early protein"
Promoter	5872..5877	"TATA box for the Major Late Promoter"	
CDS	Complement (6868..7389)	gene	"hypothetical" =

			"hypothetical 19kD protein"
CDS	7829..8425	gene="L1"	"probable DNA binding agnoprotein"
CDS	Complement (join (8422..10389, 13848..13856))	gene="pTP"	"DNA terminal protein precursor"
CDS	9757..10032	gene="hypothetical"	"hypothetical 9.7kD protein"
misc_RNA	10422..10595	"virus-associated RNA I"	
CDS	10890..12026	gene="L1"	"55KD protein"
CDS	12051..13817	gene="L1"	"pIIIa protein"
polyA_site	13830..13835	"polyA site for L1"	
CDS	13905..15539	gene="L2"	"penton base protein"
CDS	15553..16131	gene="L2"	"pVII"
CDS	16174..17223	gene="L2"	"protein V"
polyA_site	17498..17503	"polyA site for L2"	
CDS	17555..18001	gene="L3"	"protein VI"
CDS	18420..21254	gene="L3"	"hexon protein"
CDS	21291..21920	gene="L3"	"23K proteinase"
polyA_site	21940..21945	"polyA site for L3"	
polyA_site	Complement (21952..21957)	"polyA site for E2A"	
CDS	Complement (22006..23559)	gene="E2A"	"DNA binding protein"
CDS	23590..26076	gene="L4"	"hexon assembly-associated 100KD protein"
CDS	25778..26375	gene="L4"	"22K protein"
CDS	Join (25778..26159, 26296..26651)	gene="L4"	"33KD protein"
CDS	26722..27405	gene="L4"	"proteinVIII"
Promoter	27087..27092	"TATA box for the E3 genes"	
CDS	27405..27725	gene="E3"	"12.5KD protein"
CDS	27679..28002	gene="E3"	"16KD glycoprotein"
CDS	28104..28622	gene="E3"	"18.5 protein"
CDS	28652..29191	gene="E3"	"20.1KD protein"
CDS	29204..29773	gene="E3"	"20.1KD protein, duplicate copy"
CDS	29788..30021	gene="E3" "	"9K glycoprotein
CDS	30063..30338	gene="E3"	"10.3KD protein"
CDS	30310..30747	gene="E3"	"14.9KD protein"
CDS	30740..31150	gene="E3"	"14KD protein"
polyA_site	31183..31188	"polyA site for E3"	
CDS	Complement (31194..31355)	gene="U"	"U protein"
CDS	31370..32329	gene="L5"	"fiber protein"
polyA_site	Complement (32354..32359)	"polyA signal for E4"	
CDS	Complement (32370..32621)	gene="E4"	"ORF6/7"
CDS	Complement (32618..33517)	gene="E4"	"33.2KD protein"
CDS	Complement (33420..33788)	gene="E4"	"13.6KD protein"
CDS	33643..34152	gene="L5" "	"agnoprotein
CDS	Complement (33797..34150)	gene="E4"	"11KD protein"
CDS	Complement (34147..34536)	gene="E4"	"14.3KD protein"
polyA_site	34561..34566	"polyA signal for L5"	
CDS	Complement (34578..34955)	gene="E4"	"13.9KD protein"
Promoter	Complement (35037..35042)	"TATA box for the E4 promoter"	
repeat_region	Complement (35212..35345)	"the inverted terminal repeat"	

Table 40: Ad3FS_navy (Accession No. AY599836; SEQ ID NO: 576) Sequence Features and putative gene products

Feature Type	Location	Comment or Gene Locus	Product
repeat_region	1..111	"the inverted terminal repeat"	
promoter	480..485	"TATA box for E1A"	
CDS	join (576..647,1248..1349)	gene="E1A"	"6.9k protein"
CDS	join (576..1062,1248..1453)	gene="E1A"	"25K protein"
CDS	join (576..1155,1248..1453)	gene="E1A"	"29K protein"
polyA_site	1492..1497	"polyA site for E1A"	
promoter	1547..1552	"TATA box for E1B"	
CDS	1601..2137	gene="E1B"	"19K small T-antigen protein"
CDS	1906..3384	gene="E1B"	"55K large T-antigen protein"
Promoter	3428..3433	"TATA box for pIX"	
polyA_site	3448..3453	"polyA signal for E1B"	
CDS	3478..3894	gene="pIX"	"proteinIX"
polyA_site	3907..3912	"polyA signal for pIX"	
polyA_site	complement (3923..3928)	"polyA signal for E2B"	
CDS	complement (join (3946..5279,5558..5570))	gene="E2B"	"proteinIVa2"
CDS	complement(5049..8417)	gene="E2B"	"DNA polymerase"
Promoter	5870..5875	"TATA box for the Major Late Promoter"	
CDS	6142..6462	gene="hypothetical"	"hypothetical 11.5K early protein"
CDS	7131..7418	gene="hypothetical"	"hypothetical 10.4K early protein"
CDS	7827..8423	gene="L1"	"probable DNA binding agnoprotein"
CDS	complement (8227..8562)	gene="E2B"	"hypothetical 12.6K early protein"
CDS	complement (join (8420..10378,13840..13848))	gene="E2B"	"Terminal protein precursor,aka Bellet's protein"
CDS	complement (9532..9846)	gene="hypothetical"	"11.3K early protein"
CDS	9746..10021	gene="hypothetical"	"9.7K early protein"
misc_RNA	10411..10584	"VA RNA I"	
misc_RNA	10662..10838	"VA RNA II"	
CDS	10861..12018	gene="L1"	"55K protein"
CDS	12043..13809	gene="L1"	"hexon associated proteinIIIa precursor"
polyA_site	13822..13827	"polyA signal for L1"	
CDS	13897..15531	gene="L2"	"penton base protein"
CDS	15545..16123	gene="L2"	"pVII 21K protein"
CDS	16166..17218	gene="L2"	"pV from L2"
polyA_site	17493..17498	"polyA signal for L2"	
CDS	17550..18302	gene="L3"	"pVI"
CDS	18415..21243	gene="L3"	"hexon protein"
CDS	21286..21915	gene="L3"	"23K proteinase"
polyA_site	21935..21940	"polyA signal for L3"	
CDS	complement (21947..21952)		
CDS	complement (22002..23552)	"E2A"	"DNA binding protein"
CDS	23583..26057	gene="L4"	"100K protein"
CDS	25759..26358	gene="L4"	"22K protein"
CDS	join (25759..26107,26289..26632)	gene="L4"	"33K protein"
CDS	26702..27385	gene="L4"	"pVIII, hexon associated

			protein precursor"
Promoter	27067..27072	"TATA box for the E3 gene"	
CDS	27385..27705	gene="E3"	"12.2K glycoprotein"
CDS	27659..28099	gene="E3"	"16K glycoprotein"
CDS	28084..28602	gene="E3"	"18.5K glycoprotein"
CDS	28632..29171	gene="E4"	"20.1K glycoprotein"
CDS	29184..29753	gene="E3"	"20.1K glycoprotein"
CDS	29985..30260	gene="E3"	"10.3K glycoprotein"
CDS	30232..30669	gene="E3"	"14.9K glycoprotein"
CDS	30662..31072	gene="E3"	"15.3K protein"
polyA_site	31105..31110	"polyA signal for E3"	
CDS	complement (31116..31277)	gene="U exon"	"U exon protein"
CDS	31292..32251	gene="L5"	"fiber protein"
polyA_site	complement (32276..32281)	"polyA signal for E4"	
CDS	complement (32292..32543)	gene="E4"	"ORF6/7"
CDS	complement (32540..33439)	gene="E4"	"34K protein"
CDS	complement (33342..33710)	gene="E4"	"13.6K protein"
CDS	33565..34074	gene="L5"	"DNA binding agnoprotein"
CDS	complement (33719..34072)	gene="E4"	"ORF3"
CDS	complement (34069..34458)	gene="E4"	"14.3K protein"
polyA_site	34483..34488	"polyA signal for L5"	
CDS	complement (34500..34877)	gene="E4"	"13.9K protein"
Promoter	complement (34959..34964)	"TATA box for the E4 gene"	Promoter
repeat_region	complement (35155..35265)	"the inverted terminal repeat"	repeat_region

Table 41: Ad4 (Accession No. AY594253; SEQ ID NO: 577) Sequence Features and putative gene products

Feature Type	Location	Comment or Gene Locus	Product
repeat_unit	1..116	"ITR"	
promoter	472..511	"E1A"	
CDS	576..1154	gene="E1A"	"ORF1; putative"
CDS	join (576..650, 1236..1340)	gene="E1A"	"early E1A 6.8 KD protein" similarity to Simian Adenovirus 25 11 kDa, GI:17227344
CDS	join (576..1142, 1235..1441)	gene="E1A"	"EARLY E1A 28 KD PROTEIN" similarity to Simian Adenovirus 25 28.2 kDa, GI:17227342
CDS	join (576..1049, 1235..1441)	gene="E1A"	"early E1A 24.6 KD protein" similarity to Simian Adenovirus 25 24.8 kDa, GI:17227343
polyA_signal	1499..1504	"E1A"	
promoter	1553..1592	"E1B"	
CDS	join (1600..2001, 2003..2029)	gene="E1B"	"small T-antigen (E1B 19K)"
CDS	1600..2115	gene="E1B"	"early E1B 20 KD protein" similarity to Simian Adenovirus 25 20.5 kDa, GI:17227345
CDS	join (1905..2123, 3259..3276)	gene="E1B"	"early E1B 8.2 KD protein" similarity to Simian Adenovirus 25 10.1 kDa, GI:17227348
CDS	1905..3356	gene="E1B"	"large T antigen" similarity to Simian Adenovirus 25 54.7 kDa, GI:17227347

CDS	join (1905..2153, 3141..3356)	gene="E1B"	"early E1B 16.8 KD protein" similarity to Simian Adenovirus 25 18.5 kDa, GI:17227346
CDS	3441..3869	gene="IX"	"protein IX (hexon-associated protein)" similarity to Simian Adenovirus 25 pIX, GI:17227349
polyA_signal	3880..3885	"E1B and IX"	
polyA_signal	complement (3902..3907)	"E2B and IVa2"	
CDS	complement (join (3930..5263, 5542..5554))	gene="IVa2"	"IVa2 protein (maturation protein)" similarity to Simian Adenovirus 25 pIVa2, GI:17227350
CDS	complement (join (5033..8605, 12212..12220))	gene="E2B(POL)"	"DNA polymerase" similarity to Simian Adenovirus 25 TPA: pol, GI:33694808
CDS	5105..5674	gene="E2B"	"19.4 KD early protein" similarity to Human Adenovirus 7 hypothetical 20.6 kD early protein, GI:58522
CDS	6126..6446	gene="E2B"	"11.5 KD early protein" similarity to Human Adenovirus 7 hypothtical 11.5 kD early protein, GI:58524
CDS	7814..8407	gene="L1"	"DNA-binding protein (agnoprotein)" similarity to Simian Adenovirus 25 21.9 kDa, GI:17227351
CDS	join (7814..7819, 8536..8928)	gene="E2B"	"14.1 KD early protein" similarity to Human Adenovirus 7 hypothetical 14.5 kD early protein, GI:58528
CDS	complement (join (8404..10323, 12212..12220))	gene="E2B(pTP)"	"precursor terminal protein" similarity to Simian Adenovirus 25 TPA: pTP, GI:33694809
misc_RNA	10356..10514	"virus-associated RNA I"	"VA RNA-I, 159 nt"
promoter	complement (10457..10496)	"E2B"	
promoter	10541..10580	"L1"	
misc_RNA	10575..10743	"virus-associated RNA II"	"VA RNA-II, 169 nt"
CDS	10765..11937	gene="L1(52K)"	"52K protein" similarity to Simian Adenovirus 25 42.9 kDa (52K), GI:17227352
polyA_signal	11942..11947	"L1(52K)"	
CDS	11961..13736	gene="L1(IIIa)"	"protein IIIa" similarity to Simian Adenovirus 25 TPA: pIIIa, GI:33694811
polyA_signal	13749..13754	"L1(IIIa)"	
promoter	13758..13797	"L2"	
CDS	13815..15422	gene="L2(penton)"	"penton protein(protein III)" similarity to Simian Adenovirus 25 pIII,

			GI:17227353
polyA_signal	15425..15430	"L2(penton)"	
CDS	15426..16007	gene="L2(pVII)"	"major core protein (protein VII)" similarity to Simian Adenovirus 25 pVII, GI:17227354
CDS	16055..17080	gene="L2(pV)"	"minor core protein (protein V)" similarity to Simian Adenovirus 25 TPA: pV, GI:33694814
CDS	17103..17336	gene="L2(pX)"	"protein X (protein mu)" similarity to Simian Adenovirus 25 TPA: pX, GI:33694815
polyA_signal	17357..17362	"L2(pX)"	
CDS	17368..18141	gene="L3(pVI)"	"protein VI (hexon-associated protein)" similarity to Simian Adenovirus 25 pVI, GI:17227356
CDS	18248..21058	gene="L3(hexon)"	"hexon protein (protein II)" similarity to Simian Adenovirus 25 pII (hexon), GI:17227357
CDS	21082..21702	gene="L3(23K)"	"late L3 23K proteinase (Adenain)" similarity to Simian Adenovirus 25 protease, GI:33694818
polyA_signal	21725..21730	"L3"	
polyA_signal	complement (21767..21772)	"E2A"	
CDS	complement (21774..23312)	gene="E2A(DBP)"	"early E2A DNA-binding protein" similarity to Simian Adenovirus 25 DNA-binding protein, GI:17227358
CDS	23341..25716	gene="L4(100K)"	"100K protein" similarity to Simian Adenovirus 25 TPA: 100K, GI:33694820
Promoter	complement (23345..23384)	"E2A"	
CDS	25439..25978	gene="L4(22K)"	"22K protein" similarity to Simian Adenovirus 25 TPA: 22K, GI:33694822
CDS	join(25439..25756,25926..26249)	gene="L4(33K)"	"33K protein" similarity to Simian Adenovirus 25 TPA: 33K (24.3 kDa), GI:17227359
CDS	26318..27001	gene="L4(pVIII)"	"L4 protein VIII" similarity to Simian Adenovirus 25 pVIII, GI:17227360
CDS	27002..27322	gene="E3"	"E3 12.1 kDa protein " similarity to Simian Adenovirus 25 11.6 kDa, GI:17227361
CDS	27276..27908	gene="E3"	"E3 23.3 kDa protein" similarity to Simian Adenovirus 25 TPA: E3 CR1-alpha1, GI:33694825

CDS	27890..28414	gene="E3"	"E3 19 kDa protein " similarity to Simian Adenovirus 25 TPA: E3 gp19K (19.3 kDa), GI:33694826
CDS	28445..29107	gene="E3"	"E3 24.8 kDa protein " similarity to Simian Adenovirus 25 22.3 kDa, TPA: E3 CR1-gamma1, GI:17227364
CDS	29275..29439	gene="E3"	"E3 6.3 kDa protein"
CDS	29436..30260	gene="E3"	"E3 29.7 kDa protein" similarity to Simian Adenovirus 25 TPA: E3 CR1-delta1, GI:33694829
CDS	30269..30544	gene="E3"	"E3 10.4 kDa protein" similarity to Simian Adenovirus 25 9.9 kDa, GI:17227365
CDS	30550..30990	gene="E3"	"E3 14.5 kDa protein" similarity to Simian Adenovirus 25 15.6 kDa, GI:17227366
CDS	30983..31384	gene="E3"	"E3 14.7 kDa protein" similarity to Simian Adenovirus 25 14.7 kDa, GI:17227367
polyA_signal	31424..31429	"E3"	
promoter	31473..31512	"L5"	
CDS	31645..32922	gene="L5(fiber)"	"fiber protein" similarity to Simian Adenovirus 25 pIV(TPA: fiber), GI:17227368
polyA_signal	32982..32987	"L5"	
polyA_signal	complement (32998..33003)	"E4"	
CDS	complement (33018..33212)	gene="E4"	"E4 7.4 KD protein " similarity to Simian Adenovirus 25 Ad9 ORF7-like protein, GI:17227369
CDS	complement (join (33018..33266, 33992..34165))	gene="E4"	"E4 15.9 KD protein" similarity to Simian Adenovirus 25 TPA: E4 ORF6/7, GI:33694835
CDS	complement (33266..34165)	gene="E4"	"E4 34.6 KD protein" similarity to Simian Adenovirus 25 33 kDa, GI:17227370
CDS	complement (34068..34436)	gene="E4"	"E4 14.1 KD protein" similarity to Simian Adenovirus 25 13.2 kDa, GI:17227371
polyA_signal	complement (34388..34393)	"E4"	
CDS	complement (34445..34798)	gene="E4"	"E4 13.7 KD protein" similarity to Simian Adenovirus 25 12.8 kDa, GI:17227372
CDS	complement (34795..35184)	gene="E4"	"E4 14.6 KD protein" similarity to Simian Adenovirus 25 14.2 kD,

			GI:17227373
CDS	complement (35232..35606)	gene="E4"	"E4 13.5 KD protein" similarity to Simian Adenovirus 25 TPA: E4 ORF1, GI:33694840
repeat_unit	complement (35875..35990)	"ITR"	

Table 42: Ad4vaccine (Accession No. AY594254; SEQ ID NO: 578) Sequence Features and putative gene products

