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(54) **Title:** NEW LABELLING STRATEGIES FOR THE SENSITIVE DETECTION OF ANALYTES

(57) **Abstract:** The present invention relates to methods and reagents for detecting analytes, e.g. nucleic acids. The new methods and reagents allow a simple and sensitive detection even in complex biological samples.

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New Labeiiing Strategies for the Sensitive Detection of Analytes

Description

The present invention relates to methods and reagents for detecting analytes, e.g. nucleic acids. The new methods and reagents allow a simple and sensitive detection even in complex biological samples.

Background of the Invention

The rapid analysis of genetic material for specific target sequences, e.g. for the presence of single nucleotide polymorphisms, the presence of a certain gene, e.g. a resistance gene, or of mRNA requires easy to use, efficient and reliable new tools. The major problem is the need to detect the DNA or RNA of interest directly in small biological samples such as patient blood or plants. These provide the analyte only in minute amounts. In order to reach the required sensitivity an amplification step is usually required wherein either the nucleic acid analyte is amplified prior to analysis or a detection method is used in which the minute detection signal, directly obtained from the DNA/RNA analyte, is amplified.

Methods for the amplification of the nucleic acid analyte include PCR and other nucleic acid amplification protocols. PCR amplification has the major advantage that, within a pool of different DNA strands obtained from the biological material, only the DNA sequence of interest is amplified. This is the basis for the reliable analysis of single genes in complex biological samples. PCR amplification, however, requires complex process steps which, in some cases, are too inconvenient and expensive. Amplification of the detection signal may be achieved by binding an enzyme such a horse radish peroxidase to the analyte, which converts a given substrate continuously into a colored product.

DNA metallization is another way to amplify the detection signal. A single

metallic particle attached to DNA/RNA (the nucleus) catalyzes the deposition of ever more metal, which catalyzes further metal deposition [1-9]. The signal induced by metal deposition grows accordingly in an exponential manner. The metal deposition can be detected either electrically, if the analyte is placed within two electrodes, or optically (e.g. with the eye) because the deposited metal gives rise to a black spot e.g. on paper, in the gel, or in the test tube. In principle, metal deposition is the most sensitive detection method because a small metal cluster (nucleus) is sufficient to start the reaction. In practice, however, the sensitivity of the method is limited by unspecific metal nucleation e.g. through impurities in close spatial vicinity to the analyte for example, on the electrodes, in the gel, or on the paper holding the analyte. In fact unspecific metal deposition is the major reason why silver staining of DNA is not routinely used in oligonucleotide analytics. Silver staining is further complicated by the fact that DNA is unable to build the initiation nucleus itself. It requires prior modification. The method of choice today is the reaction of DNA with glutaraldehyde which covalently attaches to the DNA by sequence-unspecific binding to primary amine groups on nucleobase [7]. This adduct, if treated with a silver salt, reduces the Ag^+ of the salt to atomic silver which, while bound to the DNA, functions as the required nucleus. Further treatment of the nucleated DNA with silver salts and reducing agents initiates the exponential metal deposition. Another possibility is to exchange the counterions on the DNA strand by Ag^+, which is subsequently reduced to give Ag^0 nucleation sites. The major disadvantage is that the glutaraldehyde also reacts with impurities or other chemical species close to the analyte, which again induces unspecific silver deposition.

Metal clusters such as Au, Pd particles or Pt-complexes attached to DNA also function as nucleation sites for further metal deposition up to the construction of conducting wires [1-9]. Here the clusters are attached to reactive groups which form a covalent bond with DNA or to units that just intercalate or bind otherwise to DNA/RNA. All these methods label the entire DNA in a biological sample and therefore do not allow sequence-specific

marking and hence sequence-specific analysis of a target DNA such as a single gene in a complex biological sample.

The preparation of labelled DNA domains by a telomerase-mediated incorporation of amine-modified nucleoside triphosphates into a primer-initiated modified telomer repeat is described in [8]. The amine-containing telomers are functionalized with activated gold nanoparticle N-succinimidyl esters to yield gold nanoparticle DNA strands. Enlargement of these nanoparticle sites by further metal deposition along the DNA indeed yields rapid growth of the metal clusters up to the construction of DNA templated molecular nanowires. However, the efficiency of amine-modified triphosphate incorporation into the growing telomer end is low and requires triphosphate doping which results in a distribution of nucleation sites. Thus, the procedure does not allow sequence-specific labelling.

Site-specific labelling of DNA has also recently been attempted via a complex lithographic method [4]. According to this method, a partial protection of DNA molecules is effected by binding of RecA. The unprotected DNA sequences are then treated with glutaraldehyde which marks these sequences for metallization. Site-specific reduction of silver ions by the DNA-bound aldehyde functions results in wire formation along these regions. A sequence-specific labelling of nucleic acid molecules in a complex biological sample is not possible, however.

Although these documents demonstrate the interest in new labelling strategies of DNA, the complicated processes involved in order to achieve marking prevents these systems from being used for any real application. In particular, these methods are unable to selectively label DNA or RNA sequences of interest directly in a crude biological sample.

Thus it was an object of the present invention to provide novel methods and reagents which allow a simple, efficient and specific detection of analytes, particularly of nucleic acids in complex biological samples.

Summary of the Invention

A first aspect of the present invention relates to methods and reagent kits for detecting an analyte, e.g. an analyte, e.g. a nucleic acid in a sample, wherein an association product of the analyte to be detected with a novel aldehyde-functionalized compound is formed, which allows sequence-specific detection by forming marker groups, e.g. metal depositions around aldehyde groups in said association product.