Feature Type	Location	Comment or Gene Locus	Product
repeat_unit	1..116	"ITR"	
promoter	472..511	"E1A"	
CDS	576..1154	gene="E1A"	"ORF1: putative"
CDS	join (576..650, 1236..1340)	gene="E1A"	"early E1A 6.8 KD protein" similarity to Simian Adenovirus 25 11 kDa, GI:17227344
CDS	join (576..1142, 1235..1441)	gene="E1A"	"early E1A 28 KD protein" similarity to Simian Adenovirus 25 28.2 kDa, GI:17227342
CDS	join (576..1049, 1235..1441)	gene="E1A"	"early E1A 24.6 KD protein" similarity to Simian Adenovirus 25 24.8 kDa, GI:17227343
polyA_signal	1499..1504	"E1A"	
promoter	1553..1592	"E1B"	
CDS	Join (1600..2001, 2003..2029)	gene="E1B"	"small T-antigen (E1B 19K)"
CDS	1600..2115	gene="E1B"	"early E1B 20 KD protein" similarity to Simian Adenovirus 25 20.5 kDa, GI:17227345
CDS	join (1905..2123, 3259..3276)	gene="E1B"	"early E1B 8.2 KD protein" similarity to Simian Adenovirus 25 10.1 kDa, GI:17227348
CDS	1905..3356	gene="E1B"	"large T antigen" similarity to Simian Adenovirus 25 54.7 kDa, GI:17227347
CDS	join (1905..2153, 3141..3356)	gene="E1B"	"early E1B 16.8 KD protein" similarity to Simian Adenovirus 25 18.5 kDa, GI:17227346
CDS	3441..3869	gene="IX"	"protein IX (hexon-associated protein)" similarity to Simian Adenovirus 25 pIX, GI:17227349
polyA_signal	3880..3885	"E1B and IX"	
polyA_signal	complement (3902..3907)	"E2B and IVa2"	
CDS	complement (join (3930..5263, 5542..5554))	gene="IVa2"	"IVa2 protein (maturation protein)" similarity to Simian Adenovirus 25 pIVa2, GI:17227350
CDS	complement (join (5033..8605, 12212..12220))	gene="E2B(POL)"	"DNA polymerase" similarity to Simian

			Adenovirus 25 TPA: pol, GI:33694808
CDS	5105..5674	gene="E2B"	"19.4 KD early protein" similarity to similar to Human Adenovirus 7 hypothetical 20.6 kD early protein, GI:58522
CDS	6126..6446	gene="E2B"	"11.5 KD early protein" similarity to similar to Human Adenovirus 7 hypothtical 11.5 kD early protein, GI:58524
CDS	7814..8407	gene="L1"	"DNA-binding protein (agnoprotein)" similarity to Simian Adenovirus 25 21.9 kDa, GI:17227351
CDS	join (7814..7819, 8536..8928)	gene="E2B"	"14.1 KD early protein" similarity to similar to Human Adenovirus 7 hypothetical 14.5 kD early protein, GI:58528
CDS	complement (join (8404..10323, 12212..12220))	gene="E2B(pTP)"	"precursor terminal protein" similarity to Simian Adenovirus 25 TPA: pTP, GI:33694809
misc_RNA	10356..10514	"virus-associated RNA I"	"VA RNA-I, 159 nt"
promoter	complement (10457..10496)	"E2B"	
promoter	10541..10580	"L1"	
misc_RNA	10575..10743	"virus-associated RNA II"	"VA RNA-II, 169 nt"
CDS	10765..11937	gene="L1(52K)"	"52K protein" similarity to Simian Adenovirus 25 42.9 kDa (52K), GI:17227352
polyA_signal	11942..11947	"L1(52K)"	
CDS	11961..13736	gene="L1(IIIa)"	"protein IIIa" similarity to Simian Adenovirus 25 TPA: pIIIa, GI:33694811
polyA_signal	13749..13754	"L1(IIIa)"	
promoter	13758..13797	"L2"	
CDS	13815..15422	gene="L2(penton)"	"penton protein(protein III)" similarity to Simian Adenovirus 25 pIII, GI:17227353
polyA_signal	15425..15430	"L2(penton)"	
CDS	15426..16007	gene="L2(pVII)"	"major core protein (protein VII)" similarity to Simian Adenovirus 25 pVII, GI:17227354
CDS	16055..17080	gene="L2(pV)"	"minor core protein (protein V)" similarity to Simian Adenovirus 25 TPA: pV, GI:33694814
CDS	17103..17336	gene="L2(pX)"	"protein X (protein mu)" similarity to Simian Adenovirus 25 TPA: pX, GI:33694815
polyA_signal	17357..17362	"L2(pX)"	
CDS	17368..18141	gene="L3(pVI)"	"protein VI (hexon-associated protein)" similarity to Simian

			Adenovirus 25 pVI, GI:17227356
CDS	18248..21058	gene="L3(hexon)"	"hexon protein (protein II)" similarity to Simian Adenovirus 25 pII (hexon), GI:17227357
CDS	21082..21702	gene="L3(23K)"	"late L3 23K proteinase (Adenain)" similarity to Simian Adenovirus 25 protease, GI:33694818
polyA_signal	21725..21730	"L3"	
polyA_signal	complement (21767..21772)	"E2A"	
CDS	complement (21774..23312)	gene="E2A(DBP)"	"early E2A DNA-binding protein" similarity to Simian Adenovirus 25 DNA-binding protein, GI:17227358
CDS	23341..25716	gene="L4(100K)"	"100K protein" similarity to Simian Adenovirus 25 TPA: 100K, GI:33694820
promoter	complement (23345..23384)	"E2A"	
CDS	25439..25978	gene="L4(22K)"	"22K protein" similarity to Simian Adenovirus 25 TPA: 22K, GI:33694822
CDS	join (25439..25756, 25926..26252)	gene="L4(33K)"	"33K protein" similarity to Simian Adenovirus 25 TPA: 33K (24.3 kDa), GI:17227359
CDS	26321..27004	gene="L4(pVIII)"	"L4 protein VIII" similarity to Simian Adenovirus 25 pVIII, GI:17227360
CDS	27005..27325	gene="E3"	"E3 12.1 kDa protein " similarity to Simian Adenovirus 25 11.6 kDa, GI:17227361
CDS	27279..27911	gene="E3"	"E3 23.3 kDa protein" similarity to Simian Adenovirus 25 TPA: E3 CR1-alpha1, GI:33694825
CDS	27893..28417	gene="E3"	"E3 19 kDa protein " similarity to Simian Adenovirus 25 TPA: E3 gp19K (19.3 kDa), GI:33694826
CDS	28449..29111	gene="E3"	"E3 24.8 kDa protein " similarity to Simian Adenovirus 25 22.3 kDa, TPA: E3 CR1-gamma1, GI:17227364
CDS	29279..29443	gene="E3"	"E3 6.3 kDa protein"
CDS	29440..30264	gene="E3"	"E3 29.7 kDa protein" similarity to Simian Adenovirus 25 TPA: E3 CR1-delta1, GI:33694829
CDS	30273..30548	gene="E3"	"E3 10.4 kDa protein" similarity to Simian

			Adenovirus 25 9.9 kDa, GI:17227365
CDS	30554..30994	gene="E3"	"E3 14.5 kDa protein" similarity to Simian Adenovirus 25 15.6 kDa, GI:17227366
CDS	30987..31388	gene="E3"	"E3 14.7 kDa protein" similarity to Simian Adenovirus 25 14.7 kDa, GI:17227367
polyA_signal	31428..31433	"E3"	
promoter	31477..31516	"L5"	
CDS	31649..32926	gene="L5(fiber)"	"fiber protein" similarity to Simian Adenovirus 25 pIV(TPA: fiber), GI:17227368
polyA_signal	32986..32991	"L5"	
polyA_signal	complement (33002..33007)	"E4"	
CDS	complement (33022..33216)	gene="E4"	"E4 7.4 KD protein " similarity to Simian Adenovirus 25 Ad9 ORF7-like protein, GI:17227369
CDS	complement (join (33022..33270, 33996..34169))	gene="E4"	"E4 15.9 KD protein" similarity to Simian Adenovirus 25 TPA: E4 ORF6/7, GI:33694835
CDS	complement (33270..34169)	gene="E4"	"E4 34.6 KD protein" similarity to Simian Adenovirus 25 33 kDa, GI:17227370
CDS	complement (34072..34440)	gene="E4"	"E4 14.1 KD protein" similarity to Simian Adenovirus 25 13.2 kDa, GI:17227371
polyA_signal	complement (34392..34397)	"E4"	
CDS	complement (34449..34802)	gene="E4"	"E4 13.7 KD protein" similarity to Simian Adenovirus 25 12.8 kDa, GI:17227372
CDS	complement (34799..35188)	gene="E4"	"E4 14.6 KD protein" similarity to Simian Adenovirus 25 14.2 kD, GI:17227373
CDS	complement (35236..35610)	gene="E4"	"E4 13.5 KD protein" similarity to Simian Adenovirus 25 TPA: E4 ORF1, GI:33694840
repeat_unit	complement (35879..35994)	"ITR"	

Table 43: Ad4FS_navy (Accession No. AY599835; SEQ ID NO: 579) Sequence Features and putative gene products

Feature Type	Location	Comment or Gene Locus	Product
repeat_region	1..208	"ITR"	
CDS	576..1121	gene="E1A"	"ORF1: putative"
CDS	Join (576..650,1203..1307)	gene="E1A"	"early E1A 6.8 KD protein" similarity to similar to Simian Adenovirus 25 11 kDa,

			GI:17227344
CDS	join (576..1109, 202..1408)	gene="E1A"	"early E1A 27 KD protein" similarity to Simian Adenovirus 25 28.2 kDa, GI:17227342
CDS	join (576..1016, 202..1408)	gene="E1A"	"early E1A 23.5 KD protein" similarity to Simian Adenovirus 25 24.8 kDa, GI:17227343
polyA_signal	1464..1469	"E1A"	
promoter	1518..1557	"E1B"	
CDS	Join (1565..1966, 1968..1994)	gene="E1B"	"small T antigen"
CDS	1565..2119	gene="E1B"	"early E1B 21.5 KD protein" standard_name - Simian Adenovirus 25 20.5 kDa, GI:17227345
CDS	join (1870..2127, 3263..3280)	gene="E1B"	"early E1B 9 KD protein" similarity to Simian Adenovirus 25 10.1 kDa, GI:17227348
CDS	1870..3360	gene="E1B"	"large T antigen (55 KD)" similarity to Simian Adenovirus 25 54.7 kDa, GI: 17227347
CDS	join (1870..2157, 3145..3360)	gene="E1B"	"early E1B 17.9 KD protein" similarity to Simian Adenovirus 25 18.5 kDa, GI:17227346
CDS	3444..3872	gene="IX"	"protein IX (hexon-associated protein)"
polyA_signal	3882..3887	"E1B and IX"	
polyA_signal	Complement (3904..3909)	"E2B and IVa2"	
CDS	Complement (join (3935..5268, 5547..5559))	gene="IVa2"	"IVa2 protein (maturation protein)"
CDS	complement (join (5038..8610, 12152..12160))	gene="E2B(POL)"	"DNA polymerase"
CDS	5110..5679	gene="E2B"	"19.4 KD early protein" similarity to similar to Human Adenovirus 7 hipothetical 20.6 kD early protein, GI:58522
CDS	6131..6451	gene="E2B"	"11.5 KD early protein" similarity to similar to Human Adenovirus 7 hypothetical 11.5 kD early protein, GI:58524
CDS	7819..8412	gene="L1"	"DNA-binding protein (agnoprotein)" similarity to Simian Adenovirus 25 21.9 kDa, GI:17227251
CDS	join (7819..7824, 8541..8933)	gene="E2B"	"14.1 KD early protein" similarity to similar to Human Adenovirus 7 hypothetical 14.5 KD early protein, GI:58528
CDS	complement (join (8409..10328, 12152..12160))	gene="E2B(pTP)"	"precursor terminal protein"
misc_RNA	10361..10519	"virus-associated RNA I"	"VA RNA-I, 159 nt"
promoter	complement(10462..10501)	"E2B"	
promoter	10542..10581	"L1"	
misc_RNA	10584..10684	"virus-associated RNA II"	"VA RNA-II, 101 nt"

CDS	10705..11877	gene="L1(52K)"	"52K protein"
polyA_signal	11882..11887	"L1(52K)"	
CDS	11901..13682	gene="L1(IIIa)"	"protein IIIa"
polyA_signal	13696..13701	"L1(IIIa)"	
promoter	13755..13794	"L2"	
CDS	13762..15369	gene="L2(penton)"	"penton protein(protein III)"
polyA_signal	15372..15377	"L2(penton)"	
CDS	15373..15954	gene="L2(pVII)"	"major core protein (protein VII)"
CDS	16002..17027	gene="L2(pV)"	"minor core protein (protein V)"
CDS	17050..17283	gene="L2(pX)"	"protein X (protein mu)"
CDS	17343..18074	gene="L3(pVI)"	"protein VI (hexon-associated protein)"
CDS	18181..20991	gene="L3(hexon)"	"hexon protein (protein II)"
CDS	21015..21635	gene="L3(23K)"	"23K protease"
polyA_signal	21661..21666	"L3"	
polyA_signal	complement (21703..21708)	"E2A"	
CDS	complement (21710..23242)	gene="E2A(DBP)"	"early E2A DNA-binding protein"
promoter	complement (23170..23209)	"E2A"	
promoter	23211..23250	"L4"	
CDS	23271..25634	gene="L4(100K)"	"100K protein"
CDS	25369..25884	gene="L4(22K)"	"22K protein"
CDS	join (25369..25674, 25844..26158)	gene="L4(33K)"	"33K protein"
CDS	26226..26909	gene="L4(pVIII)"	"L4 protein VIII"
CDS	26910..27230	gene="E3"	"E3 12.1 kDa protein"
CDS	27184..27816	gene="E3"	"E3 23.3 kDa protein"
CDS	27798..28322	gene="E3"	"E3 19 kDa protein"
CDS	28352..28987	gene="E3"	"E3 24.8 kDa protein"
CDS	29296..30105	gene="E3"	"E3 29.7 kDa protein"
CDS	30114..30389	gene="E3"	"E3 10.4 kDa protein"
CDS	30395..30835	gene="E3"	"E3 14.5 kDa protein"
CDS	30828..31229	gene="E3"	"E3 14.7 kDa protein"
polyA_signal	31279..31284	"E3"	
promoter	31292..31331	"L5"	
CDS	31464..32741	gene="L5(fiber)"	"fiber protein"
polyA_signal	32801..32806	"L5"	
polyA_signal	complement (32817..32822)	"E4"	
CDS	complement (32837..33031)	gene="E4"	"E4 7.4 KD protein"
CDS	complement (join (32837..33085, 33811..33984))	gene="E4"	"E4 15.9 KD protein"
CDS	complement (33085..33984)	gene="E4"	"E4 34.6 KD protein"
CDS	complement (33887..34255)	gene="E4"	"E4 14.1 KD protein"
polyA_signal	complement (34207..34212)	"E4"	
CDS	complement (34264..34617)	gene="E4"	"E4 13.7 KD protein"
CDS	complement (34614..35003)	gene="E4"	"E4 14.6 KD protein"
CDS	complement (35051..35425)	gene="E4"	"E4 13.5 KD protein"
repeat_region	complement(35758..35965)	"ITR"	

Table 44: Ad4FS_AF (Accession No. AY599837; SEQ ID NO: 580) Sequence Features and putative gene products

Feature Type	Location	Comment or Gene Locus	Product
repeat_region	1..208	"ITR"	
CDS	575..1120	gene="E1A"	"ORF1; putative"
CDS	Join (575..649, 1202..1306)	gene="E1A"	"early E1A 6.8 KD protein" similarity to Simian Adenovirus 25 11 kDa, GI:17227344
CDS	Join (575..1108, 1201..1407)	gene="E1A"	"early E1A 27 KD protein" similarity to Simian Adenovirus 25 28.2 kDa, GI:17227342
CDS	Join (575..1015, 1201..1407)	gene="E1A"	"early E1A 23.5 KD protein" similarity to Simian Adenovirus 25 24.8 kDa, GI:17227343
polyA_signal	1463..1468	"E1A"	
promoter	1517..1556	"E1B"	
CDS	join (1564..1965, 1976..1993)	gene="E1B"	"small T antigen (16.5 KD)"
CDS	1564..2115	gene="E1B"	"early E1B 21.5 KD protein" similarity to Simian Adenovirus 25 20.5 kDa, GI:17227345
CDS	join (1869..2123, 3258..3269)	gene="E1B"	"early E1B 9KD protein" similarity to Simian Adenovirus 25 10.1 kDa, GI:17227348
CDS	join (1869..2615, 2618..3355)	gene="E1B"	"large T antigen (55 KD)" similarity to Simian Adenovirus 25 54.7 kDa, GI:17227347
CDS	join (1869..2153, 3140..3355)	gene="E1B"	"early E1B 17.9 KD protein" similarity to Simian Adenovirus 25 18.5 kDa, GI:17227346"
CDS	3439..3867	gene="IX"	"protein IX (hexon-associated protein)"
polyA_signal	3877..3882	"E1B and IX"	
polyA_signal	complement (3899..3904)	"E2B and IVa2"	
CDS	complement (join (3931..5264, 5543..5555))	gene="IVa2"	"IVa2 protein (maturation protein)"
CDS	complement (join (5034..8606, 12151..12159))	gene="E2B(POL)"	"DNA polymerase"
CDS	5106..5675	gene="E2B"	"19.4 KD early protein." similarity to similar to Human Adenovirus 7 hypothetical 20.6 kD early protein, GI:58522
CDS	6127..6447	gene="E2B"	"11.5 KD early protein" similarity to similar to Human Adenovirus 7 hypothtical 11.5 kD early protein, GI:58524
CDS	7815..8408	gene="L1"	"DNA-binding protein (agnoprotein)" similarity to Simian Adenovirus 25 21.9 kDa, GI:17227351
CDS	join (7815..7820, 8537..8929)	gene="E2B"	"14.1 KD early protein"