More particularly, an embodiment of this aspect relates to a method for detecting an analyte in a sample comprising the steps:

(i) providing a sample;

(ii) contacting the sample with a functionalized compound comprising at least one functional group selected from an aldehyde group, a protected aldehyde group, an aldehyde precursor group or a handle group for introducing an aldehyde group, a protected aldehyde group or an aldehyde precursor group, under conditions wherein said compound forms an association product with the analyte to be detected;

(iii) if necessary, reacting the handle group with a reaction partner, comprising an aldehyde group, a protected aldehyde group or an aldehyde precursor group,

(iv) if necessary, converting protected aldehyde groups and aldehyde precursor groups to aldehyde groups,

(v) contacting said association product having aldehyde groups with a marker reagent under conditions wherein marker groups are formed around aldehyde groups in said association product, and

(vi) detecting said marker groups.

A further embodiment of this first aspect relates to a reagent kit for detecting an analyte in a sample, comprising:

(a) a functionalized compound comprising a functional group selected from an aldehyde group, a protected aldehyde group or an aldehyde

precursor group, or a handle group for introducing an aldehyde group, a protected aldehyde group or an aldehyde precursor group,

(b) optionally a reaction partner for the handle group comprising an aldehyde group, a protected aldehyde group or an aldehyde precursor group,

(c) optionally an aldehyde-forming reagent capable of converting protected aldehyde groups and aldehyde precursor groups to aldehyde groups, and

(d) a marker reagent.

Still a further embodiment of this first aspect relates to a compound of formula (I):

A – S – N

wherein A is a functional group selected from an aldehyde group, a protected aldehyde group or an aldehyde precursor group,
S is a spacer or a bond, preferably a covalent bond, and
N is a nucleic acid or nucleic acid analogue building block such as a nucleosidic or nucleotidic compound.

In a second aspect the present invention relates to methods and reagent kits for detecting an analyte, e.g. a nucleic acid in a sample involving the use of a Click-functionalized compound which forms an association product with the analyte to be detected. The sequence-specific introduction of marker groups is effected by reacting the Click-functionalized compound with a suitable reaction partner comprising marker groups or marker precursor groups.

An embodiment of this second aspect relates to a method for detecting an analyte in a sample comprising the steps:

(i) providing a sample;

(ii) contacting the sample with a functionalized compound comprising at least one functional group which is a first reaction partner for a Click

reaction under conditions wherein said compound forms an association product with the analyte to be detected,

(iii) contacting the association product with a second reaction partner for a Click reaction under conditions wherein a Click reaction between the first and second reaction partner occurs, wherein the second reaction partner further comprises a marker group or a marker precursor group,

(iv) if necessary, converting marker precursor groups to marker groups, and

(v) detecting said marker groups.

A further embodiment of this second aspect relates to a reagent kit for detecting an analyte in a sample, comprising:

(a) a functionalized compound comprising at least one functional group which is a first reaction partner for a Click reaction,

(b) a second reaction partner for a Click reaction, wherein the second reaction partner further comprises a marker group or a marker precursor group, and

(c) optionally a marker forming reagent capable of converting marker precursor groups to marker groups.

Still a further embodiment of this second aspect relates to a compound of the formula (II):

$$C - S - N$$

wherein C is a functional group which is a first reaction partner for a Click reaction,

S is a spacer or a bond, preferably a covalent bond and

N is a nucleic acid or nucleic acid analogue building block such as a nucleosidic or nucleotidic compound.

In a third aspect the present invention relates to methods and reagent kits

for detecting an analyte, e.g. a nucleic acid in a sample involving the use of a photosensitizer compound which forms an association product with the analyte to be detected. Preferably, photosensitizer groups are sequence-specifically introduced into a nucleic acid. The presence of photosensitizer groups is detected by irradiating the labelled association product in contact with a photosensitive medium, wherein the presence of photosensitizer groups selectively causes a site-specific formation of marker groups in the marker medium.

An embodiment of this third aspect relates to a method for detecting an analyte in a sample by forming an association product of the analyte and a functionalized compound comprising photosensitizer groups and effecting an energy transfer, particularly a transfer of radiation energy from the photosensitizer groups to a photosensitive medium wherein the energy transfer causes selective formation of marker groups in the photosensitive medium.

A further embodiment of this third aspect relates to a method for detecting an analyte in a sample comprising the steps:

(i) providing a sample;

(ii) contacting the sample with a functionalized compound comprising at least one functional group selected from a photosensitizer group or a handle group for introducing a photosensitizer group under conditions wherein said compound forms an association product with the analyte to be detected;

(iii) if necessary, reacting the handle group with a reaction partner comprising a photosensitizer group;

(iv) irradiating said association product in contact with a photosensitive medium under conditions wherein marker groups are formed in said photosensitive medium in the presence of photosensitizer groups in said association product, and

(v) detecting said marker groups.

Still a further embodiment of this third aspect relates to a reagent kit for detecting an analyte in a sample, comprising:

(a) a functionalized compound comprising at least one functional group selected from a photosensitizer group or a handle group for introducing a photosensitizer group;

(b) optionally a reaction partner for the handle group comprising a photosensitizer group, and;

(c) a photosensitive medium which forms marker groups upon irradiation in the presence of photosensitizer groups.

The present invention allows a highly sensitive detection of an analyte, e.g. nucleic acids or nucleic acid binding proteins, in biological samples, e.g. clinical samples, environmental samples or agricultural samples. Preferred applications include, but are not limited to, the detection of genetic variabilities, e.g. single nucleotide polymorphisms (SNPs), pesticide or medicament resistances, tolerances or intolerances, genotyping, e.g. the detection of species or strains of organisms, the detection of genetically modified organisms or strains, or the detection of pathogens or pests, and the diagnosis of diseases, e.g. genetic diseases, allergic diseases, autoimmune diseases or infectious diseases. A further preferred application is the detection of nucleic acids in samples for brand protection, wherein products such agricultural products, food products, or goods of value and/or packaging of these products are encoded with product-specific information, e.g. but not limited to production site, date production, distributor etc., and wherein this information is detected with the methods as described above.

Detailed Description of Preferred Embodiments

The invention provides methods and reagents that allow specific labelling of analytes with marker groups, e.g. with reactive aldehyde groups in a complex sample. In a preferred embodiment, metal deposition, e.g. silver deposition, can be effected specifically on the aldehyde groups associated with the nucleic acid to be detected. In a further preferred embodiment,

metal deposition, e.g. silver deposition can be effected specifically by energy transfer from photosensitizing groups into a photosensitive medium, e.g. photographic paper. Due to the specific labelling procedure, the background is strongly reduced and higher sensitivities and reliabilities are obtained.

The present invention comprises the detection of an analyte. The detection may be a qualitative detection, e.g. the determination of the presence or absence of an analyte, e.g. a specific nucleic acid sequence in the sample to be analysed. The invention, however, also allows quantitative detection of an analyte, e.g. a nucleic acid sequence, in the sample to be analysed. Qualitative and/or quantitative detection may comprise the determination of labelling groups according to methods known in the art.

The analyte to be detected is preferably selected from nucleic acids and nucleoside-, nucleotide- or nucleic acid-binding molecules, e.g. nucleoside-, nucleotide- or nucleic acid-binding proteins. More preferably, the analyte is a nucleic acid, e.g. any type of nucleic acid which can be detected according to known techniques, particularly hybridization techniques. For example, nucleic acid analytes may be selected from DNA, e.g. double-stranded or single-stranded DNA, RNA, or DNA-RNA hybrids. Particular examples of nucleic acid analytes are genomic DNA, mRNA or products derived therefrom, e.g. cDNA.

The method of the invention can be carried out according to any known test format which is suitable for the detection of analytes, particularly nucleic acid analytes in a sample. For example, the method may involve the detection of analytes immobilized on solid surfaces such as membranes, e.g. in Southern or Northern blots, chips, arrays or particles such as beads. Further, the detection can be carried out in gels, e.g. after electrophoretic separation of the sample in gels, e.g. agarose or polyacrylamide gels. The method may involve the detection of single analytes or the parallel detection of a plurality of analytes, e.g. in a chip or microarray format.

In a preferred embodiment the detection involves irradiating a photosensitive medium in the presence of a sample containing an association product indicative for an analyte wherein the association product comprises photosensitizer groups capable of effecting an energy transfer to the photosensitive medium wherein marker groups are formed in the medium.

The sample may be any sample which may contain the analyte to be detected. For example, the sample may be a biological sample, such as an agricultural sample, e.g. a sample comprising plant material and/or material associated with the site where plants grow, plant materials are stored or processed. On the other hand, the sample may also be a clinical sample, such as a tissue sample or a body fluid sample such as blood, serum, plasma, etc, particularly of human origin. Further types of samples include, but are not limited to, environmental samples, soil samples, food samples, forensic samples or samples from valuable goods which are tested for brand protection.

Due to its high sensitivity, the method of the present invention is suitable for detecting analytes directly without amplification. According to the invention, even minute amounts of analytes, e.g. of nucleic acids, e.g. 0.1 ng or lower, preferably 0.01 ng or lower, more preferably 1 pg or lower, still more preferably 0.1 pg or lower, even more preferably 0.01 pg or lower and most preferably 0.001 pg or lower may be determined even without amplification. An especially high sensitivity may be obtained by incorporating multiple modified nucleotides into a nucleic acid molecule by using unprotected aldehyde groups and/or by using optimized staining techniques. For example, the detection of an analyte, e.g. a gene, in a biological sample, might be performed by a combination of Southern blotting and the inventive method. It should be noted, however, that the method of the present invention also allows the detection of nucleic acids combined with an amplification step, which may be carried out according to known protocols such as PCR or modifications thereof, such as asymmetric PCR, real-time

PCR, reverse transcription PCR, etc, or other amplification protocols such as LCR.

In a preferred embodiment of the invention, a sequence-specific detection of the analyte is carried out, wherein for example a nucleic acid having a specific sequence is distinguished from other nucleic acid sequences in the sample or a polypeptide capable of binding a specific nucleic acid sequence is distinguished from other polypeptides in the sample. Such a sequence-specific detection preferably comprises a sequence-specific hybridization reaction by which the nucleic acid sequence to be detected is associated with a compound carrying a marker group or a marker precursor group. It should be noted, however, that the present invention also allows sequence-unspecific detection of nucleic acids, e.g. detection of any nucleic acids present in a sample.

In order to identify the analyte to be detected, the sample may be contacted with an aldehyde-functionalized, Click-functionalized or photosensitizer-functionalized compound under conditions wherein an association product with the analyte, e.g. a nucleic acid is formed. An aldehyde-functionalized compound comprises a functional group which may be an aldehyde group, a protected aldehyde group, an aldehyde precursor group, i.e. a group which may be converted to an aldehyde group without a significant detrimental effect on the detection procedure or a handle group for introducing an aldehyde group, a protected aldehyde group or an aldehyde precursor group.

The functionalized compound may comprise a single functional group or a plurality of functional groups. For example, a functionalized compound may be coupled to a dendrimeric moiety comprising a plurality, e.g. 2, 3, 4, 5, 6, 7, 8 or more functional groups as indicated above. Dendrimeric moieties may be synthesized by known techniques. Preferably dendrimeric moieties are synthesized via Click reactions, e.g. as described in Example 5.