			similarity to similar to Human Adenovirus 7 hypothetical 14.5 KD early protein, GI:58528
CDS	complement (join (8405..10324, 12151..12159))	gene="E2B"	"precursor terminal protein"
misc_RNA	10357..10515	"virus-associated RNA I"	"VA RNA-I, 159 nt"
promoter	complement (10458..10497)	"E2B"	
promoter	10541..10580	"L1"	
misc_RNA	10583..10683	"virus-associated RNA II"	"VA RNA-II, 101 nt"
CDS	10704..11876	gene="L1(52K)"	"52K protein"
polyA_signal	11881..11886	"L1(52K)"	
CDS	11900..13681	gene="L1(IIIa)"	"protein IIIa"
polyA_signal	13695..13700	"L1(IIIa)"	
promoter	13754..13793	"L2"	
CDS	13761..15368	gene="L2(penton)"	"penton protein(protein III)"
polyA_signal	15371..15376	"L2(penton)"	
CDS	15372..15953	gene="L2(pVII)"	"major core protein (protein VII)"
CDS	16001..17026	gene="L2(pV)"	"minor core protein (protein V)"
CDS	17049..17282	gene="L2(pX)"	"protein X (protein mu)"
CDS	17314..18072	gene="L3(pVI)"	"protein VI (hexon-associated protein)"
CDS	18179..20989	gene="L3(hexon)"	"hexon protein (protein II)"
CDS	21013..21633	gene="L3(23K)"	"L3 23K proteinase(Adenain)"
polyA_signal	21659..21664	"L3"	
polyA_signal	complement (21701..21706)	"E2A"	
CDS	complement (21708..23240)	gene="E2A(DBP)"	"early E2A DNA-binding protein"
promoter	complement (23168..23207)	"E2A"	
promoter	23209..23248	"L4"	
CDS	23269..25632	gene="L4(100K)"	"100K protein"
CDS	25367..25882	gene="L4(22K)"	"22K protein"
CDS	join (25367..25672, 25842..26156)	gene="L4(33K)"	"33K protein"
CDS	26224..26907	gene="L4(pVIII)"	"L4 protein VIII"
CDS	26908..27228	gene="E3"	"E3 12.1 kDa protein"
CDS	27182..27814	gene="E3"	"E3 23.3 kDa protein"
CDS	27796..28320	gene="E3"	"E3 19 kDa protein"
CDS	28350..28985	gene="E3"	"E3 24.8 kDa protein"
CDS	29295..30104	gene="E3"	"E3 29.7 kDa protein"
CDS	30113..30388	gene="E3"	"E3 10.4 kDa protein"
CDS	30394..30834	gene="E3"	"E3 14.5 kDa protein"
CDS	30827..31228	gene="E3"	"E3 14.7 kDa protein"
polyA_signal	31278..31283	"E3"	
promoter	31291..31330	"L5"	
CDS	31463..32740	gene="L5(fiber)"	"fiber protein"
polyA_signal	32800..32805	"L5"	
polyA_signal	complement (32816..32821)	"E4"	
CDS	complement (32836..33030)	gene="E4"	"E4 7.4 KD protein"
CDS	complement (join (32836..33084, 33810..33983))	gene="E4"	"E4 15.9 KD protein"
CDS	complement (33084..33983)	gene="E4"	"E4 34.6 KD protein"
CDS	complement (33886..34254)	gene="E4"	"E4 14.1 KD protein"
polyA_signal	complement (34206..34211)	"E4"	

CDS	complement (34263..34616)	gene="E4"	"E4 13.7 KD protein"
CDS	complement (34613..35002)	gene="E4"	"E4 14.6 KD protein"
CDS	complement (35050..35424)	gene="E4"	"E4 13.5 KD protein"
repeat_region	complement (35757..35964)	"ITR"	

Table 45: Ad5FS (Accession No. AY601635; SEQ ID NO: 581) Sequence Features and putative gene products

Feature Type	Location	Comment or Gene Locus	Product
CDS	11565..12297	"52/55 K protein gene"	protein_id="AAA96406.1"
CDS	12318..14075	product="protein IIIa"	protein_id="AAA96407.1"
CDS	16286..16474	product="protein pVII"	protein_id="AAA96408.1"
CDS	16544..17650	product="protein V"	protein_id="AAA96409.1"
CDS	17774..17920	product="protein 5 precursor"	protein_id="AAA96410.1"
CDS	18003..18755	product="protein pVI"	protein_id="AAA96411.1"
CDS	25819..26484	"100 K protein"	protein_id="AAA96412.1"
Exon	26485..26514	"of a 33 K protein"	
Exon	26713..27083	"of a 33 K protein"	
CDS	27174..27857	product="protein pVIII"	protein_id="AAA96413.1"

Table 46: Ad7 (Accession No. AY594255; SEQ ID NO: 582) Sequence Features and putative gene products

Feature Type	Location	Comment or Gene Locus	Product
repeat_region	1..108	"the inverted terminal repeat"	
promoter	481..486	"TATA box for E1A"	
CDS	Join (577..648, 1250..1351)	gene="E1A"	"6kD protein"
CDS	Join (577..1156, 1250..1455)	gene="E1A"	"E1A 28kD protein"
CDS	Join (577..1063, 1250..1455)	gene="E1A"	"mRNAII product, homologne of gi|209784"
polyA_site	1494..1499	"polyA site for E1A gene, GenScan Prediction"	
promoter	1549..1554	"TATA box for E1B"	
CDS	1603..2139	gene="E1B"	"19kD small T antigen, homologous to the unnamed protein product in Ad7, gi|58518"
CDS	1908..3386	gene="E1B"	"55kD protein, homologous to gi|58519 in Ad7"
CDS	3144..3386	gene="E1B"	"hypothetical protein derived from 1.2kB mRNA"
Promoter	3384..3389	"TATA box for proteinIX"	
polyA_site	3405..3410	"possible polyA site for the E1b genes"	
CDS	3481..3897	gene="proteinIX"	"hexon associated protein IX, homologous to the unnamed protein gi|58521, in Ad7"
polyA_site	3910..3915	"Genscan predicted polyA site for the proteinIX gene"	
polyA_site	complement (3928..3933)	"Genscan predicted polyA site	

		for E2B genes"	
CDS	complement (join (3950..5283, 5562..5574))	gene="IVa2"	"maturation protein IVA2"
CDS	Complement (5053..8421)	gene="E2B"	" DNA polymerase"
Promoter	5874..5879	"TATA box for the major late promoter"	
CDS	7987..8427	gene="L1"	"DNA binding protein,homologous to protein gi|17227351 in Adenovirus type B"
CDS	complement (8231..8575)	gene="E2B"	"hypothetical 12.6kD early protein, gi|139931 in Ad7"
CDS	complement (8424..10346)	gene="E2B"	"terminal protein precursor, homologue in Ad7 is gi|74214"
CDS	8550..8951	gene="L1"	"hypothetical 14.5kD protein"
CDS	complement (9545..9859)	gene="E2B"	"11.3kD early protein, homologue in Ad7 is gi|139914"
CDS	9759..10034	gene="L1"	"9.7kD hypothetical protein, homologue in Ad7 is gi|140138"
misc_RNA	10423..10592	"VA RNA I"	
misc_RNA	10668..10838	"VA RNA II"	
CDS	10890..12026	gene="L1"	"55kD protein"
CDS	12051..13817	gene="L1"	"peripentonal hexon associated protein IIIa"
polyA_site	13830..13835	"Genscan predicted polyA site for L1"	
CDS	13905..15539	gene="L2"	"penton base protein (III)"
polyA_site	15545..15550	"Genscsan predicted polyA site for L2"	
CDS	15550..16128	gene="L2"	"protein VII precursor"
CDS	16171..17000	gene="L2"	"minor core protein, protein V"
polyA_site	17497..17502	"Genscan predicted polyA site for L2"	
CDS	17554..18306	gene="L3"	"protein VI precursor"
CDS	18419..21232	gene="L3"	"hexon protein"
CDS	21269..21898	gene="L3"	"23K protease"
polyA_site	21918..21923	"Genscan predicted polyA site for L3"	
polyA_site	complement (21930..21935)	"Genscan predicted polyA site for E2A"	
CDS	complement (21985..23538)	gene="E2A"	"DNA binding protein"
CDS	23569..26055	gene="L4"	" 100k hexon-assembly associated protein"
CDS	complement (24924..25133)	gene="hypothetical"	"hypothetical protein"
CDS	25757..26356	gene="L4"	"22K protein"
CDS	join (25850..26225, 26275..26630)	gene="L4"	"33kD protein"
polyA_site	26662..26667	"possible polyA site for the L4 gene"	
CDS	26700..27383	gene="L4"	"protein VIII, hexon-associated protein precursor"
Promoter	27065..27070	"TATA box for E3"	

CDS	27383..27703	gene="E3"	"12.1kD glycoprotein"
CDS	27657..28097	gene="E3"	"16.1kD protein"
CDS	28082..28600	gene="E3"	"19.3kD MHC classI antigen-binding glycoprotein precursor"
CDS	28630..29169	gene="E3"	"hypothetical 20.6kD protein"
CDS	29182..29751	gene="E3"	"20.6kD protein"
CDS	29766..29966	gene="E3"	"7.7kD protein"
CDS	30083..30313	gene="E3"	"10.3kD protein"
CDS	30285..30722	gene="E3"	"14.9kD protien"
CDS	30715..31122	gene="E3"	"14.7kD protein"
polyA_site	31128..31133	"Genscan predicted polyA site for E3"	
CDS	complement (31141..31305)	gene=""	"U protein"
CDS	31320..32297	gene="L5"	"fiber protein"
polyA_site	complement (32317..32322)	"Genscan prediction for polyA site of E4"	
CDS	complement (32333..32584)	gene="E4"	"orf 6/7 protein"
CDS	complement (32581..33480)	gene="E4"	"33.2kD protein"
CDS	complement (33383..33751)	gene="E4"	"13.6kD protein"
CDS	33606..34115	gene="L5"	"agnoprotein"
CDS	complement (33760..34113)	gene="E4"	"34kD protein"
CDS	complement (34110..34499)	gene="E4"	" 130aa protein"
polyA_site	34122..34127	"possible polyA site for the L5 gene"	
CDS	complement (34541..34918)	gene="E4"	"13.9kD protein"
Promoter	complement (35000..35005)	"TATA box for E4"	
repeat_region	complement (35199..35306)	"the inverted terminal repeat"	

Table 47: Ad7FS_navy (Accession No. AY601634; SEQ ID NO: 583) Sequence Features and putative gene products

Feature Type	Location	Comment or Gene Locus	Product
repeat_region	0..135	"the inverted terminal repeat"	
promoter	479..484	"TATA box for E1A"	
CDS	575..1168	gene="E1A"	"hypothetical E1A protein"
CDS	join (575..646, 1249..1350)	gene="E1A"	"6KD protein"
CDS	join (575..1154, 1249..1454)	gene="E1A"	"mRNAI, 28 KD E1A protein"
CDS	join (575..1061, 1249..1454)	gene="E1A"	"mRNAII protein"
polyA_signal	1493..1498	"polyA signal for E1A gene"	
promoter	1548..1553	"TATA box for E1B"	
CDS	1602..2138	gene="E1B"	"20KD small T antigen"
CDS	1907..3385	gene="E1B"	"transformation associated 55KD protein"
Promoter	3383..3388	"TATA box for proteinIX"	
polyA_signal	3401..3406	"possible polyA signal for E1B gene"	
CDS	3479..3895	gene="pIX"	"proteinIX"
polyA_signal	3908..3913	"polyA signal for the proteinIX gene"	
polyA_signal	complement (3926..3931)	"possible polyA signal for E2B genes"	
CDS	complement (join (5560..5572, 3948..5281)	gene="E2B"	"maturation protein IVa2"
CDS	complement (5051..8419)	gene="E2B"	"DNA polymerase"

Promoter	5872..5877	"TATA box for the major late promoter"	
CDS	6144..6464	gene="hypothetical"	"hypothetical protein A-106"
CDS	complement (6868..7389)	gene="E2B"	"hypothetical 19KD protein"
CDS	7133..7420	gene="L1"	"hypothetical 10.4KD protein"
CDS	7829..8425	gene="L1"	"15.3KD agnoprotein"
CDS	complement (8328..8573)	gene="E2B"	"hypothetical 12.6kD early protein"
CDS	complement (8422..10344)	gene="E2B"	"preterminal DNA-binding protein"
CDS	8548..8949	gene="hypothetical"	"hypothetical 14.5KD early protein"
CDS	9757..10032	gene="hypothetical"	"hypothetical 9.7KD protein"
Misc_RNA	10424..10584	"VA RNA I"	
Misc_RNA	10655..10829	"VA RNA II"	
CDS	10806..11975	gene=L1"	"55KD protein"
CDS	12000..13766	gene="L1"	"peripentonal hexon associated protein IIIA"
polyA_signal	13779..13784	"polyA signal for L1"	
CDS	13854..15488	gene="L2"	"penton base protein"
CDS	15500..16078	gene="L2"	"major core protein precursor pVII"
CDS	16121..17173	gene="L2"	"minor core protein precursor pV"
polyA_signal	17448..17453	"possible polyA signal for L2"	
CDS	17505..18239	gene="L3"	"pVI precursor"
CDS	18352..21156	gene="L3"	"the hexon protein"
CDS	21193..21822	gene="L3"	"23KD proteinase"
polyA_signal	21842..21847	"possible polyA signal for L3"	
polyA_signal	complement (21854..21859)	"possible polyA signal for E2A"	
CDS	complement (21911..23464)	gene="E2A"	"DNA binding protein"
CDS	23495..25984	gene="L4"	"100KD protein"
CDS	25686..26285	gene="L4"	"22KD protein"
CDS	join (25686..26034,26204..26559)	gene="L4"	"33KD protein"
CDS	26719..27312	gene="L4"	"pVIII protein"
Promoter	26994..26999	"putative TATA box for the E3 gene"	
CDS	27312..27632	gene="E3A"	"12.1KD glycoprotein"
polyA_signal	27391..27396	"possible polyA signal for L4"	
CDS	27586..28026	gene="E3A"	"16.1KD protein"
CDS	28011..28529	gene="E3A"	"19KD MHC classI antigen-binding glycoprotein"
CDS	28559..29083	gene="E3A"	"20.3KD glycoprotein"
CDS	29110..29679	gene="E3A"	"20.3KD protein"
CDS	29694..29819	gene="E3A"	"7.7KD protein"
CDS	29931..30206	gene="E3B"	"10.3KD protein"
CDS	30178..30615	gene="E3B"	"14.9KD protein"
CDS	30608..31015	gene="E3B"	"15.3KD protein"
polyA_signal	31021..31026	"putative polyA signal for E3"	
CDS	31213..32190	gene="L5"	"fiber protein"
polyA_signal)	complement (32209..32214)	"polyA signal for the E4 gene"	
CDS	complement (32225..32476)	gene="E4"	"ORF6/7"
CDS	complement (32473..33372)	gene="E4"	"32KD protein"

CDS	complement (33275..33643)	gene="E4"	"13.6KD protein"
CDS	33498..34007	gene="L5"	"agnoprotein"
CDS	complement (33652..34005)	gene="E4"	"13KD protein"
CDS	complement (34002..34391)	gene="E4"	"130aa protein
CDS	complement (34433..34810)	gene="E4"	"13.9KD protein"
Promoter	complement (34891..24896)	"possible TATA box for the E4 gene"	
repeat_region	complement (35062..35197)	"the inverted terminal repeat"	

Table 48: Ad7vaccine (Accession No. AY594256; SEQ ID NO: 584) Sequence Features and putative gene products

Feature Type	Location	Comment or Gene Locus	Product
misc_feature	1..136	"the inverted terminal repeat"	
promoter	476..481	"TATA box for the E1A genes"	
CDS	join (572..647, 1247..1348)	gene="E1A"	"E1A 6kD protein"
CDS	join (572..1157, 1246..1452)	gene="E1A"	"E1A mRNA I protein, homologous to the 29.1 kD protein in Ad11"
CDS	join (572..1067, 1246..1452)	gene="E1A"	"E1A mRNA II protein, homologous to the 25.7kD E1A protein in Ad 11"
polyA_site	1490..1495		
promoter	1545..1550	"TATA box for E1B"	
CDS	1599..2136	gene="E1B"	" 20kd protein, small T antigen"
CDS	1904..3382	gene="E1B"	"55kD protein"
promoter	3380..3385	"TATA box for pIX"	
CDS	3476..3892	gene="pIX"	"protein IX"
polyA_site	3905..3910		
polyA_site	complement (3923..3928)		
CDS	complement (join (3945..5278, 5557..5569))	gene="E2B"	"pIVA2"
CDS	complement (5048..8416)	gene="E2B"	"DNA polymerase"
promoter	5869..5874	"TATA box for the major late promoter"	
CDS	6141..6461	gene="hypothetical"	"A-106 hypothetical protein"
CDS	7826..8422	gene=" agnoprotein gene"	"13.6kD agnoprotein"
CDS	complement (8419..10341)	gene="E2B"	"DNA terminal protein"
CDS	complement (9540..9854)	gene="hypothetical"	"11.3kD hypothetical protein"
CDS	9754..10029	gene="hypothetical"	"protein=9.7kD hypothetical protein"
misc_RNA	10403..10821	"VA RNA, SHORTENED DUE TO A 25bp DELETION"	"VA RNA"
CDS	10828..11997	gene="L1"	"55kD protein"
CDS	12022..13788	gene="L1"	"pIIIA precursor"
CDS	13876..15510	"L2"	"penton protein III precursor"
polyA_site	15512..15517		
CDS	15520..16098	gene="L2"	"protein VII precursor"
CDS	16141..17193	gene=" L2"	"protein V"
polyA_site	17467..17472		
CDS	17523..18275	gene="L3"	"protein VI precursor"
CDS	18388..21192	gene="L3"	"hexon"
CDS	21229..21858	gene="L3"	"23K protease"
polyA_site	21878..21883		

polyA_site	complement (21890..21895)		
CDS	complement (21947..23500)	gene="E2A"	"DNA binding protein"
CDS	23531..26020	gene="L4"	"hexon protein"
CDS	25722..26321	gene="L4"	"33KD protein"
CDS	join (25722..26070, 26252..26595)	gene="L4"	"33kD protein"
CDS	26665..27348	gene="L4"	"pIII protein"
promoter	27030..27035	"TATA box for E3"	
CDS	27348..27668	gene="E3"	"12.1kD glycoprotein"
CDS	27622..28062	gene="E3"	"16.1kD protein"
CDS	28047..28565	gene="E3"	"18.3kD glycoprotein precursor"
CDS	28595..29134	gene="E3"	"E3 20.1kD protein"
CDS	29147..29716	gene="E3"	"E3 20.6kD protein duplication"
CDS	29731..29856	gene="E3"	"E3 7.7kD protein"
CDS	29969..30244	gene="E3"	"E3 10.3kD protein"
CDS	30249..30653	gene="E3B"	"E3B 14.9kD protein precursor"
CDS	30646..31053	gene="E3B"	"E3B 14.7kD protein"
polyA_site	31059..31064		
CDS	31251..32228	gene="L5"	"L5 fiber protein"
polyA_site	complement (32247..32252)		
CDS	complement (32263..32514)	gene="E4"	"E4 orf6/7"
polyA_site	32764..32769		
CDS	complement (33313..33681)	gene="E4"	"E4 13.6kD protein"
CDS	33536..34045	gene="probable agnoprotein gene"	"probable agnoprotein"
CDS	complement (33690..34043)	gene="E4"	"E4 13kD protein"
CDS	complement (34040..34429)	gene="E4"	"13.9kD protein"
CDS	complement (34471..34848)	gene="E4"	"hypothetical protein"