The functional group is attached to a compound which is capable of forming an association product with the analyte. The compound may be a nucleosidic or nucleotidic compound, e.g. a nucleoside or nucleoside analogue or a nucleotide or nucleotide analogue or an oligomer or polymer comprising at least one functionalized compound, e.g. a nucleic acid or nucleic acid analogue. A nucleosidic or nucleotidic compound is a nucleoside or nucleotide analogue or a nucleotide or nucleotide analogue capable of being incorporated into nucleic acids or nucleic acid analogues, e.g. by chemical or enzymatic methods. The resulting nucleic acid or nucleic analogue should be capable of forming association products, e.g. nucleic acid hybrids, with the analyte. Preferably, the compound comprises a base moiety, e.g. a nucleobase or another heterocyclic base moiety capable of forming base pairs with a nucleobase, and a backbone moiety, e.g. comprising a sugar moiety and optionally a phosphate moiety in nucleosides or nucleotides or a different backbone moiety in nucleoside or nucleotide analogues.

Preferred examples of functional nucleosidic compounds, wherein the nucleobase is 7-dN-G, C, 7-dN-A or T, and R is a functional group are shown in Figure 1.

Preferably, the functional group is attached to a base moiety, e.g. to a nucleobase. The functional group, however, may also be attached to a backbone moiety, e.g. a sugar group, a phosphate group or, in the case of nucleoside or nucleotide analogues, a modified sugar group, a modified phosphate group or peptide backbone moiety, etc. Preferably, the functional group is covalently attached to the compound via a direct bond or via a spacer. If the attachment is effected via a spacer, the functional group may be linked to an aliphatic or cycloaliphatic group, an aromatic or heteroaromatic group, an alkene group and/or an alkyne group. More preferably, the functional group may be linked to aromatic or heteroaromatic groups or to alkyne groups. Especially preferred aldehyde groups include aromatic and aliphatic aldehyde groups such as benzaldehyde, or aldehyde

groups in aldoses such as trioses, tetroses, pentoses or hexoses like glucose or mannose.

The functional group may be a free aldehyde group. The functional group may also be a protected aldehyde group, i.e. group which may be converted under the assay conditions to an aldehyde group. A preferred protected aldehyde group is an acetal or hemiacetal group which can be converted into a free aldehyde group by treatment with acids, e.g. organic or inorganic acids. Preferred examples of acetal or hemiacetal groups are acetal groups formed with a polyalcohol such as propane diol or ethylene glycol, or hemiacetal groups in a sugar or in a sugar-related compound such as an aldose sugar, e.g. glucose or galactose. Further examples of protected aldehyde groups are imino groups (e.g. =NH groups), which give aldehyde groups upon treatment with acids, thioacetal or dithioacetal groups (e.g. C $(SR)_2$ groups wherein R may be an alkyl radical) which give aldehyde groups upon treatment with mercury salts, oxime groups (e.g. =NOH groups),which give aldehyde groups upon treatment with acids, hydrazone groups (e.g. =N-NHR groups wherein R may be an alkyl radical) which give aldehyde groups upon treatment with acids and imidazolone or imidazolidine groups or benzothiazole or dihydrobenzothiazole groups which give aldehydes upon hydrolysis, e.g. with acid. Specific examples of functionalized compounds comprising free or protected aldehyde groups and methods for preparing such compounds are shown in Figures 2, 3a, 3c, 7, 8, 9d, and 9e.

The functional group may also be an aldehyde precursor group, i.e. a group which may be converted to an aldehyde group without a significant detrimental effect on the nucleic acid detection procedure. Preferred aldehyde precursor groups may be selected from carboxylic acids and carboxylic acid derivatives including nitriles which give aldehydes upon reduction and primary alcohols which give aldehydes upon oxidation.

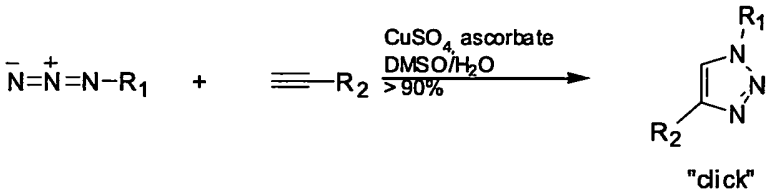
In a different embodiment, the functional group may be a photosensitizer group, i.e. a group which is capable of effecting an energy transfer, e.g. a

transfer of light energy, to a photosensitive medium, i.e. a photographic medium such as photographic paper. The photosensitizer groups may be selected from known fluorescent and/or dye labelling groups such as cyanine-based indoline groups, quinoline groups, for example commercially available fluorescent groups such as Cy5 or Cy5.5. Specific examples of photosensitizer groups are shown in Figure 22.

The functional group may also be a handle group, i.e. a group for introducing an aldehyde group, a protected aldehyde group or an aldehyde precursor group or for introducing a photosensitizer group by reaction with a suitable reaction partner, i.e. a compound comprising one of the above groups. In a preferred embodiment, the handle groups are selected from Click functionalized groups, i.e. groups which may react with a suitable reaction partner in a cycloaddition reaction wherein a cyclic, e.g. heterocyclic linkage between the Click functional group and the reaction partner is formed, and wherein the reaction partner comprises an aldehyde or a protected aldehyde group or a photosensitizer group. An especially preferred example of such a Click reaction is a (3+2) cycloaddition between azide and alkyne groups which results in the formation of 1,2,3-triazole rings. Thus, aldehyde groups, may be generated by performing a Click reaction of an azide or alkyne handle group and a corresponding reaction partner, i.e. a reaction partner comprising the complementary alkyne or azide group and additionally an aldehyde, a protected aldehyde group or an aldehyde precursor. In a further embodiment of the invention, the reaction partner of the Click-functionalization, however, may also contain different marker or marker precursor groups such as fluorescence marker groups or photosensitizer groups.

An especially preferred embodiment of the Click reaction comprises a copper catalyzed (3+2) cycloaddition between an azide and an alkyne group. The irreversible formation of 1,2,3-triazoles as a result of the azide/alkyne cycloaddition is orthogonal, the required chemical groups are small (incorporation with minimal disruption of the biomolecule's

environment) and selective due to the lack of azides and alkynes found in nature.



wherein R_1 and R_2 are organic radicals.

Specific examples of Click-functionalized compounds and methods for preparing such compounds are shown in Figures 3b, 9a-c and 10. Specific examples of reaction partners for Click-functionalized compounds are shown in Figure 11 and 12.

The functional group, e.g. an aldehyde-functionalized group or a Click-functionalized group or a photosensitizer-functionalized group is preferably attached to a nucleobase which may be selected from naturally occuring and non-naturally occuring purine and pyrimidine bases. Preferably, the nucleobases are selected from cytidine, uracil, thymine, adenine, guanine, 7-deazaadenine, 7-deazaguanine, inosine and xanthine. The functional group is preferably attached to position 5 or 6, more preferably to position 5, of a pyrimidine nucleobase or to position 7 or 8, more preferably to position 7 of a purine nucleobase, particularly if an enzymatic incorporation into a nucleic acid is desired.

The functional group may be covalently attached to the compound, e.g. via a direct bond or a spacer, e.g. a spacer having a chain length up to 20 atoms. The spacer may be a flexible spacer, e.g. an alkylene-based spacer, optionally containing heteroatoms such as O, S, and/or N or an at least partially rigid spacer, e.g. a spacer which comprises at least one rigid group selected from alkene groups, alkyne groups, cyclic groups, particularly aromatic or heteroaromatic groups, but also cycloaliphatic groups and

combinations thereof. If the functionalization compound comprises a Click-functionalization group which is the first reaction partner for a Click-reaction and subsequently reacted with a second reaction partner for a Click-reaction, an attachment of the functional group via a direct bond, a flexible spacer or an partially rigid spacer is preferred wherein the flexible spacer could for example have a chain length up to 6 atoms, more particularly up to 4 atoms, and wherein a partially rigid spacer preferably has a chain length of up to 20 atoms, e.g. up to 10 atoms and comprises at least one rigid group as defined above, particulary an alkyne group, and at least one flexible group, e.g. an alkylene group. If on the other hand, the functional group is an aldehyde group or a protected aldehyde group or an aldehyde precursor group attachment via or a partially rigid spacer as defined above or an at least partially rigid spacer having a chain length of from 2 to 10 atoms is preferred. The structure of a rigid group-containing spacer, e.g. a partially rigid spacer, is preferably such that the rigid group is directly attached to the nucleobase. A preferred example of a partially rigid spacer is shown in Fig. 15a and b.

The functionalized compound is capable of forming an association product with the analyte to be detected. On the one hand, the functionalized compound may be selected from compounds which can be incorporated into nucleic acids or nucleic acid analogues, i.e. nucleic acid or nucleic acid analogue building blocks. Preferred examples for such compounds are nucleotides or nucleotide analogues, e.g. aldehyde-functionalized nucleotides or nucleotide analogues, Click-functionalized nucleotides or nucleotide analogues or photosensitizer-functionalized nucleotides or nucleotide analogues. On the other hand, the functionalized compound may be selected from nucleic acids or nucleic acid analogues, e.g. aldehyde-functionalized nucleic acids or nucleic acid analogues, Click-functionalized nucleic acids or analogues or photosensitizer-functionalized nucleic acids or analogues.

The term "nucleotide" according to the present invention particularly relates

to ribonucleotides, 2'-deoxyribonucleotides or 2', 3'-dideoxyribonucleotides. Nucleotide analogues may be selected from sugar- or backbone modified nucleotides, particularly of nucleotide analogs which can be enzymatically incorporated into nucleic acids. In preferred sugar-modified nucleotides the 2'-OH or H-group of the ribose sugar is replaced by a group selected from OR, R, halo, SH, SR, NH_2, NHR, NR_2 or CN, wherein R is C_1-C_6 alkyl, alkenyl or alkynyl and halo is F, Cl, Br or I. The ribose itself can be replaced by other carbocyclic or heterocyclic 5- or 6-membered groups such as a cyclopentane or a cyclohexene group. In preferred backbone modified nucleotides the phospho(tri)ester group may be replaced by a modified group, e.g. by a phosphorothioate group or a H-phosphonate group. Further preferred nucleotide analogues include building blocks for the synthesis of nucleic acid analogs such as morpholino nucleic acids, peptide nucleic acids or locked nucleic acids.

Aldehyde-, Click- or photosensitizer- functionalized nucleic acids may be oligonucleotides, e.g. nucleic acids having a length of up to 30 nucleotide (or nucleotide analogue) building blocks or polynucleotides having a length or more than 30 nucleotide (or nucleotide analogue) building blocks. Preferably, the nucleic acids and nucleic analogues are capable of specific binding to the analyte, e.g. capable of hybridizing with a nucleic acid analyte under assay conditions. The minimum length is preferably 12 and more preferably 14 nucleotide (or nucleotide analogue) building blocks.