Table 49: Ad16 (Accession No. AY594256; SEQ ID NO: 585) Sequence Features and putative gene products

Feature Type	Location	Comment or Gene Locus	Product
repeat_region	1..114	"the inverted terminal repeat"	
promoter	478..483	"TATA box of the E1 promoter"	
CDS	join (574..645, 1247..1348)	gene="E1A"	"6.3 kDa protein"
CDS	join (574..1060, 1247..1452)	gene="E1A"	"25.7 kDa protein"
CDS	join(574..1153,1247..1452)	gene="E1A"	"28 kDa protein"
polyA_signal	1489..1494	"polyA signal for E1A"	
promoter	1544..1549	"TATA box for the E1B gene"	
CDS	1598..2134	gene="E1B"	"19K small T-antigen protein"
CDS	1903..3381	gene="E1B"	"55K large T antigen protein"
promoter	3444..3449	"TATA box for pIX"	
CDS	3476..3892	gene="pIX"	"proteinIX"
polyA_signal	3905..3910	"polyA signal for pIX"	
polyA_signal	complement(3923..3928)	"polyA signal for E2B "	
CDS	complement (join (3945..5278, 5557..5569))	gene="E2B"	"maturation protein pIVa2"
CDS	complement (5048..8416)	gene="E2B"	"DNA polymerase"
promoter	5869..5874	"TATA box for the Major Late Promoter"	
CDS	7130..7417	gene="hypothetical"	"hypothetical 10.4K early protein"
CDS	7826..8422	gene="hypothetical"	"probable DNA binding agnoprotein"

CDS	complement (8226..8570)	gene="E2B"	"hypothetical 12.6K early protein"
CDS	complement(join(8419..10386,13843..13851))	gene="E2B"	"Terminal protein precursor"
CDS	10851..12020	gene="L1"	"55K protein"
CDS	12045..13811	gene="L1"	"protein IIIa precursor"
polyA_signal	13825..13830	"polyA signal for L1"	
CDS	13902..15569	gene="L2"	"penton base protein"
CDS	15582..16160	gene="L2"	"protein VII precursor"
CDS	16203..17255	gene="L2"	"32K proteinV"
CDS	17284..17511	gene="L2"	"proteinX"
polyA_signal	17529..17534	"polyA signal for L2"	
CDS	17586..18284	gene="L3"	"protein VI precursor"
CDS	18450..21272	gene="L3"	"the hexon protein"
CDS	21309..21938	gene="L3"	"23K protease"
polyA_signal	21958..21963	"polyA signal for L3"	
polyA_signal	complement (21970..21975)	"polyA signal for E2A"	
CDS	complement (22027..23580)	gene="E2A"	"early DNA binding protein"
CDS	23611..26097	gene="L4"	"100k protein"
CDS	25799..26398	gene="L4"	"22K protein"
CDS	join (25799..26147, 26317..26672)	"33K protein"	gene="L4"
CDS	26742..27425	gene="L4"	"protein VIII precursor"
promoter	27107..27112	"TATA box for E3"	
CDS	27425..27745	gene="E3A"	"12.2K glycoprotein"
CDS	27699..28139	gene="E3A"	"16.1K membrane protein"
polyA_signal	27734..27739	"possible polyA signal for L4"	
CDS	28124..28642	gene="E3"	"18.5K glycoprotein precursor"
CDS	28672..29211	gene="E3"	"20.1K protein"
CDS	29224..29793	gene="E3"	"20.5K glycoprotein"
CDS	29808..30023	gene="E3"	"7.7K protein"
CDS	30133..30408	gene="E3"	"10.3K protein"
CDS	30380..30817	gene="E3"	"14.9K protein"
CDS	30810..31217	gene="E3"	"14.7K protein"
polyA_signal	31258..31263	"polyA signal for E3"	
CDS	complement (31269..31433)	gene="U"	"U exon protein"
CDS	31448..32509	gene="L5"	"the fiber protein"
polyA_signal	complement (31735..31740)	"polyA signal for E4"	
polyA_signal	32520..32525	"possible polyA signal for L5"	
CDS	complement (32552..32803)	gene="E4"	"ORF6/7"
CDS	complement (32800..33696)	gene="E4"	"34K protein"
CDS	complement (33599..33967)	gene="E4"	"13.6K protein"
CDS	33822..34331	gene="L5"	"DNA binding agnoprotein"
CDS	complement (33976..34329)	gene="E4"	"13K protein"
CDS	complement (34326..34715)	gene="E4"	"14.3K protein"
CDS	complement (34757..35134)	gene="E4"	"13.9K protein"
promoter	complement (35216..35221)	"TATA box for E4"	
repeat_region	complement (35409..35522)	"the inverted terminal repeat"	

Table 50: Ad1 (Accession No. AF534906; SEQ ID NO: 586) Sequence Features and putative gene products

Feature Type	Location	Comment or Gene Locus	Product
CDS	join (560..1112, 1230..1546)	gene="E1a"	"32 kDa protein"
CDS	join (560..976, 1232..1546)	gene="E1a"	"26 kDa protein"
CDS	join (560..643, 1236..1319)	gene="E1a"	"6 kDa protein"

CDS	1717..2259	gene="E1a"	"21 kDa protein"
CDS	2022..3524	gene="E1b"	"transformation-associated protein 55 kDa"
CDS	join (2022..2270, 3291..3524)	gene="E1b"	"E1b"
CDS	join (2022..2270, 3233..3277)	gene="E1b"	"E1b"
CDS	3621..4043	gene="IX"	"hexon-associated protein 14.5 kDa"
CDS	complement (4102..5460)	gene="IVa2"	"virion morphogenesis-associated protein 51 kDa"
CDS	complement (5208..8378)	gene="IVa2"	"DNA polymerase 120 kDa"
CDS	7989..8438	gene="L1"	"16.7 kDa protein"
CDS	complement (8594..10552)	gene="E2b"	"terminal protein 75 kDa"
CDS	complement (10598..10996)	"unknown"	
CDS	11059..12306	gene="L1"	"47 kDa protein"
CDS	12327..14084	gene="IIIa"	"peripentonal hexon-associated protein 65 kDa"
CDS	14166..15890	gene="L3_1"	"penton protein 64 kDa"
CDS	15897..16493	gene="pro-VII"	"major core protein 22 kDa precursor"
CDS	16563..17669	gene="pV"	"minor core protein 42 kDa"
CDS	17793..17939	gene="L2"	"pmu 8.8 kDa"
CDS	18022..18774	gene="pVI"	"hexon-associated protein 27 kDa precursor"
CDS	18861..21755	gene="L4"	"hexon protein 109 kDa"
CDS	21788..22402	gene="L3_1"	"endopeptidase 23 kDa"
CDS	complement(22500..24089)	gene="E2a_1"	"DNA-binding protein 59 kDa"
CDS	24118..26541	gene="L5"	"hexon assembly-associated protein 90 kDa"
CDS	join(26252..26566,26769..27137)	gene="E2a_2"	"virion morphogenesis-associated protein 25 kDa"
CDS	27225..27908	gene="pVIII"	"hexon-associated protein 25 kDa"
CDS	27909..28232	gene="E3A"	"12 kDa protein"
CDS	28775..29257	gene="E3"	"glycosylated membrane protein 18.6 kDa"
CDS	29532..29816	gene="E3"	"10.7 kDa protein"
CDS	30106..30507	gene="E3"	"14.9 kDa protein"
CDS	31101..32849	gene="L5"	"fiber protein 62 kDa"
CDS	complement (join (33976..34063, 34768..34865, 35232..35594))	gene="E4"	"20 kDa protein"
CDS	complement (join (33976..34063, 34768..35054, 35232..35594))	gene="E4"	"27 kDa protein"
CDS	complement (join (33976..34063, 34768..35168, 35232..35594))	gene="E4"	"32 kDa protein"
CDS	complement (join (34764..34865, 35232..35594))	gene="E4"	"17 kDa protein"
CDS	complement (join (34764..35054, 35232..35594))	gene="E4"	"24 kDa protein"
CDS	complement (join (34764..35168, 35232..35594))	gene="E4"	"28.6 kDa protein"

Table 51: Ad21 (Accession No. AY601633; SEQ ID NO: 587) Sequence Features and putative gene products

Feature Type	Location	Comment or Gene Locus	Product
repeat_unit	1..114	"ITR"	
CDS	join(574..645,1247..1348)	gene="E1A"	"E1A 6.8 KD protein"
CDS	join(574..1155,1249..1452)	gene="E1A"	"E1A 28.4 KD protein"
CDS	join(574..1062,1249..1452)	gene="E1A"	"E1A 24.6 KD protein"
polyA_signal	1491..1496	"E1A"	
promoter	1541..1580	"E1B and IX"	
CDS	1905..3383	gene="E1B"	"E1B large T antigen"
CDS	3477..3893	gene="IX"	"protein IX (hexon-associated protein)"
polyA_signal	3906..3911	"E1B and IX"	
polyA_signal	complement (3924..3929)	"E2B and IVa2"	
CDS	complement (join (3946..5279, 5558..5570))	gene="IVa2"	"IVa2 protein (maturation protein)"
CDS	complement (5049..8417)	gene="E2B(POL)"	"DNA polymerase"
CDS	6142..6462	gene="unassigned"	"hypothetical 11.5 KD protein"
CDS	complement (6866..7387)	gene="unassigned"	"hypothetical 19 KD protein"
CDS	7131..7418	gene="unassigned"	"hypothetical 10.4 KD protein"
CDS	join (7827..8228, 9478..9495)	gene="unassigned"	"DNA binding protein"
CDS	complement (8227..8571)	gene="unassigned"	"hypothetical 12.6 KD protein"
CDS	complement (8420..10342)	gene="E2B(pTP)"	"DNA terminal protein"
CDS	8546..8947	gene="unassigned"	"hypothetical 14.5 KD protein"
CDS	complement (9541..9855)	gene="unassigned"	"hypothetical 11.5 KD protein"
CDS	9755..10030	gene="unassigned"	"hypothetical 9.7 KD protein"
promoter	complement (10521..10560)	"E2B and IVa2"	
promoter	10576..10615	"L1"	
CDS	10857..12026	gene="L1(52K)"	"L1 52K protein"
CDS	12054..13805	gene="L1(IIIa)"	"protein IIIa"
CDS	13878..15563	gene="L2(penton)"	"penton protein(protein III)"
polyA_signal	15565..15570	"L2 (penton)"	
CDS	15572..16150	gene="L2(pVII)"	"major core protein (protein VII)"
CDS	16190..17251	gene="L2(pV)"	"minor core protein (protein V)"
CDS	17280..17510	gene="L2(pX)"	"protein X (protein mu)"
polyA_signal	17528..17533	"L2 (X)"	
promoter	17542..17581	"L3"	
CDS	17583..18332	gene="L3(pVI)"	"protein VI (hexon-associated protein)"
CDS	18454..21303	gene="L3(hexon)"	"hexon protein (protein II)"
CDS	21340..21969	gene="L3(23K)"	"23K proteinase (Adenain)"
polyA_signal	21989..21994	"L3"	
polyA_signal	complement (22001..22006)	"E2A"	
CDS	complement (22058..23611)	gene="E2A(DBP)"	"early E2A DNA-binding protein"
promoter	complement (23560..23599)	"E2A"	
promoter	23601..23641	"L4"	

CDS	23642..26113	gene="L4(100K)"	"100K protein"
CDS	25815..26414	gene="L4(22K)"	"22K protein"
CDS	join (25815..26163, 26354..26688)	gene="L4(33K)"	"33K protein"
polyA_signal	26559..26564	"L4 (100K and 22K)"	
CDS	26758..27441	gene="L4(pVIII)"	"L4 protein VIII"
CDS	27441..27761	gene="E3"	"E3 12.1 KD protein"
CDS	27715..28155	gene="E3"	"E3 16 KD protein"
polyA_signal	27750..27755	"E3"	
CDS	28140..28658	gene="E3"	"E3 19.2 KD protein"
CDS	28688..29227	gene="E3"	"E3 20 KD protein"
CDS	29240..29827	gene="E3"	"E3 21.2 KD protein"
CDS	29857..30084	gene="E3"	"E3 8.8 KD protein"
CDS	30124..30399	gene="E3"	"E3 10.3 KD protein"
CDS	30371..30808	gene="E3"	"E3 16.6 KD protein"
CDS	30801..31208	gene="E3"	"E3 15.3 KD protein"
CDS	31406..32377	gene="L5(fiber)"	"fiber protein"
polyA_signal	32380..32385	"L5"	
polyA_signal	complement (32397..32402)	"E4"	
CDS	complement (join (32409..32660, 33383..33556))	gene="E4"	"E4 16 KD protein"
CDS	complement (32657..33556)	gene="E4"	"E4 34.7 KD protein"
CDS	complement (33459..33827)	gene="E4"	"E4 14.3 KD protein"
CDS	33682..34191	gene="unassigned"	"agonoprotein" similarity to Human Adenovirus B agonoprotein, GI: 32967054
CDS	complement (33836..34189)	gene="E4"	"E4 13.6 KD protein"
CDS	complement (34186..34575)	gene="E4"	"E4 14.4 KD protein"
CDS	complement (34617..34994)	gene="E4"	"E4 14.2 KD protein"
repeat_unit	complement (35269..35382)	"ITR"	

For the products designated above in Tables 39-51, the present inventors note that it is routine in the art by referring to the universal genetic code to translate the nucleic acid sequence identified in the "location" column to the corresponding amino acid sequence. As such, the amino acid sequences designated in the "product" column have not been explicitly listed.

Referring now to the drawings, wherein like reference numerals designate identical or corresponding parts throughout the several views. Herein, "meaningful" relates generally to a predetermined level of statistical significance or certainty of a result. Alternatively, meaningful indicates a predetermined level of usefulness to a user for drawing a conclusion regarding the presence of a specific biological entity or group of entities. For example, BLAST returns an E-value (corresponding to a probability), where the product of the E-value with the number of known sequences (probability times opportunities) within the database corresponds to the total number of sequence database records that could return the same similarity value (bit score) for the queried subsequence. If a reshuffling of the submitted test sequence returns the same E-value, the original result was not meaningful. Further, the term "Comparable" used herein refers generally to data that includes a sufficient amount (for example, a system or user-defined threshold number or percentage) of actual base calls (non-Ns) to return meaningful results from a similarity search. Additionally, the term "Comparable" can be used interchangeably with respect to the usefulness of results returned to a user from a similarity search using the data. Conversely, the term "non-Comparable" refers generally to data that includes a sufficient amount (in number or percentage) of non-base calls (Ns) to cause less meaningful or ambiguous results from a similarity search.

The system, including the REPI (Resequencing Pathogen Identifier), is designed to automatically and algorithmically parse an output of a incomplete nucleotide or polypeptide sequences by selecting and editing sequence data into subsequences more suitable for sequence similarity searches. To accomplish this objective, the system includes several functional steps, or filters, to modify the data as little as possible while extracting Comparable data from the sequence data. As described above, due to the nature of the resequencing microarray, the sequences often contain large amounts of non-base calls (Ns). Similarity searches such as BLAST typically return ambiguous results for sequences with a large amount of non-base calls. Examples of ambiguous results include, but are not limited to low bit scores and expect (E) values that do not predict a unique similarity match. Therefore an embodiment of the present system extracts those portions, or subsequences, of original sequences that are most likely to return meaningful results from a similarity search.

FIG. 11(a) is an exemplary schematic drawing of an embodiment of the present invention. Sequence data 203 are first processed by an Automated Subsequence Parsing module (ASP) 209 of the system 208. The ASP 209 filters the sequence data 203 and selects only those subsets which are likely to result in predetermined probability (e.g. a BLAST expect value of < 1.0E-9) matches 211a. These subsets are then compared to a sequence database 109 using, for example, a similarity search algorithm, and the results are returned to the system for further analysis and summarization 214. The resulting search summary 213 is then presented to a user for more in depth analysis 215. Because sequence subsets inherently unlikely to return statistically relevant (e.g. a BLAST expect value of < $1.0e^{-9}$) search results are removed by the ASP, the results 213 returned to the user generally include a higher proportion of significant (e.g. a BLAST expect value of < $1.0e^{-9}$) matches 213a than the conventional method of submitting an unparsed sequence. In particular embodiments using a BLAST or BLAST-like similarity search algorithm, expect values between $1.0e^{-150}$ to 2 are preferable. More preferably, expect values are between $1.0e^{-9}$ and 0.5. Even more preferably, embodiments involving BLAST include a bit score and expect value that allows the unique identification of a single pathogen database record. Optionally, the system 208 further filters results in the summary to display only those subsequence matches meeting criteria set by a user or predetermined by the system. These criteria can include but are not limited to: bit score, expect value (chance that another sequence could result in an identical score), or another score derived from the relative positions of subsequences or the microarray signal intensities of regions used to make base calls. Also illustrated in FIG. 11(a) is the enhanced ability of the shared sequence database and comparison resource 109 to provide results to additional users 219 over a network connection 217.