Functionalized nucleic acid or nucleic acid analogue building blocks may be incorporated into nucleic acids by standard techniques for chemical synthesis and/or by enzymatic incorporation. Chemical synthesis for example may be carried out by standard phosphoramidite chemistry using modified nucleoside phosphoramidites as building blocks in standard synthesis protocols. Other types of preferred building blocks for chemical synthesis include H-phosphonate or phosphorotriester modified nucleosides.

On the other hand, modified nucleotides may be incorporated into nucleic

acids by enzymatic methods. Surprisingly, it was found that aldehyde- or Click-functionalized nucleoside triphosphates are accepted as enzyme substrates by nucleic acid synthesizing enzymes such as DNA polymerases, RNA polymerases, reverse transcriptases or telomerases. For example, it was found that modified nucleoside triphosphates are accepted by DNA polymerases commonly used for primer extension and amplification protocols, e.g. thermostable DNA polymerases such as Taq polymerase, Vent polymerase, Pfx polymerase, Pwo polymerase, or Therminator polymerase as described in Example 7. Enzymes accept modified triphosphates without loss in fidelity and allow a template-based incorporation into nucleic acids such as DNA and RNA.

The method of the present invention provides various embodiments of analyte detection. For example, functionalized nucleic acid building blocks, e.g. nucleotides or nucleotide analogues, together with appropriate enzymes, may be provided which are enzymatically incorporated into a nucleic acid molecule which forms the association product with the analyte. In the present invention, a single type of functionalized nucleotide or a plurality of different types of functionalized nucleotides may be employed. Alternatively or additionally, a functionalized nucleic acid or nucleic acid analogue may already be present, which has been manufactured, e.g. by chemical or enzymatic synthesis, and which specifically binds, e.g. by hybridization to the analyte to be detected.

In a preferred embodiment the method comprises a primer extension reaction optionally in combination with subsequent nucleic acid amplification steps such as PCR. For example, at least one primer molecule may be provided which hybridizes under assay conditions with a nucleic acid analyte to be detected or the complement thereof. The bound primer is then extended wherein a detectable extension product is obtained which is indicative for the presence and/or amount of the nucleic acid analyte to be detected. According to this embodiment, functionalized primers and/or functionalized nucleotides or nucleotide analogues for incorporation into the

extension product may be used.

Alternatively and/or additionally the method of the invention may comprise the use of functionalized hybridization probes which hybridize under the assay conditions with the nucleic acid analyte to be detected or the complement thereof wherein the formation of a hybridization product is indicative for the presence and/or amount of the nucleic acid analyte to be detected.

The detection method of the invention may be carried out by any known nucleic acid detection protocols, e.g. involving the use of solid supports. For example, a solid support, e.g. a chip or array or a particulate material such as a bead may be provided to which a capture probe is bound capable of hybridizing to the analyte to be detected. The solid phase bound nucleic acid analyte may be detected by using functionalized hybridization probes which hybridize with the nucleic acid analyte in a different sequence part as the capture probe does and subsequent detection of the bound hybridization probe, e.g. with a metallization reagent. This method is particularly suitable for the diagnostic applications in the agricultural and clinical field, e.g. for the detection of DNA and/or mRNA from plants, e.g. genetically modified plants, DNA from pathogens or plant pests etc.

In a specific embodiment, the detection may involve contacting the association product of the analyte and a functionalized compound comprising a photosensitizer group with a photosensitive medium, e.g. by transferring a sample or sample aliquot in which an association product may be present onto the photosensitive medium, e.g. by spotting, pipetting etc. Upon irradiation, an energy transfer from the photosensitizer group to the photosensitive medium is effected such that marker groups such as metal, e.g. silver, nuclei are formed in the photosensitive medium in the presence, but not in the absence, of photosensitizer groups. If necessary, the marker groups may be subjected to a development procedure, e.g. a chemical or photochemical development procedure according to photographic

techniques. The photosensitive medium may be any solid support or any supported material capable of forming marker groups, e.g. metal nuclei. Preferably, the photosensitive medium is a light sensitive medium, such as light sensitive paper or a light sensitive emulsion or gel on a supportive material. More preferably the photosensitive medium is a photographic medium such as photographic paper. Irradiation is carried out under conditions, e.g. of wavelengths and/or intensity of irradiation light, under which selective marker group formation takes place in the presence of photosensitizer groups. Preferably, irradiation takes place with infrared light and/or with long wave visible light, depending on the sensitivity of the medium. The irradiation wavelength may be e.g. 500 nm or higher, 520 nm or higher, 540 nm or higher, 560 nm or higher, 580 nm or higher for visible light or 700 nm to 10 µm, for infrared light.

An important aspect of the invention is the detection of genetic variabilities, e.g. single nucleotide polymorphisms (SNPs). The genome of, for example humans, contains nucleotide sequence variations at an average frequency of up to 0.1%. Therefore, these variabilities provide excellent markers for the identification of genetic factors contributing to complex disease susceptibility [16, 17]. Although there is a wide range of techniques available for the detection of SNPs, most of these methods are slow, require extensive instrumentation, and PCR amplification [18]. The present method, however, is both inexpensive and flexible enough to accommodate low, moderate and high-throughput screening needs with high speed, sensitivity and efficiency. Several possibilities exist to label selectively only the fully matching or the mismatching strands allowing to use the method of the invention for the detection of SNPs.

For example, the detection of nucleic acid matches or mismatches, e.g. in SNPs, may comprise the use of functionalized hybridization probes which hybridize under the assay conditions with the nucleic acid analyte to be detected for the complement thereof and subjecting the hybridization product to a treatment procedure wherein a hybridization product containing at least

one mismatch is dissolved and wherein the presence of an undissolved hybridization product is indicative for the presence and/or amount of a nucleic acid which has a fully complementary sequence (i.e. no mismatch) to the hybridization probe.