FIG. 11(b) is an exemplary embodiment of REPI, itself an embodiment of the system. Sequence data 203' are first processed by an Automated Subsequence Parsing module (ASP) 209' of the REPI 208'. The ASP 209' filters the sequence data 203' and selects only those subsets which are likely to result in high probability matches 211a'. These subsets are then compared to a sequence database 109' using a similarity search algorithm, and the results are returned to the REPI for further analysis and summarization 214'. The resulting search summary 213' is then presented to a user for more in depth analysis 215'. As sequence subsets inherently unlikely to return statistically relevant search results are removed by the ASP, the results 213' returned to the user generally include a higher proportion of significant matches 213a' than the conventional method of submitting an unparsed sequence. Optionally, the REPI 208' further filters results in the summary to display only those subsequence matches meeting criteria set by a user or predetermined by the system. Also illustrated in FIG. 11(b) is the enhanced ability of the shared sequence database and comparison resource 109' to provide results to additional users 219' over a network connection 217'.

FIG. 11(c) is an exemplary screen shot of an interface (a graphical user interface in this case) for an embodiment of the system in software form. This particular embodiment can interface with network and local BLAST servers (either or both), and enables the modification of several common BLAST parameters 251. Additionally, as described in more detail below, parameters specific to the parsing algorithm 253, such as the window size, are optionally made available to a user.

FIG. 12 is a flowchart describing the general functionality of the CIBSI, including the ASP. The CIBSI receives "raw" sequence data at the start of the operation S301. REPI may receive sequence data in a variety of formats, including but not limited to FASTA, MSF, GCG, Clustal, BLC, PIR, MSP, PFAM, POSTAL, and JNET. In the case of conventional and resequencing microarrays, the sequence data typically takes the form of multiple sequences of base calls corresponding to multiple tiled regions of the microarray in FASTA format.

In addition to its flexibility with respect to sequence data formats, the system accepts sequence data from a variety of different source types. As described above, these types include, but are not limited to, manual or automated Sanger sequencing, shotgun sequencing, conventional microarrays, resequencing microarrays, microelectrophoretic sequencing, sequencing by hybridization (SBH), Edman degradation and variants thereof, Cyclic-array sequencing on amplified molecules, Cyclic-array sequencing on single molecules, and non-cyclical, single-molecule, real-time methods such as nanopore sequencing. Alternatively, the raw sequence S301 can be comprised of transcript nucleic acids (messenger ribonucleic acid (mRNA) or intermediate phase sequences used for viral transcription and translation. For example, in an embodiment of the invention directed towards RNA transcripts, RNA can either be hybridized directly to an array after it is fragmented (as done with Affymetrix gene expression arrays) or converted to DNA using reverse transcriptase. Tile regions are constructed from exon (protein coding sequences) regions of the genome and a resequencing array is used to analyze which of the sequences made it into transcripts. In alternative embodiments, the process described in FIG. 12 corresponds to amino acid sequences, where the set of raw sequence(s) S301 may represent direct reads of amino acids or sequences inferred from amino acid compositions as measured by high-resolution mass spectrometry. Optionally, raw amino acid or protein data in which relative position is not conserved is analyzed to include relative position data.

In a resequencing microarray, the structure of the overall gene sequence is suggested by the position of the partial sequences within the overall structure of the resequencing tile. For example, the resequencing array may only give reads of 5-10 consecutive base calls at a time, each of which are separated by a consecutive series of Ns. FIG. 33 depicts a more general description of this concept that is applicable to any collection of partial sequence reads. Thus, any collection of nucleotide base calls or amino acid sequences which have no apparent relationship to one another can first be compared to a "Virtual Sequence" against which the shorter detected sequences are compared. The consecutive base calls, or partial sequences, are then related as individual portions of a collective sequence. Thus, in order for the partial sequence data from the microarray or any other sequence generation platform to be more effectively and efficiently processed by the CIBSI, the partial sequences are first assembled into a collective arrangement, or composite sequence. To determine which partial sequences should be combined and submitted, each detected subsequence is compared using a similarity search with a group of reference sequences stored in memory. The partial sequences that result satisfactory matches when compared against one of the reference sequences are then stored as part of a composite sequence to be submitted the CIBSI for analysis.

The process for formatting the sequence data extracted from a resequencing microarray is depicted in the

flowchart shown in FIG. 33. The sequence information is extracted from the resequencing microarray or any other nucleotide or polypeptide sequencing platform S2403, and processed to detect partial sequences separated by a consecutive series of Ns S2405. The step of detecting the partial sequences may be carried out by a windowing function which initiates a viewing window upon the detection of a base call and ends the viewing window when another series of Ns are detected. Thus a window is created around the partial sequence data, and the Ns separating the partial sequence reads are trimmed away. A scanning operation may also be performed on the sequence data that identifies each consecutive series of Ns, thereby indicating the groups of base-calls corresponding to the partial sequences.

Each identified partial sequence is then compared against a stored reference sequence S2409 to determine whether the partial sequence corresponds to one of the stored reference sequences. This comparison will yield a statistical value indicating the similarity between the stored reference sequence and the partial sequence. Then, if the statistical value is beyond a predetermined threshold, the partial sequence is stored S2413 to be combined with other partial sequences SS2415. Alternatively, if the statistical value is below a predetermined threshold, the partial sequence is discarded. This process continues until all the partial sequences are compared, thus generating a composite set of data to be submitted to the CIBSI, as discussed below.

The system then performs a Control Check S303 before extracting a candidate subsequence S305. After extraction of a candidate subsequence, the system then trims the non-calls (Ns) from the beginning and end of the candidate subsequence S307. Then the system checks the length of the trimmed candidate subsequence S309 to determine whether an alternative sequence or subsequence should be selected S311, the candidate subsequence is ready to go to a similarity search server or be added to a similarity search queue S315, or whether an additional check of the percentage or proper base calls in the subsequence meets an acceptable threshold for sending it to be compared (using a similarity search). The selection of an alternative sequence or subsequence S311 is accomplished in one embodiment through the use of a sliding window algorithm. For those sequences that are sent to be compared S315, the system gathers the results returned from the similarity search server, performs statistical analysis on these results and filters them for the user according to user preferences S317. Optionally, the system can simply return similarity search results for the submitted subsequences. Also, as will be made more evident given the exemplary embodiments described below, the steps of the algorithm can be rearranged or modified in alternative embodiments. Further, as also described in more detail below, the behavior of the system is predetermined by the system or optionally defined by the user.

The following paragraphs describe each of the main functional steps shown in FIG. 12 in more detail.

FIG. 13 is an exemplary flowchart of a control check module for performing the Control Check step S303. Here, a sequence is first checked to see if it is a control sequence often outputted by microarrays S403 that do not correspond to a biological sample, but instead confirm that the microarray is functioning properly. The control sequence incorporated into the microarray is specifically designed to be a nonsense, uniquely identifiable, or non-naturally occurring sequence; therefore, by default, a control sequence will not return a significant similarity. If a sequence is not a control, the system may optionally check if the sequence matches an alternative custom parameter flag S407 before continuing on to the next step S409. In the case that the sequence is recognized as either a control or matching a custom parameter, the system optionally performs a supplementary function corresponding to the custom parameter or moves onto the next sequence S405.

FIG. 14is an exemplary flowchart of the extract subsequence step S305. Having preliminary selected a sequence S501, the system views the sequence within the context of a window of size Z S503, where Z is a

Window Size parameter corresponding to a number of returned base calls. This "viewing window" is typically smaller in length than the size of a typical sequence and can begin at any point in the sequence. Then the system calculates a percentage of actual base calls (non-Ns) contained within the window S505. In the illustrated example, the calculation is performed by associating a "1" with valid bases and a "0" with all Ns. In one embodiment, the window size Z can be selected from a range preferably between two base calls and half the length of the smallest target or input sequence. As the window size Z increases, the module becomes more permissive with respect to selecting candidate subsequences including more non-base calls.

The calculated percentage is then compared to a First Jump Threshold parameter, A (for example, 25%), which can either be predetermined by the system or selected by a user S507. If the calculated percentage of actual base calls within the window does not satisfy the criteria defined by the First Jump Threshold, A, the system advances the window a number of base calls S509 according to a First Window Jump parameter, X, that may also be predetermined by the system or selected by the user, but is preferably between one and Z, the Window Size parameter. Advancement of the window at this or any other point can occur in any direction (for example, towards the end of the sequence). In the case of the calculated percentage of actual base calls within the window satisfies the criteria defined by the First Jump Threshold A, the system marks the beginning of a candidate subsequence S511 at the beginning of the sliding window. The window is then moved incrementally a number of base calls S513 according to a Second Window Jump parameter, Y, and at each slide increment, the percentage of actual base calls within the window is calculated S515. If the calculated percentage of actual base calls within the candidate subsequence fails to meet the criteria set by a Second Jump Threshold B, the system marks the end of the candidate subsequence at the base call of the sequence corresponding to the base call at the end of the window S519. For each sequence, the system searches for the largest continuous string(s) of usable data. As the Window Jump parameters X and Y increase, the module becomes more permissive with respect to selecting candidate subsequences with a greater number of non-base calls. As the Jump Thresholds A and B increase *ceteris paribus*, the module becomes less permissive.

FIG. 14(b) is an example of a sliding window algorithm according to an embodiment of the present invention. The beginning and end positions of the sliding window 551 determine the length and contents of the candidate subsequence 553. This subsequence is then trimmed in a Trim function described below.

FIG. 15 is an exemplary flowchart describing in more detail the Trim function S307 performed by the system. In this particular functional module, the system detects the beginning Ns of a candidate subsequence S603 and subsequently trims the beginning Ns from the candidate subsequence S605. The system then recognizes that the actual start of the candidate subsequence has changed S607 and adjusts the location and contents of the candidate subsequence accordingly. A similar set of actions is performed to remove the Ns at the end of the candidate subsequence S613, S617. Trimming increases optimality of the algorithm since the sliding window method described herein allows for sequences to begin and end with Ns. Alternatively, the sliding window function can be adapted or replaced to detect and avoid Ns and the beginning and/or end of a candidate subsequence, thus obviating the need for this step.

The next function of the system is a length evaluation S309. FIG. 16 shows an exemplary flowchart detailing a method for performing the Check Length step S309. The length of the candidate subsequence is calculated S703 and compared against a First Length Threshold parameter, E S705. If the length of the candidate subsequence is not greater than E (for example, 20 nucleotides), the system returns to the extract subsequence step S305. If the First Length Threshold parameter E is met, the length of the candidate subsequence is compared

against a Second Length Threshold parameter, F (for example, 50 nucleotides) S709. If the length of the candidate subsequence exceeds F, the candidate subsequence is sent to the similarity search (comparison) server or added to a queue S711 for batch processing of selected subsequences by the server. In the case that the candidate subsequence exceeds E but does not exceed F, the system moves on to the step of checking the percentage of actual base calls within this intermediate-length (for example, a subsequence with a length between 20 and 50 nucleotides) candidate subsequence S713. The First and Second Length Threshold parameters E and F can vary over a range as wide as the greatest searchable subsequence. Further, the module becomes more permissive as E and F decrease.

FIG. 17 shows an exemplary flowchart of the Calculate Percentage function S313. Within this function, a percentage of actual base calls is calculated for an intermediate-length candidate subsequence S803. This calculated percentage is compared S805 against an Intermediate Percentage Threshold, H, which is selected by the user or predetermined by the system. If the calculated percentage of actual base calls is less than the Intermediate Percentage Threshold parameter, H (for example, 60%), the system returns S807 to the Extract Subsequence step to search for an alternative candidate subsequence. If the calculated percentage exceeds H, the intermediate-length candidate subsequence is sent to either the queue for batch processing of subsequences or sent to the similarity search server immediately S809. As the Intermediate Percentage Score Threshold parameter increases, the module becomes less permissive of subsequences with larger amounts of non-base calls.

In addition to receiving results from the similarity search regarding submitted subsequences, the system optionally provides further analysis of the submitted subsequences. FIG. 18(a) is an exemplary flowchart describing in more detail the actions of the system within module S317 of FIG. 12. This module begins after a subsequence or group of subsequences has been compared S901. At this point, the system reads the similarity search output S903 and analyzes the output, and calculates additional descriptive statistics regarding submitted subsequences that are selected by the user or predetermined by the system S905.

The analysis performed and statistics calculated by the system include, but are not limited to, the selected subsequence length as a percentage of the sequence and the subsequence length in base calls, which together can be used to indicate what portion of the target biological entity gene was identified. The subsequence length and percentage of subsequence base calls allow a researcher to monitor the system's algorithms and functional steps. Further, in the case of resequencing microarrays, threshold parameters for base calling algorithms including, but not limited to, GDAS, can be monitored. In an alternative embodiment, the system accepts and also formats statistical results returned from the similarity search, allowing the user to manipulate and organize results using a provided graphical user interface. FIG. 18(b) is an example of output results data according to an embodiment of the present invention.

Optionally, the system can store all of the outputs returned by a similarity search and analysis described above S907, including, for example, BLAST results. The system also optionally displays S909 all of the results or a subset of the results returned by a similarity search and/or calculated by this system to the user. Certain embodiments of the present invention then allow these results to be sent and saved for archiving or transfer S911.

The following table illustrates exemplary ranges and preferable subranges for several exemplary parameters and thresholds described above.

Preferred subranges:

Table 52

Expect Value Threshold		1.0 E-9	1.0 E-8 – 1.0 E-10	1.0 E-7 – 1.0 E-11
Window Size	Z	20	10 – 30	1 – *
First Jump Threshold	A	25%	15% - 35%	1% - 99%
First Window Jump	X	1	1 – 5	1 - *
Second Window Jump	Y	1	1 – 5	1 - *
Second Jump Threshold	B	25%	15% - 35%	1% - 99%
First Length Threshold	E	20	10 – 30	1 – *
Second Length Threshold	F	50	40 – 60	1 – *
Interm. Percentage Threshold	H	60%	50% - 70%	1% - 99%
* constrained by system parameters such as random access memory (RAM), processor speed, etc.				

In yet another embodiment of the system, the search (comparison) output can be analyzed for Optimization Parameters, J, S913. As described above, Parameters and Thresholds of the system, including but not limited to A, B, X, Y, E, F, and H, are set by the user or predetermined by the system. Alternatively, an embodiment of the system enables the optimization of one or several of these variables by the system itself or through the use of a complementary functional module. For example, optimization of a Parameter or Threshold could be performed in accordance with well-known optimization (for example, SIMPLEX linear programming) or Artificial Intelligence (including state space search methods such as uniform or heuristic search) techniques by analyzing system performance recorded over the course of multiple uses or "passes" of system operation. Corresponding Optimization parameters, J, can be used, for example, to automatically alter the various parameters and thresholds used in the previous steps and run the process again using these new optimized parameters S917. Alternatively, instead of starting again from the raw data file, the Optimization Parameter J can be used to refine output of selected subsequences S915 by using the Optimization Parameters J to alter parameters related to, for example, the behavior or function of a similarity search algorithm used in conjunction with the system. The Optimization Parameters can be adjusted by a user or the system itself to enhance system performance with respect to, for example, speed or relevant/meaningful similarity search results.

FIG. 19 is an exemplary flowchart describing yet another embodiment of the present invention that utilizes its extensible, kernel-like nature. In particular, the system analysis 1017 is used to optimize or otherwise alter parameters corresponding to the operation or behavior of the similarity search algorithm 1009. For instance, this alteration may be related to optimization parameters J described above calculated or interpolated from the REPI's analyzed results 1017. Altering the similarity search parameters (for example, BLAST parameters) alters the method and scoring system typically used in a similarity search. In particular, the illustrated iterative analysis may result in more or less stringent thresholds for suggesting possible matches of test subsequences to known sequences, thus altering or optimizing the output 1019 of the system.

The description of the present invention is further aided by the following detailed example. The following detailed example corresponds to an exemplary embodiment of the invention and is not intended to set forth restrictions on the invention with regard to system operation, parameter settings, sequence data, etc.

An embodiment of the REPI was used to ascertain which base call subsequences from the CustomSeq /

GCOS /GDAS process would likely return significant BLAST results through the use of a customized sliding window algorithm. Subsequently, REPI automatically returns BLAST outputs to the end user that allow probabilistic assignments to the likelihood that a given set of base calls correspond to a particular microbial sequence. Moreover, the REPI automatically links sequence fragments to individual pathogens.

Raw sequence data from the resequencing microarray chips is provided by the Genetic Data Analysis Software version 2.0 (GDAS) packaged with the microarray reader from Affymetrix. GDAS base calling is based on a previously described base-calling algorithm (Cutler et al., 2001). Each of the FASTA output files containing the base calls obtained from the GDAS software was analyzed using specialized software (an embodiment of REPI) that is an exemplary embodiment of the present invention described herein.