The treatment for the dissolution of mismatch-containing hybridization products may comprise a mismatch digestion treatment, i.e. the use of mismatch detecting enzymes which cleave the hybridization product depending on the presence of a mismatch. Suitable enzymes for such a mismatch digestion treatment include mismatch-glycosylases such as those encoded by the genes hMSH2 and hMLH1 and Mut S, Mut L and Mut H. Additional proteins are MutY and Mig.Mth1. Mig.Mth1 cuts T out of a TG mismatch, MutY cuts out A in an AG mismatch and the enzyme TDG cuts out T in a TG mismatch.

Alternatively or additionally, mismatch-containing hybridization products may be dissolved by a differential hybridization treatment involving the adjustment of hybridization conditions, e.g. in view of temperature, salt concentration and/or washing with dimethyl ammonium chloride, wherein a mismatch containing hybridization product is dissolved and the fully complementary hybridization product remains stable.

In a still further embodiment, mismatches, e.g. SNPs, may be determined by enzyme-catalyzed selective primer elongation. For this purpose a primer is provided, wherein the 3' end of the primer is directly located upstream of a potential mismatch site on the template analyte. A primer extension is only possible when a nucleotide which is complementary to the next base on the template is present. By selecting a single type of functionalized nucleotide and determining whether it is incorporated into the primer or not, the base on the potential mismatch site can be determined.

The method of the invention comprises the detection of marker groups which are incorporated into an association product of the analyte with a

functionalized compound. The marker groups are preferably selected from metal deposition-forming groups, e.g. aldehyde-functionalized groups, from fluorescent or fluorescence-forming groups or from redox active groups.

The formation of metal depositions requires the treatment of aldehyde groups with a metallization reagent, e.g. a reagent comprising metal atoms and/or ions selected from Ag, Au, Bi, Cu, Pd or Pt which can be selectively deposited around aldehyde groups, e.g. by reduction. Preferably, the metallization reagent comprises an Ag^+ salt such as an Ag-ammonium complex, i.e. the Tollens reagent. Further preferred examples of metallization reagents are Cu $(NO_3)/I_2$, platinum terpyridine complexes such as [Pt(terpy)Cl]Cl, $Pd(OAc)_2$ or $KAuCl_4$.

Further, the functionalized groups may also function as a handle to attach other marker groups such as fluorescent marker groups. For example, marker compounds with amino groups may be coupled to aldehyde groups by reductive amination in the presence of a reducing agent such as sodium cyanoborohydride. Alternatively hydrazone or oxime formation may be used to provide marker groups.

The detection of the marker groups may be carried out according to known methods. For example, metal depositions may be determined qualitatively and/or quantitatively by optical methods and/or electrical methods. In a preferred embodiment, metal depositions on a solid surface may be determined by measuring electrical parameters, e.g. conductivity. Fluorescent marker groups may be determined qualitatively and/or quantitatively by known fluorescent measurement methods, e.g. excitation via a suitable light source such as a laser and detecting the emitted fluorescent light.

In a further embodiment, the invention comprises the detection of marker groups which are site-specifically formed in a photosensitive medium in the presence of photosensitizer groups in an association product of the analyte

with a functionalized compound. The photosensitizer groups are preferably selected from fluorescent or luminescent groups. The photosensitizer groups can be incorporated directly into the association product or via a handle, e.g. via a Click-reaction as explained above in detail. The photosensitive medium comprises groups which, when irradiated in the presence of photosensitizer groups, form detectable marker groups such as metal nuclei which can be developed according to standard photographic techniques, e.g. by chemical or photochemical development techniques.

The invention also relates to reagent kits for detecting analytes, e.g. nucleic acid analytes in a sample which comprise a functionalized compound having attached at least one functional group as described above. Generally, the kit may comprise a compound of formula (III)

F-S-N

wherein F is any functional group as described above, e.g. a group A as defined in formula (I), a group C as defined in formula (II) and/or a photosensitizer group;
S is a spacer or a bond, preferably a covalent bond, and
N is a nucleic acid or nucleic acid analogue building block such as a nucleosidic or nucleotidic compound.

The reagent kit may optionally contain an aldehyde forming reagent or a second partner for a Click-reaction and marker or marker-forming reagents or a photosensitive medium. The kits are preferably used in a method as indicated above.

Further, the present invention relates to an aldehyde-functionalized compound of formula (I) or a Click-functionalized compound of formula (II) as indicated above. The functionalized compounds may be building blocks for the chemical or enzymatic synthesis of nucleic acids or nucleic acid analogues or precursors thereof. Preferably, the compounds are nucleoside

triphosphates, particularly ribose, 2'-deoxyribose or 2'-, 3'-dideoxyribose nucleoside triphosphates or analogues thereof which may be enzymatically incorporated into nucleic acids.

Furthermore, the compounds may be building blocks for the chemical synthesis of nucleic acids, or nucleic acid analogues such as peptide nucleic acids, morpholino nucleic acids or locked nucleic acids. To this end nucleoside phosphoramidites, H-phosphonates, phosphotriesters or Fmoc and/or Boc protected nucleobase amino acids are suitable.

The invention also relates to a nucleic acid or nucleic acid analogue molecule having incorporated therein at least one compound of formula (I) and/or formula (II). The molecule may be a nucleic acid selected from DNA and RNA or a nucleic acid analogue, e.g. selected from peptidic nucleic acids, morpholino nucleic acids or locked nucleic acids as described in detail above.