In the case of the present examples, the sequence output of GDAS is most often a scattered mixture of contiguous sequence calls (A, T, C or G) that are interspersed with varying amounts of no-calls (Ns) where the GDAS software does not make a base call due to weak hybridization signal on the chip and/or high background hybridization caused by non-specific binding (Cutler et al., 2001). An example output of the GDAS output for an Adenovirus 4 (+) clinical sample for the Ad4FIBER tile region is shown below:

```
>Ad4FIBER:609124A2-8.7.03- 2hour hybridization  Start=12 End=1245
tcccnacgatgcagncnncnnncgacnangcccttcatcaaccctcccttcgnnctcttcagntggnttc
caagaaaagccccctgggggtgttgncentaggnnntnnncgaccctgncncnccangaatggggaaanca
cncnnantntggngnannnngtggaccttgacgnctcgggaaanctcnttgcaancncagncnnnaagnn
cattgnnnctnntagnttttnccancaacnccattnnnnnttaacatggnnnccccttaanncnccaaag
ntggaaanctnncctincaagnttctnncnccattaagtatattnngnnnnnnnnntnnnnnntnnntnn
nctnnnctttngctcaggtttnggacngnnnngnagngntnngncagtacagttagcctctncnctinc
atttgnngnnaaagggaanaaaagnttnnnntnnntnnnggnttgcatgttacaacaggaantgcaatt
gaaagcaacattagntgggctnaaggtnnaaaatttgaagatggtgccanagcnncaaacattggtaagn
nntnnnnnntnnnaaccagnagnncagaancaggagntaanaangcttnncaanccaagntaaanttgn
atctggncncagctttgncagcncaggagnnntaatgnctggcaataaagncnnngananattancttg
tggacaacgcctgacccatcannaaactgncaaatnctngcngaaaangangcaaanctancnctttgct
tnacnnagnnngnnagncaaatnctggccactgnancagntttggntgntagaagnggnancntaaaccc
aattnctggcacagnaagcagngctcaagnttttcnncgntttgatgcaancngtgntctttancngan
cactcnannnnnaaaaaatactggggctacnggnaaggagatagcatagatggcactncatacaccaatg
ctgttggntncntgccaaattcancagcttntnnaaagacncaaagttctnctnntaaaaataatntann
nngncaagnatnnatgaatggngntgtttnaaaacccangcttcttnctatanctcttaatggnnctgnt
gacaccaccagtgcatnntnnntttnattttcntncacctggactaacggaagctanatcggagcaacat
ttggagctaactcatacaccttcncntacanngcccannaannn
```

In the examples provided, REPI was interfaced to a local BLAST (NCBI nt) database (contained on an Apple G5 single processor (1.8 GHz) computer with 4.5 GB of random access memory) via a CGI (Perl) interface. Displayed results included all database sequences within an expect value (E-value) threshold of 1.0e-9. The E-value represents the number of alignments expected at random given the size of the search space, the scoring matrix, and the gap penalties; the lower the E-value the less likely the database sequence similarity matches was in fact a random identification.

The REPI output is comprised of the (Comparable) subsequence and its name, followed by the names,

lengths, E-values, and bits scores for each match with that subsequence in descending order of bit scores. The name is reported as the GenBank record's FASTA definition line and includes the sequence length. The score is the normalized score computed from the scoring matrix and gap penalties, the higher the score the greater the similarity.

The REPI output of the example listed above is shown below. For each Comparable subsequence, REPI returns (in descending order of bit score ranking) all GenBank data records having expect values of < the evalue threshold value, currently 1.0 E-9. The highest bit score is achieved for the adenovirus 4 prototype while field strains from Air Force and Navy training sites are suitably distinguished by lower bit scores.

```
>Ad4FIBER:609124A2-8.7.03- 2hour hybridization  Start=12 End=1245
 Subsequence:
tcccnacgatgcagncnncnnncgacnangcccttcatcaaccctcccttcgnnctcttcagntg
gnttccaagaaaagccccctgggggtgttgnccntaggnnntnnncgaccctgncncnccangaat
ggggaaancacncnnantntggngnannnngtggaccttgacgnctcgggaaanctcnttgcaan
cncagncnnnaagnncattgnnnctnntagntttttnccancaacnccattnnnnnttaacatggn
nncccctttannenccaaagntggaaanctnnccttncaagnttctnncnccattaagtatattn
ngnnnnnnnnnnt
 Subsequence Percentage of Target: 27%
 Subsequence Length: 337
 Number of Subsequence Base Calls: 249
 Percentage of Subsequence Base Calls: 74%
      gi|434913|emb|X76547.1|AV4FIB1 Adenovirus type 4 gene for
fiber protein; Length = 1375
           evalue: 3.35737E-33, score: 149.17 for Ad4FIBER
      lcl|AY599837 | Human Adenovirus serotype 4, USAF Field
Strain | 35,964bp; Length = 35964
           evalue: 4.51313E-20, score: 105.558 for Ad4FIBER
      lcl|AY599835 | Human Adenovirus serotype 4, US Navy Field
Strain | 35,965bp; Length = 35965
           evalue: 4.51313E-20, score: 105.558 for Ad4FIBER
      lcl|AY594254 | Human Adenovirus serotype 4, vaccine
strain#| 35,994bp; Length = 35994
           evalue: 4.34733E-17, score: 95.646 for Ad4FIBER
      lcl|AY594253 |Human Adenovirus Serotype 4| 35,990bp; Length
= 35990
           evalue: 4.34733E-17, score: 95.646 for Ad4FIBER
     gi|17105037|gb|AF394196.1|AF394196 Simian adenovirus 25,
complete genome; Length = 36521
           evalue: 2.58354E-12, score: 79.7872 for Ad4FIBER
     gi|33694802|tpg|BK000413.1| TPA: Simian adenovirus 25,
complete genome; Length = 36519
           evalue: 2.58354E-12, score: 79.7872 for Ad4FIBER
```

gi|22796371|emb|AJ315930.1|HAD315930 Human adenovirus type 4 DNA; Length = 12718

evalue: 2.58354E-12, score: 79.7872 for Ad4FIBER

Subsequence:

tnnntnnnctnnnctttttngctcaggtttnggacngnnnngnagngntnngncagtacagttagc
ctctncnctttncatttgnngnnaaagggaananaaaagnttnnnntnnntnnnggnttgcatgtta
caacaggaantgcaattgaaagcaacattagntgggctnaaggtnnaaaatttgaagatggtgcc
anagcnncaaacattggtaagnnntnnnnnntnnnaaccagnagnncagaancaggagntaanaa
ngcttnnccaanccaagntaaanttgnatctggncncagctttgncagcncaggagnnntaatgn
ctggcaataaagncnnnganananattanctttgtggacaacgcctgacccatcannaaactgncaa
atnctngcngaaaangangcaaanctancnctttgcttnacnnagnnngnnagncaaatnctggc
cactgnancagntttggntgntagaagnggnancntaaacccaattnctggcacagnaagcagng
ctcaagnttttcnncgntttgatgcaancngtgntcttttancngancactcnannnnnaaaaaa
tactggggctacnggnaaggagatagcatagatggcactncatacaccaatgctgttggntncnt
gccaaattcancagcttntnnaaagacncaaagttctnctnntaaaaataatntannnngncaag
natnnatgaatggngntgtttnaaaacccangcttcttnctatanctcttaatggnnctgntgac
accaccagtgcatnntnnntttnatttttcntncacctggactaacggaagctanatcggagcaac
atttggagctaactcatacaccttcncntacanngcccannaa

Subsequence Percentage of Target: 72%

Subsequence Length: 888

Number of Subsequence Base Calls: 701

Percentage of Subsequence Base Calls: 79%

gi|434913|emb|X76547.1|AV4FIB1 Adenovirus type 4 gene for fiber protein; Length = 1375

evalue: 3.29583E-171, score: 609.077 for Ad4FIBER

lcl|AY599837 | Human Adenovirus serotype 4, USAF Field Strain | 35,964bp; Length = 35964

evalue: 7.18119E-160, score: 571.412 for Ad4FIBER

lcl|AY599835 | Human Adenovirus serotype 4, US Navy Field Strain | 35,965bp; Length = 35965

evalue: 1.75062E-157, score: 563.482 for Ad4FIBER

lcl|AY594254 | Human Adenovirus serotype 4, vaccine strain#| 35,994bp; Length = 35994

evalue: 6.18269E-148, score: 531.765 for Ad4FIBER

lcl|AY594253 |Human Adenovirus Serotype 4| 35,990bp; Length = 35990

evalue: 6.18269E-148, score: 531.765 for Ad4FIBER

gi|303967|gb|L19194.1|ADRFIBERX Mastadenovirus h4 fiber protein, complete cds; Length = 1346

evalue: 1.50721E-145, score: 523.835 for Ad4FIBER

gi|22796371|emb|AJ315930.1|HAD315930 Human adenovirus type

```
4 DNA; Length = 12718
            evalue: 3.67425E-143, score: 515.906 for Ad4FIBER
      gi|17105037|gb|AF394196.1|AF394196 Simian adenovirus 25,
complete genome; Length = 36521
            evalue: 2.91419E-51, score: 210.623 for Ad4FIBER
      gi|33694802|tpg|BK000413.1| TPA: Simian adenovirus 25,
complete genome; Length = 36519
            evalue: 2.91419E-51, score: 210.623 for Ad4FIBER
```

In this detailed example, the REPI parameters were set as follows:

Table 53

Expect Value Threshold		1.0 E-9
Window Size	Z	20
First Jump Threshold	A	25%
First Window Jump	X	1
Second Window Jump	Y	1
Second Jump Threshold	B	25%
First Length Threshold	E	20
Second Length Threshold	F	50
Intermediate Percentage Threshold	H	60%

In addition to the embodiments described above, the extensible nature of the system allows for ready adaptation to a number of higher bioinformatics tasks that utilize discontinuous segments of nucleotide or amino acid sequences. Several examples of these supplementary applications are described below.

In the previous examples, the present inventors provided data showing that sequence fragments can be linked automatically to individual target sequences. In several more preferred embodiments, this approach discriminates between a mixture and a recombination within a set of orthologous biological target sequences. Herein, an ortholog is defined generally as a same gene in a different species, usually an indication of common genetic ancestry.

More specifically, the system attempts to perform automatic alignment of sequence calls from different tile regions of the resequencing microarray to detect the presence of homologous sequence fragments on different tiled regions of the array, allowing inference of a mixture of target sequences. Optionally, the system further determines that the sequence outputs from different tiled regions representing orthologous genes are not mixtures of orthologous genes but correspond to a contiguous sequence that may have arisen by a genetic recombination event between different regions of two or more orthologous genes.

In such additional embodiments, the system allows for automatic detection of highly overlapping or homologous sequence fragments on different tiled regions of the array, allowing inference of a mixture of target sequences. Further, the system optionally determines that the sequence outputs from different tiled regions are not highly overlapping but correspond to contiguous sequence that may be registered to positions within known

target sequences to infer a genetic recombination event.

FIG. 21 illustrates an exemplary embodiment of methods for distinguishing between mixtures of different targets and recombinants between targets in a test sample according to an embodiment of the present system. These example methods can be integrated into or supplemented with the methods described above with respect to FIG. 12, and are also applicable to distinguishing between protein mixtures and hybrid proteins. In this example, the system determines the relative position of gene subsequences detected by the resequencing microarray (with or without an initial similarity search) with respect to the entire nucleotide sequence that codes for a protein S1201. The relative position corresponds generally to the location of the subsequence within the whole sequence. The whole sequence is available in a database that can be comprised of public and/or private sequence records. For example, a subsequence can be determined to correspond to a front (for example, 5'), middle, or end (for example, 3') of an entire sequence. Moreover, this determination of position can be made of a candidate subsequence or a selected subsequence. Next, the system performs an alignment procedure to compare and match subsequences according to their position S1203. The algorithm used to perform S1203 can be one used for local pairwise alignment (e.g. BLASTN, BLASTP, or BLASTX) between two sequences, one which simultaneously performs alignments between multiple sequences (e.g. ClustalW or Clustal_X (Thompson et al., 1997; Thompson et al., 1994)), or an alternate one obtained from the public domain or through private development. In one embodiment, the system groups subsequences corresponding to the front, middle, and end portions of like sequences. Subsequently, the system evaluates the fit of the grouped subsequences with each other S1205.

Fit among subsequences can be evaluated, for example, through detection of appropriate amounts of overlap among the sequences. In one embodiment, the fit is a quantitative relationship between the length (or bit score) of the homologous overlap region in relation to the non-overlapping sequence(s), and the relationship of each to the overall sequence of the whole gene for a given protein. In addition to traditional methods of evaluating overlapping biological sequences, the system optionally analyzes sequence overlap using synchronization and detection methods applicable to analog and digital communications. Moreover, the issue of identifying overlapping sequences is not unlike that problem posed by initial synchronization in digital communication systems. Accordingly, one method that may be employed according to the present invention is the use of a sliding correlator. In a sliding correlator, two sequences (a data sequence, and a hypothesis sequence), are compared to one another by correlating the two sequences. The two sequences are shifted in position with respect to one another, and shifting stops only when the correlation result is detected to be above a predetermined level. In practice, a sliding correlator is often preceded by some other method for reducing the area of search such as the transmission of a synchronization preamble. Likewise, according the present invention, an already-detected overlap between subsequences may be used as a preamble in order to limit the amount of time required for the synchronization process. This type of synchronization is described in Bhargva, et al. "Digital Communications By Satellite" John Wiley and Sons, Chapter 9, pages 269-291. Likewise, other synchronization or acquisition algorithms may be applied such as those described in § 8.22 of Sklar, B. "Digital Communications Fundamentals and Applications", Prentice Hall, 1988, pages 453, 460. The acquisition criterion used is selected based on a sufficiently low probability of false acquisition. In this case, the acquisition criterion may be the probability of false detection of 10%, although 9%, 8%, 7%, 6% inclusive, down to 0.1% may be employed.

If the subsequences do not exceed a predetermined threshold of fit, the system begins analysis of an alternative subsequence S1207. That is, if two or more potentially homologous or orthologous sub-sequences do

not fit a model for either mixture or recombination, the system can proceed to search for other subsequences S1201. The collection of grouped subsequences can be compared to the entire (target) sequence using a similarity search algorithm S1211. In such a case, the level of similarity S1213 between the linked subsequences and a target sequence provides data indicating whether the detected biological sequences are from a mixture of different biological entities or whether the detected sequences indicate a recombination. Alternatively, the system employs a method of check points to evaluate overlapping hybridization between portions of subsequences. The check point method performs such an evaluation at multiple points along the subsequences S1209. In this approach, the number of checkpoints is compared against a threshold S1215 to provide evidence distinguishing between a biological mixture and a recombination.

For example, a co-infection of two viruses of the same type might produce a recombinant within a single gene that is identical to one virus except for the 5' end, which has been substituted with the corresponding section of the second viral gene for the same protein. When this new recombinant virus genome is hybridized on a resequencing microarray, it might produce signals from the corresponding sections of the resequencing tile regions. An embodiment of the present invention includes an assembly algorithm to construct a "model" of the target sequence showing which parts might fit together to form an entire target. If the two have significant overlap (for example, demonstrating homology beyond some threshold value), one might conclude that there is probably a mixture. But if there were little or no overlap, there would remain a possibility that there is a recombinant. The degree of overlap (or lack of) could be affected by low concentrations of target with correspondingly smaller amounts of the tiles being filled in. This same principle can be applied even more readily, and with greater impact, on viruses where the recombination is a steady and recurring event, as in the case of retroviruses, where recombinations between viral genes result in the formation of new viral strains. In fact, such described functionality is essential for the distinction of mixtures of target sequences versus a recombination between target sequences. Moreover, this additional functionality may also be used to more rapidly detect common regions in detected (and possibly) new recombinations and assist in the design PCR primers to assist in broader studies of recombinations detected by the system.

Not only is the present inventive approach able to distinguish between mixtures of biological entities and recombination events within a given entity (described elsewhere herein), an additional embodiment of the system advantageously provides an end user with quantitative estimate of the relative amount of target sequence that was detected in the resequencing microarray assay. Such decision-quality information is of increased utility when, for example, a clinician or clinical laboratory technician attempts to assign cause and effect when multiple pathogen genomic signatures are detected. Further, supplementing data regarding the presence of a biological substance(s) with data regarding the (relative and absolute) abundance of the biological substance(s) provides additional context for decision-making by an end user. Further, an embodiment of the system is configured to automatically analyze and compare such "presence" and "abundance" data to provide an end user with decision-quality information.

Embodiments of the system are configured to utilize two types of data for providing abundance information. The first is the absolute intensity of the hybridization signals on the chip. A non-linear relationship exists between the amount of target in solution and the amount that actually hybridizes and the resulting signal. However, an estimate of the amount of target nucleic acid in the sample could be made by comparison with a standard curve prepared under control conditions. For example, the signal intensity data is readily available from the .CEL file in the Affymetrix data hierarchy and is typically used for quantitative assessment of gene expression

changes . An embodiment of the system accommodates the inclusion of intensity values within the data it inputs, outputs, and handles. Secondly, the percentage of base calls, both as a percentage of the total tile region size and as a percentage of base calls within a selected subsequence satisfying the sliding window algorithm, can be used as a measure of concentration. Results from tests performed by the inventors show that both of these percentage metrics decrease with decreasing target concentration, although the correct target sequence can still be identified.

FIG. 22 is an exemplary illustration of an embodiment of the CIBSI that incorporates intensity data with results of a similarity search to provide a user with decision-quality information. Intensity data 1314 is input from, for example, a spectrum analysis tool of a microarray. The intensity data is analyzed in the context of the results of the similarity search to perform more robust analysis 1319 of detected sequences and consequently provide decision-quality information 1321 to the user. Decision-quality information includes, for example, a measure of a relative abundance of detected sequences or subsequences corresponding to distinct or related biological entities. An additional embodiment incorporates intensity data 1314 in distinguishing between mixtures and recombinations as described previously. The intensity data 1314 in such a case would provide an additional dimension of information when applying digital communications methodologies for interpreting sequence data returned from the similarity search.

In another very preferred embodiment, the system allows for the analysis of transcriptional markers (e.g. RNA) that have been resequenced using the presently described type of microarray (via hybridization of RNA or complementary cDNA). In a method analogous to that described above for inference of genomic recombination events, transcriptional sequences may also be assembled to determine biological entity viability and transcriptional editing events that can serve as markers for infection.

Further, the system optionally is adaptable for use with biological sequences other than nucleic acids and their related transcriptional products such as the amino acids sequences of proteins. Generally, proteomic applications of the present invention are consistent with the system's ability to handle biological sequence data and optimize such data for comparison against known sequences. The studies of gene expression and protein evolution have lead to amino acid sequence databases (and associated similarity search algorithms) similar in scale and accessibility as genetic sequence databases described above. Moreover, the analysis of spectrum data returned from mass spectrometry methods for sequencing proteins lends itself conveniently to even more elaborate embodiments of the invention. For example, protein sequence spectrum data includes intensity data similar to those used in the analysis of microarrays. As described above with respect to other types of sequences, an advanced embodiment of the invention provides for the handling and utilization of such intensity data to provide higher quality information to an end user.

In addition to the use of the system in diagnostic applications, alternative embodiments of the system facilitate the design of more effective and efficient resequencing microarrays for use with diagnostic embodiments of the system. A more effective approach to choosing and designing probes for inclusion on microarrays inevitably leads to more efficient use of the real estate on a given microarray. Consequently, microarrays can be made to accurately detect a larger variety of biological sequences for a given size, or microarrays tailored for specific applications can be made cheaper and more accessible by reducing the required number of probes required on a microarray, which increases the opportunity for size reduction and higher manufacturing yields. One key driver of designing a microarray is resolution. Generally, resolution as described herein refers to the discriminatory power to distinguish between closely related strains of a biological entity. For example, some applications may require a high resolution to distinguish between Air Force and Navy Field Strain of adenovirus,

while other applications require only identification of the presence of an adenovirus. The embodiments described below illustrate uses of the system in enabling a microarray designer to objectively and systematically balance resolution and microarray size/density.

FIG. 23 illustrates an exemplary embodiment of methods utilizing the system for accelerated design and refinement of a resequencing microarray or other probe or array-based assay. To begin, test sequences are selected corresponding to types of biological sequences (which, in turn, correspond to biological entities including pathogens) that are intended to be detected by a microarray S1403. Preferably a composition of more than one known or estimable biological sequence that may or may not be closely related, the selected sequences can be chosen through a variety of methods including, but not limited to, phylogenic trees and Hidden Markov Models (Eddy, 1998). These selected test sequences then undergo multiple alignment using a multiple alignment algorithm such as CLUSTALW S1405. Performing multiple alignment leads to a consensus sequence S1407, typically corresponding to common regions of the test sequences where commonalities are determined by comparison to a certain similarity threshold (for example, CLUSTALW weights, CLUSTALW parameter setting percentage to determine consensus). The resultant consensus sequence is then input into an embodiment of the system to yield one or more subsequences of the consensus sequence that are determined as likely able to yield meaningful results from a similarity search S1409. In one approach, the subsequence(s) from the consensus sequence are then "hybridized" with the originally selected test sequences through a simulation that mimics the behavior and limitations of, for example, an Affymetrix resequencing microarray S1413. Hybridization rules include, but are not limited to, rules for tolerance and detection of insertions, deletions, and substitutions of various numbers of base pairs or at various locations within an entire sequence. The output simulated hybridization patterns between the test sequences and the consensus sequence are then obtained S1415 and subsequently submitted to the system for automated comparison using a similarity search S1417. The results of the similarity search are then compared S1419 to the set of originally selected test sequences. Generally, a similarity search returns at least one known biological entity and an associated probability that the submitted sequence or subsequences is from that known entity. Thus, comparison of the similarity search results can confirm or deny that a probe based on a relevant portion of a consensus sequence would be effective in correctly hybridizing to, and consequently identifying, the collection of test sequences of concern to a user. In the case that the results confirm the effectiveness of the consensus sequence (or some subset thereof), that sequence can be implemented in a region of a resequencing microarray S1421. Alternatively, if the comparison suggests that the test sequences of concern would not be adequately detected, then the system can be used in further redesign of a new probe S1423. One embodiment of such a redesign process includes reevaluation of several of the steps within the original design process, some of which are illustrated in FIG. 23. For example, the results are affected by the diversity of range of selected test sequences and their weighting according to their prevalence in the environment S1425. Additionally, weighting of the consensus algorithm is adjustable S1427 as well as functional parameters related to the system S1429. Furthermore, the various methods implemented in simulating hybridization are adjustable, including a wholesale change of algorithm and Signal-to-Noise Ratio thresholds S1431.

Accordingly, the functionality of the system provides accelerated and more effective design of resequencing microarrays compared to a conventional method of subjectively choosing probes.

The above aspects related to design are further illustrated by the following example conducted by the inventors. In this example, a method is described for creating a consensus sequence to be used as a target

sequence on a microarray that is capable of identifying those test sequences used to create it. FIG. 24 illustrates an exemplary embodiment of the method described below.

Beginning with 15 adenovirus hexon gene sequences, these sequences are arranged according to phylogeny using a dendrogram (for example, see FIG. 25). The dendrogram is used to graphically represent and evaluate the genetic relationships among selected test sequences. Although Ad1 and Ad5 are the greatest outliers with respect to the other sequences, all 15 shown adenovirus hexon gene sequences are selected in this example as an initial set of test sequences S1503. Selection of the initial set of test sequences S1503 is optionally provided automatically by the system according to predetermined or user-defined parameters. For example, the distances between the sequences in the dendrogram provide a numerical threshold set for determining the minimum or maximum distance required to combine sequences in a candidate consensus sequence.

Next, all selected test sequences are subjected to a multiple alignment analysis S1505 such as ClustalW (Thompson et al., 1994), a sample output of which is shown at FIG. 26. A consensus sequence is then calculated from this alignment S1507. The example illustrates this step performed by Cons (EMBOSS interface to ClustalW) at FIG. 27, with Cons run at low "plurality," a parameter allowing a user of Cons to set a cut-off for the number of positive matches below which there is no consensus. Specifically, a lower plurality allows fewer matches to build the consensus, thus creating a consensus with fewer gaps and Ns.

Once a candidate consensus sequence is calculated, it is input into REPI (or, alternatively, another embodiment of the present invention) to initially evaluate its potential effectiveness as a target sequence S1509 using an Expect threshold value of 1e-9 for returning prospective matches S1511. At this point, the REPI results are compared to the initial set of test sequences S1513 as, for example, a percentage of the initial set of test sequences present in the REPI results. If this percentage of initial test sequences identified by the REPI results is greater than a threshold (predetermined by the system or, alternatively, defined by the user), the candidate consensus sequence is the most probabilistically favorable large-scale target sequence, and the process moves to simulating hybridization S1527. In the illustrated example, the above comparison threshold is 100%, corresponding to a condition that all of the initial test sequences must be returned by REPI as exceeding the Expect threshold. Reducing this comparison threshold results in a system more permissive of a target sequence that may misidentify or fail to identify a certain number or percentage of a desired set of test sequences.

Otherwise, if each of the initial set of test sequences are not all present in the REPI results, the missing test sequences are then be evaluated with the candidate consensus sequence individually. The candidate consensus sequence are also evaluated in combination with the multiple alignments created in a previous step to identify any missing sequence segments that are critical for their identification within this consensus. The objective of the following steps is to incrementally add necessary sequence information to the original candidate consensus sequence without losing the original sequence generality of the original.

Accordingly, a multiple alignment is performed S1515 again. This time, the multiple alignment includes the current consensus sequence. Subsequently, gaps in the candidate consensus sequence are identified S1517. The gaps in the alignment of the candidate consensus sequence with the test sequences are possible positions for missing sequence data where adding incremental sequence information to the candidate consensus sequence from the missing test sequences may be beneficial.

FIG. 28 illustrates an example of gaps in results from the second multiple alignment. In this example, there are two places where the consensus sequence skips sequence data from Ad1 and Ad5, noted previously as the two greatest phylogenic outliers during the initial test sequence selection process (see FIG. 25).

Segments from the missing sequences corresponding to the gaps are then added, or "spliced," to the original consensus sequence in place of the gaps S1519 to form a "patched" consensus sequence. FIG. 29 illustrates spliced sequence data within the patched candidate consensus sequence. According to an embodiment of the present invention, splicing is done manually by a user. Optionally, the system provides automatic splicing according to parameters (predetermined by the system or set by the user) corresponding to the identification of gaps and the selection of sequence data from missing test sequences for splicing into the gaps.

After splicing S1519, the patched candidate consensus sequence is again submitted to REPI for evaluating the impact of the above manipulation S1521. Optionally, the system or user determine additional acceptability thresholds corresponding to a number (or percentage) of missing test sequences now correctly identified S1523 or a number (or percentage) of previously identified test sequences now incorrectly identified by the REPI results S1525. Such thresholds generally correspond to a tolerance for improvement or degradation in the effectiveness of a patched consensus sequence with respect to the initial candidate consensus sequence. In the illustrated example, the addition of two sequence segments is enough to add Ad1 and Ad5 to the list of REPI hits without losing any of the previously identified test sequences.

On the other hand, if the splicing operation failed to add the missing adenovirus types to the list of those identified or other sequence hits were lost in the process the new consensus sequence would be abandoned, Ad 1 and Ad5 are separated and the remaining sequences are reevaluated S1524. Alternatively, if the splicing operation failed to meet an acceptability threshold, a reevaluation is performed. Accordingly, in cases where the sequence differences among the initial set of test sequences fails to meet an acceptability threshold (for example, those described immediately above), two or more candidate consensus sequences may be necessary to provide target sequences that are able to identify a desired percentage of the initial set of test sequences. Optionally, the system accommodates consideration and evaluation of such additional candidate consensus sequences in parallel.

If all of the original sequences have been identified in the REPI results (see FIG. 30), a final consensus sequence has been formed and the hybridization potential for each of the original test sequences can be determined. FIG. 31 shows a hybridization/ binding simulation program used to perform this step. Each of the original sequences is aligned with the new consensus sequence. The simulation takes the output alignment file, produced, for example, by a bl2seq alignment program, and evaluates the number of differences in the top scoring alignment per 25mer. Optionally, the program evaluates the number of differences at longer or shorter intervals. The system then builds a resulting sequence (as shown in FIG. 31 for Ad4) based only on those positions where the 25mer's had less than 2 mismatches. Additionally, a separate threshold parameter for tolerance of mismatches is optionally provided by the system.

The sequence shown in FIG. 31 is a simulated representation of a test sequence hybridized with the current consensus sequence. The hybridization potential of each of the sequences with the final consensus sequence is then evaluated S1527. In this example, program HybBind is used to create hybridization simulation sequences for each test sequence S1529. Once the hybridization simulation sequences are all created, they are each run through REPI as if they were acquired off of the actual chip S1531.

If all of the simulated sequences match their respective sequence as the top score and top "hit" (similarity score based on bit score and/or expect value), then this potential consensus sequence has passed the evaluation process and can be used as a target sequence to identify, by type, those sequences used to create it S1535. Alternatively, if all of the simulated sequences do not match their respective sequence as the top score S1535, or the top score and E-value match multiple sequences S1533, the potential consensus fails the evaluation the

sequences are broken up into multiple groups and sent back for reevaluation S1534.

The potential sequences that did not correctly identify their respective sequence (Ad1, Ad50, Ad34, Ad3) are sent back to step one to be reevaluated for one or more consensus S1534. The potential sequences Ad4, Ad21, Ad16, Ad7, Ad5, that did correctly identify their respective sequence as the top score and E-value are grouped together and are sent back through the process described above starting with the creation of a multiple alignment to build a new candidate consensus sequence without the use of those sequences that failed and did not correctly identify themselves S1536. The new candidate consensus sequence (for example, see FIG. 32) is run through the same thresholds and evaluations, bl2seq, REPI, Hybbind and REPI again. In this case when the final simulated sequences from Hybbind are run through REPI for validation all of the sequences are able to identify their respective sequence by type as the top score and E-value therefore this potential consensus sequence has passed all evaluation and can be used as a target for sequences Ad4, Ad21, Ad16, Ad7, and Ad5.

In yet another embodiment, the system provides for tracking and analysis of time trends in sequence analysis. By performing and recording analysis similar to that described above iteratively or continuously over time, genetic or proteomic evolution and/or mutation can be tracked more easily than using the conventional method.

In a specific embodiment related to pathogen detection, the invention described herein is used for the routine diagnosis and surveillance of common respiratory pathogens in a clinical setting (at or near point-of-care). Readily obtainable samples (e.g. nasal wash, throat swab, sputum, blood, food, soil, water, or air) are processed in a simple manner to produce nucleic acid isolates that are obtained using an adsorptive process, enriched for pathogen-specific targets, amplified using a non-biased (e.g. total) or multiplexed PCR amplification method, and hybridized on the resequencing microarray for a defined of time prior to washing and imaging. The overall process is sufficiently simple such that a skilled technician (medical technologist level) will be able to perform the assay without a significant interruption in their routine work pattern. Base calls are made using the custom algorithms or using the steps specified by the vendor. REPI, or some variant thereof, is used to automatically parse the base calls made by the microarray, and provide the end-user (e.g., physician, health care provider, public health officer, or other decision-makers) with decision-quality information for management (e.g., diagnostic, treatment, prognostic and outbreak control/containment measures) of the infectious pathogen(s) that are causative of the disease symptoms and complications. This analysis occurs locally through the use of an embedded sequence database that would be queried by REPI (e.g. local dedicated BLAST server). In addition to providing a routine diagnostic functionality, the microarray used in conjunction with this embodiment also carries markers for highly improbable (e.g. avian influenza or bioterrorism) pathogens that would be cause for involvement of others, namely public health officials.

In selected embodiments of the present invention, CIBSI outputs are arranged in multiple layers. In a particular embodiment, CIBSI outputs are arranged in three layers for presentation to a user or data interpreter. A first layer of output provides "species level" information, a second layer of output provides "serotype/strain level" information, and a third layer provides "low level" information. Examples of species include, but are not limited to, Influenza A, Influenza B, Adenovirus, *S.pyogenes*, *B.anthracis*, and *F.tularensis*. Although the species level layer is presented first to a user or data interpreter, the user or data interpreter is able to select and view other layers through, for example, user inputs, predetermined display settings, or prescribed protocol by qualified individuals. Alternative embodiments provide for rules and algorithms to retrieve, organize, and present data corresponding to predetermined levels of detail within each layer.

In one embodiment, a rule for a positive at the first level is that if any one of the multiple tile regions for a species produces a positive (for example, produces a subsequence having a BLAST expect value of $1.0e^{-9}$ or less or produces a high bit score for a single pathogen database record), then the result is POSITIVE at the species level. This enables a fully autonomous first layer of detail to be established. The user can produce more information that this first layer through, for example, a human intervention step to access second or third layers of information. The second layer of output including "serotype/strain level" information enables a user to view sequence database (for example, GenBank) record names and identifiers with scores above a predetermined threshold to determine serotype and/or strain. Optionally, text search algorithms can be applied sequence databases without precise naming conventions to automatically provide serotype/strain level information (for example, through searching and parsing of GenBank data). Alternatively, the system provides for addenda (for example, adenovirus 4, AF field strain or influenza A, H3N2, Fujian 411) to be made to the first layer of information by a user or data interpreter by selecting an option next to a display field. The third layer of output includes raw CIBSI output. Optionally, algorithms may be applied to the raw CIBSI output. Other embodiments of the present invention move additional information to the first layer of output.

FIG. 20 is a block diagram of a computer system (or server) 2001 upon which an embodiment of the present invention may be implemented. It should be noted however, that the present system need not be based on a personal computer (PC) configuration, but rather a custom processor-based system that does not include the features of a general purpose computer may be used as well. Nevertheless, because the actual hardware configuration used to support the present invention, is not so restricted, an example of PC-based system is now provided. The computer system 2001 includes a bus 2002 or other communication mechanism for communicating information, and a processor 2003 coupled with the bus 2002 for processing the information. The computer system 2001 also includes a main memory 2004, such as a random access memory (RAM) or other dynamic storage device (e.g., dynamic RAM (DRAM), static RAM (SRAM), and synchronous DRAM (SDRAM)), coupled to the bus 2002 for storing information and instructions to be executed by processor 2003. In addition, the main memory 2004 may be used for storing temporary variables or other intermediate information during the execution of instructions by the processor 2003. The computer system 2001 further includes a read only memory (ROM) 2005 or other static storage device (e.g., programmable ROM (PROM), erasable PROM (EPROM), and electrically erasable PROM (EEPROM)) coupled to the bus 2002 for storing static information and instructions for the processor 2003.

The computer system 2001 also includes a disk controller 2006 coupled to the bus 2002 to control one or more storage devices for storing information and instructions, such as a magnetic hard disk 2007, and a removable media drive 2008 (e.g., floppy disk drive, read-only compact disc drive, read/write compact disc drive, compact disc jukebox, tape drive, and removable magneto-optical drive). The storage devices may be added to the computer system 2001 using an appropriate device interface (e.g., small computer system interface (SCSI), integrated device electronics (IDE), enhanced-IDE (E-IDE), direct memory access (DMA), or ultra-DMA).

The computer system 2001 may also include special purpose logic devices (e.g., application specific integrated circuits (ASICs)) or configurable logic devices (e.g., simple programmable logic devices (SPLDs), complex programmable logic devices (CPLDs), and field programmable gate arrays (FPGAs)).

The computer system 2001 may also include a display controller 2009 coupled to the bus 2002 to control a display 2010, such as a cathode ray tube (CRT), for displaying information to a computer user. The computer system includes input devices, such as a keyboard 2011 and a pointing device 2012, for interacting with a

computer user and providing information to the processor 2003. The pointing device 2012, for example, may be a mouse, a trackball, or a pointing stick for communicating direction information and command selections to the processor 2003 and for controlling cursor movement on the display 2010. In addition, a printer may provide printed listings of data stored and/or generated by the computer system 2001.

The computer system 2001 performs a portion or all of the processing steps of the invention in response to the processor 2003 executing one or more sequences of one or more instructions contained in a memory, such as the main memory 2004. Such instructions may be read into the main memory 2004 from another computer readable medium, such as a hard disk 2007 or a removable media drive 2008. One or more processors in a multi-processing arrangement may also be employed to execute the sequences of instructions contained in main memory 2004. In alternative embodiments, hard-wired circuitry may be used in place of or in combination with software instructions. Thus, embodiments are not limited to any specific combination of hardware circuitry and software.

As stated above, the computer system 2001 includes at least one computer readable medium or memory for holding instructions programmed according to the teachings of the invention and for containing data structures, tables, records, or other data described herein. Examples of computer readable media are compact discs, hard disks, floppy disks, tape, magneto-optical disks, PROMs (EPROM, EEPROM, flash EPROM), DRAM, SRAM, SDRAM, or any other magnetic medium, compact discs (e.g., CD-ROM), or any other optical medium, punch cards, paper tape, or other physical medium with patterns of holes, a carrier wave (described below), or any other medium from which a computer can read.

Stored on any one or on a combination of computer readable media, the present invention includes software for controlling the computer system 2001, for driving a device or devices for implementing the invention, and for enabling the computer system 2001 to interact with a human user (e.g., print production personnel). Such software may include, but is not limited to, device drivers, operating systems, development tools, and applications software. Such computer readable media further includes the computer program product of the present invention for performing all or a portion (if processing is distributed) of the processing performed in implementing the invention.

The computer code devices of the present invention may be any interpretable or executable code mechanism, including but not limited to scripts, interpretable programs, dynamic link libraries (DLLs), JAVA classes, and complete executable programs. Moreover, parts of the processing of the present invention may be distributed for better performance, reliability, and/or cost.

The term "computer readable medium" as used herein refers to any medium that participates in providing instructions to the processor 2003 for execution. A computer readable medium may take many forms, including but not limited to, non-volatile media, volatile media, and transmission media. Non-volatile media includes, for example, optical, magnetic disks, and magneto-optical disks, such as the hard disk 2007 or the removable media drive 2008. Volatile media includes dynamic memory, such as the main memory 2004. Transmission media includes coaxial cables, copper wire and fiber optics, including the wires that make up the bus 2002. Transmission media also may also take the form of acoustic or light waves, such as those generated during radio wave and infrared data communications.

Various forms of computer readable media may be involved in carrying out one or more sequences of one or more instructions to processor 2003 for execution. For example, the instructions may initially be carried on a magnetic disk of a remote computer. The remote computer can load the instructions for implementing all or a portion of the present invention remotely into a dynamic memory and send the instructions over a telephone line

using a modem. A modem local to the computer system 2001 may receive the data on the telephone line and use an infrared transmitter to convert the data to an infrared signal. An infrared detector coupled to the bus 2002 can receive the data carried in the infrared signal and place the data on the bus 2002. The bus 2002 carries the data to the main memory 2004, from which the processor 2003 retrieves and executes the instructions. The instructions received by the main memory 2004 may optionally be stored on storage device 2007 or 2008 either before or after execution by processor 2003.

The computer system 2001 also includes a communication interface 2013 coupled to the bus 2002. The communication interface 2013 provides a two-way data communication coupling to a network link 2014 that is connected to, for example, a local area network (LAN) 2015, or to another communications network 2016 such as the Internet. For example, the communication interface 2013 may be a network interface card to attach to any packet switched LAN. As another example, the communication interface 2013 may be an asymmetrical digital subscriber line (ADSL) card, an integrated services digital network (ISDN) card or a modem to provide a data communication connection to a corresponding type of communications line. Wireless links may also be implemented. In any such implementation, the communication interface 2013 sends and receives electrical, electromagnetic or optical signals that carry digital data streams representing various types of information.

The network link 2014 typically provides data communication through one or more networks to other data devices. For example, the network link 2014 may provide a connection to another computer through a local network 2015 (e.g., a LAN) or through equipment operated by a service provider, which provides communication services through a communications network 2016. The local network 2014 and the communications network 2016 use, for example, electrical, electromagnetic, or optical signals that carry digital data streams, and the associated physical layer (e.g., CAT 5 cable, coaxial cable, optical fiber, etc). The signals through the various networks and the signals on the network link 2014 and through the communication interface 2013, which carry the digital data to and from the computer system 2001 maybe implemented in baseband signals, or carrier wave based signals. The baseband signals convey the digital data as unmodulated electrical pulses that are descriptive of a stream of digital data bits, where the term "bits" is to be construed broadly to mean symbol, where each symbol conveys at least one or more information bits. The digital data may also be used to modulate a carrier wave, such as with amplitude, phase and/or frequency shift keyed signals that are propagated over a conductive media, or transmitted as electromagnetic waves through a propagation medium. Thus, the digital data may be sent as unmodulated baseband data through a "wired" communication channel and/or sent within a predetermined frequency band, different than baseband, by modulating a carrier wave. The computer system 2001 can transmit and receive data, including program code, through the network(s) 2015 and 2016, the network link 2014, and the communication interface 2013. Moreover, the network link 2014 may provide a connection through a LAN 2015 to a mobile device 2017 such as a personal digital assistant (PDA) laptop computer, or cellular telephone.

The system of certain embodiments of the present invention can be implemented in hardware, software, firmware, or a combination thereof. In the preferred embodiment, the system is implemented in software that is stored in a memory and that is executed by a suitable instruction execution system. If implemented in hardware, as in an alternative embodiment, the system can be implemented with any technology, which is all well known in the art.

Any process descriptions or blocks in the flow charts should be understood as representing modules, segments, or portions of code which include one or more executable instructions for implementing specific logical functions or steps in the process, and alternate implementations are included within the scope of the preferred

embodiment of the present invention in which functions may be executed out of order from that shown or discussed, including substantially concurrently or in reverse order, depending on the functionality involved, as would be understood by those reasonably skilled in the art of the present invention.

It should be emphasized that the above-described embodiments of the present invention, particularly, any "preferred" embodiments, are merely possible examples of implementations, merely set forth for a clear understanding of the principles of the invention. Many variations and modifications may be made to the above-described embodiment(s) of the invention without departing substantially from the spirit and principles of the invention. All such modifications and variations are intended to be included herein within the scope of this disclosure and the present invention and described by the following claims.

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CLAIMS

What we claim is

1. A resequencing DNA microarray comprising multiple groups of oligonucleotide probes of a length ranging from 13 to 70 nucleotides immobilized to a solid phase support, wherein each group of oligonucleotide probes is:

(a) selected to span a particular region of a distinct reference sequence,

(b) occupies a discrete area of the array termed a tiled region, and

(c) comprises at least four sets of probes arranged in a parallel fashion within said discrete area of the array, wherein said four sets of probes are selected as follows:

i) a first probe that is exactly complementary to the reference sequence; and

ii) three additional probes, each of which is identical to the first probe but for the nucleotide at a central position, which is different in each of the three sets such that all four conventional nucleotide bases are present on said array;

wherein the sequences selected for tiling include a single gene or subsequence that may represent a broad class of organism genus, species and subspecies.

2. The resequencing DNA microarray according to claim 1, wherein the length of the oligonucleotide probes is 25 nucleotides.

3. The resequencing DNA microarray according to claim 1, wherein the region of the reference sequence that is spanned by the oligonucleotide probe moves by (n + 1) nucleotides across the reference sequence for each adjacent tiled region across the microarray surface.

4. The resequencing DNA microarray according to claim 1, wherein the resequencing DNA microarray contains 18 x 18 micron features.

5. The resequencing DNA microarray according to claim 1 , wherein the resequencing DNA microarray contains 8 x 8 micron features.

6. The resequencing DNA microarray according to claim 1, wherein the sequences selected for tiling are "prototypes" representing genotypes of pathogen families.

7. The resequencing DNA microarray according to claim 1, wherein the sequences selected for tiling are "prototypes" representing a family or group of adenoviruses.

8. The resequencing DNA microarray according to claim 1, wherein the sequences selected for tiling are "prototypes" representing a family or group of influenza viruses.

9. The resequencing DNA microarray according to claim 1, wherein the sequences selected for tiling are a single gene or subsequence unique to an individual pathogenic strain.

10. The resequencing DNA microarray according to claim 1 , wherein the sequences selected for tiling encode a drug-resistance marker.

11. The resequencing DNA microarray according to claim 1, wherein the resequencing DNA microarray is RPMV1.

12. The resequencing DNA microarray according to claim 1, wherein the resequencing DNA microarray is RPMV2.

13. The resequencing DNA microarray according to claim 1, wherein said resequencing DNA microarray contains at least one reference sequence for a common pathogen and at least one biological terrorism agent.

14. A kit comprising:
(a) the resequencing DNA microarray according to claim 1, and
(b) reagents suitable for specific hybridization of target sequences to the probe sequences present on said resequencing DNA microarray.

15. A method of detecting the presence of a drug-resistance marker in a microorganism, wherein the method comprises:
(a) providing the resequencing DNA microarray according to Claim 1 ;
(b) contacting an unknown sample comprising genetic material to said resequencing DNA microarray;
(c) hybridizing the contents of said unknown sample to the probe sequences immobilized on said resequencing DNA microarray under suitable conditions and for a suitable time; and
(d) detecting the presence of a drag-resistance marker in a microorganism in said unknown sample;
wherein said detecting is by:
(i) making base calls based on the hybridization response between nucleic acids of interest in said unknown sample and the probe DNA on the resequencing DNA microarray, and
(ii) determining the sequence of the corresponding full-length gene or genomic fragment by comparing the sequence of the hybridized region to sequences present in a sequence database.

16. The method according to claim 15, wherein said method further comprises determining the identity of the drug-resistance marker by sequence comparison between the DNA sequence of the drug-resistance marker identified by said method and known resistance markers.

17. The method according to claim 15, wherein said hybridizing is for a time ranging from 15 minutes to 24 hours.

18. The method according to Claim 15, wherein the unknown sample is a biological sample.

19. The method according to claim 18, wherein said biological sample is selected from the group consisting of a nasal wash specimen, a nasal aspirate, a throat swab, a blood sample, a sputum sample, blood cells, a tissue sample, a fine needle biopsy sample, a urine specimen, a peritoneal fluid sample, a visceral fluid sample, and a pleural fluid sample, or cells therefrom.

20. The method according to claim 15, wherein said unknown sample is an environmental sample selected from the group consisting of a soil sample, an air sample and a water sample.

21. The method according to claim 15, wherein prior to said hybridizing, the unknown sample is subjected to at least one of process selected from the group consisting of:
(i) isolation of the genetic material within said sample,
(ii) enrichment for target sequences of interest within said sample,
(iii) amplification of the genetic material contained within said sample,
(iv) labeling the genetic material within said sample, and
(v) subtractive hybridization.

22. The method according to claim 15, wherein prior to said hybridizing one or more target nucleic acids of interest in the unknown sample is amplified by at least one method selected from the group consisting of specific reverse transcription, PCR, multiplex PCR and random PCR.

23. The method according to claim 15, wherein prior to said hybridizing one or more target nucleic acids of interest in the unknown sample, the unknown sample is subjected to at least one random amplification strategy selected from the group consisting of random primed, isothermal Klenow polymerase-based, Φ29DNA polymerase-based, tandem amplification, multiplex PCR, and total amplification.

24. The method according to Claim 15, wherein the genetic material present in said unknown sample has been enriched.

25. The method according to claim 15, wherein one or more target nucleic acids of interest present in said unknown sample are enriched by subtraction of the background nucleic acids from said sample.

26. The method according to claim 15, wherein one or more target nucleic acids of interest present in said unknown sample are enriched by reverse-transcriptase subtractive hybridization.

27. The method according to claim 15, wherein one or more target nucleic acids of interest present in said unknown sample are enriched by selective removal of said target nucleic acids from a mixture of nucleic acids presenting said unknown sample.

28. The method according to claim 15, wherein said detecting is by:

(i) making base calls based on the hybridization response between nucleic acids of interest in said unknown sample and the probe DNA on the resequencing DNA microarray, and

(ii) determining the sequence of the corresponding full-length gene or genomic fragment by comparing the sequence of the hybridized region to sequences present in a sequence database.

29. The method according to claim 28, wherein the base calls are made by Affymetrix GDAS software under "permissive" settings.

30. The method according to Claim 28, wherein the sequence database is GenBank.

31. A method of routine diagnosis of common respiratory pathogens by performing the method according to claim 15, wherein said unknown sample is obtained from a subject in need of routine diagnosis of common respiratory pathogens.

32. The method according to claim 31, wherein said unknown sample is obtained during a physical examination.

33. A method of surveillance of common respiratory pathogens by performing the method according to claim 15, wherein said unknown sample is obtained from a subject in need of surveillance of common respiratory pathogens.

34. The method according to claim 33, wherein said subject in need of surveillance of common respiratory pathogens has a history of respiratory pathogen infection.

35. A method of surveillance of one or more biological terrorism agents by performing the method according to claim 15, wherein said unknown sample is obtained from a subject in need of surveillance of said biological terrorism agents.

36. The method according to claim 35, wherein said subject in need of surveillance of biological terrorism agents is suspected of being exposed to said biological terrorism agents.

37. A method of detecting the presence of a microorganism belonging to a particular class of organism species or subspecies in an unknown sample, wherein the method comprises:
(a) providing a resequencing DNA microarray according to claim 1;
(b) contacting the unknown sample comprising genetic material to said resequencing DNA microarray;
(c) hybridizing the contents of said unknown sample to the probe sequences immobilized on said resequencing DNA microarray under suitable conditions and for a suitable time; and
(d) detecting the presence of a microorganism belonging to a particular class of organism species or subspecies in said unknown sample;
wherein said detecting is by:
(i) making base calls based on the hybridization response between nucleic acids of interest in said unknown sample and the probe DNA on the resequencing DNA microarray, and
(ii) determining the sequence of the corresponding full-length gene or genomic fragment by comparing the sequence of the hybridized region to sequences present in a sequence database.

38. The method according to claim 37, wherein said method further comprises determining the identity of the particular class of organism species or subspecies by sequence comparison between the DNA sequence identified by said method and known sequences present in a genomic database.

39. The method according to claim 38, wherein said determining comprises detecting a sufficient amount of pathogen sequence in order to allow a forensic assessment of the possible source of pathogens.

40. The method according to claim 37, wherein said hybridizing is for a time ranging from 15 minutes to 24 hours.

41. The method according to claim 37, wherein the unknown sample is a biological sample.

42. The method according to claim 41, wherein said biological sample is selected from the group consisting of a nasal wash specimen, a nasal aspirate, a throat swab, a blood sample, a sputum sample, blood cells, a tissue sample, a fine needle biopsy sample, a urine specimen, a peritoneal fluid sample, a visceral fluid sample, and a pleural fluid sample, or cells therefrom.

43. The method according to claim 37, wherein said unknown sample is an environmental sample selected from the group consisting of a soil sample, an air sample, and a water sample.

44. The method according to claim 37, wherein prior to said hybridizing the unknown sample is subjected to at least one of process selected from the group consisting of:
(i) isolation of the genetic material within said sample,
(ii) enrichment for target sequences of interest within said sample,
(iii) amplification of the genetic material contained within said sample,
(iv) labeling the genetic material within said sample, and
(v) subtractive hybridization.

45. The method according to claim 37, wherein prior to said hybridizing one or more target nucleic acids of interest in the unknown sample is amplified by at least one method selected from the group consisting of specific reverse transcription, PCR, multiplex PCR, and random PCR.

46. The method according to claim 37, wherein prior to said hybridizing one or more target nucleic acids of interest in the unknown sample, the unknown sample is subjected to at least one random amplification strategy selected from the group consisting of random primed, isothermal Klenow polymerase-based, Φ29DNA polymerase-based, tandem amplification, multiplex PCR, and total amplification.

47. The method according to claim 37, wherein the genetic material present in said unknown sample has been enriched.

48. The method according to Claim 37, wherein one or more target nucleic acids of interest present in said unknown sample are enriched by subtraction of the background nucleic acids from said sample.

49. The method according to claim 37, wherein one or more target nucleic acids of interest present in said unknown sample are enriched by reverse-transcriptase subtractive hybridization.

50. The method according to claim 37, wherein one or more target nucleic acids of interest present in said unknown sample are enriched by selective removal of said target nucleic acids from a mixture of nucleic acids presenting said unknown sample.

51. The method according to claims 15 and 37, wherein the sequence database is GenBank.

52. A method of routine diagnosis of common respiratory pathogens by performing the method according to claim 37, wherein said unknown sample is obtained from a subject in need of routine diagnosis of common respiratory pathogens.

53. The method according to claim 52, wherein said unknown sample is obtained during a physical examination.

54. A method of surveillance of common respiratory pathogens by performing the method according to claim 37, wherein said unknown sample is obtained from a subject in need of surveillance of common respiratory pathogens.

55. The method according to claim 54, wherein said subject in need of surveillance of common respiratory pathogens has a history of respiratory pathogen infection.

56. A method of surveillance of one or more biological terrorism agents by performing the method according to claim 37, wherein said unknown sample is obtained from a subject in need of surveillance of said biological terrorism agents.

57. The method according to claim 56, wherein said subject in need of surveillance of biological terrorism agents is suspected of being exposed to said biological terrorism agents.

58. A method of estimating the relative amount of a pathogen in a biological sample containing the same comprising:

(a) providing a resequencing DNA microarray according to claim 1 ;

(b) contacting said biological sample to said resequencing DNA microarray;

(c) hybridizing the contents of said unknown sample to the probe sequences immobilized on said resequencing DNA microarray under suitable conditions and for a suitable time; and

(d) quantifying the presence and/or identity of a drug-resistance marker in a microorganism or a microorganism belonging to a particular class of organism species or subspecies in said unknown sample.

59. The method according to claim 58, wherein said quantifying is by determining the absolute intensity of the hybridization signals on said resequencing DNA microarray.

60. The method according to claim 58, wherein said quantifying is by determining the percentage of base calls, both as a percentage of the total tile region size and as a percentage of base calls within a selected subsequence satisfying a sliding window algorithm.