Further, the invention relates to a method of synthesizing a nucleic acid or nucleic acid analogue molecule comprising incorporating at least one nucleotide or nucleotide analogue building block comprising a compound (I) and/or (II) into a nucleic acid or nucleic acid analogue molecule. The method may comprise a chemical synthesis and/or an enzymatic synthesis.

Furthermore, the invention relates to a metallization product of the nucleic acid or nucleic acid molecule as indicated above which is obtainable by treatment of an aldehyde functionalized compound containing nucleic acid with a metallization reagent as indicated in detail above.

Furthermore, the invention relates to an association product of the nucleic acid or nucleic acid analogue molecule as indicated above with an analyte as described above. Preferably, the association product is a hybridization product with a complementary nucleic acid.

In a preferred embodiment, the methods and the reagent kits of the present invention are used for agricultural applications. For example, the invention is suitable for the detection of nucleic acids from plants, plant pathogens or plant pests such as viruses, bacteria, fungi or insects. Further, the invention is suitable for detecting genetic variabilities, e.g. SNPs in plants or plant parts, plant pathogens or plant pests such as insects.

A further application is a detection or monitoring of herbicide, fungicide or pesticide resistances, tolerances or intolerances, e.g. resistances, tolerances or intolerances in fungi, insects or plants in organisms or populations of organisms. The invention is also suitable for rapid genotyping, e.g. for the rapid detection and/or differentiation of species or strains of fungi, insects, or plants. Further, detection and/or differentiation of genetically modified organisms for strains, e.g. organisms or strains of fungi, insects or plants is possible.

Due to the high sensitivity of the invention, early diagnostic of pathogens is possible, i.e. diagnostics before first symptoms of the presence of pathogens is visible. This is particularly important for the diagnosis of soy rust (Phakospora pachyrizi) or other pathogens, e.g. Blumeria graminis, Septoria tritici or Oomycetes or other pathogens for which control is only possible, if their presence is detected before it can be visually recognized.

Further, the invention is suitable for medical, diagnostic and forensic applications, e.g. in human or veterinary medicine, e.g. for the detection of nucleic acids from pathogens, e.g. human pathogens or pathogens of livestock or pet animals.

Further preferred applications include the detection of genetic variabilities, e.g. SNPs in humans or the detection of medicament resistances, tolerances or intolerances or allergies. Further, the invention is suitable for genotyping, particularly genotyping of humans in order to determine mutations associated with predisposition or enhanced risk of disorders, allergies and

intolerances. The invention may also be used for the detection of genetically modified organisms or strains, organisms or strains of bacteria or viruses but also genetically modified life stock animals etc. The invention is particularly suitable for the rapid diagnosis of diseases, e.g. genetic diseases, allergic diseases, autoimmune diseases or infectious diseases.

Furthermore, the invention is suitable for detecting the function and/or expression of genes, e.g. for research purposes.

Still a further embodiment is the use of the method for brand protection, e.g. for detecting specific information encoded in products such as valuable goods like plant protection products, pharmaceuticals, cosmetics and fine chemicals (e.g. vitamins and amino acids) and beverage products, fuel products, e.g. gasoline and diesel, consumer electronic appliances can be marked. Further, packaging of these and other products can be marked. The information is encoded by nucleic acids or nucleic acid analogues which have been incorporated into the product and/or into the packaging of a product. The information may relate to the identity of the manufacturer, to production sites, date of production and/or distributor. By means of the present invention, rapid detection of product-specific data can be carried out. A sample may be prepared from an aliquot of the product which is then contacted with one or several sequence-specific functionalized hybridization probes capable of detecting the presence of nucleic acid-encoded information in the sample.

The invention is also suitable for the field of nutrients. For example, in the feed area, animal nutrients, e.g. corn, are supplemented with a greater quantity of preservatives such as propionic acid. By applying the method of the invention, the addition of preservatives can be reduced. Further, genomic analysis with the method of the invention allows the prediction of an individual's capability to utilize specific nutrients (nutrigenomics).

Still a further preferred embodiment refers to the field of epigenetics. This

embodiment particularly refers to an analysis of DNA, e.g. genomic DNA with regard to methylation of cytosine bases. In this embodiment, the DNA may be treated with a cytosine-specific reagent, e.g. hydrazine and/or hydroxylamine. By means of the treatment, a selective reaction of either cytosine or methylcytosine residues occurs. For example, treatment with hydroxylamine leads to a selective modification of cytosine residues. Preferably, the reagent is added in a sub-stoichiometric amount in order to obtain a partial modification of e.g. cytosine residues. Subsequently, the treated DNA is analysed, e.g. by a primer extension reaction using at least one modified nucleic acid building block as indicated above, e.g. a dU and/or dC base. Preferably a Click-modified base, e.g. an alkyne-modified base is used. The primer extension reaction gives a characteristic sequencing ladder resulting from interruptions of the reaction on the modified dC or 5-methyl-dC bases (cf. Fig. 26).

A further preferred embodiment refers to the application of reporter nucleic acid molecules to a photosensitive medium, e.g. photographic paper or any other light sensitive medium. Preferably, the reporter molecules carry a photosensitizer group and a quencher group. In the absence of analyte the photosensitizer group is quenched. For example, the reporter molecule may have a hairpin structure with the photosensitizer and the quencher group on or near the termini of the molecule in close spatial relation-ship. When the reporter molecule is present as a hairpin structure, the photosensitizer group is quenched (according to the known molecular beacon technique). Thus, a reporter molecule with an intact hairpin structure cannot effect a sensibilisation when irradiating light to the photosensitize medium. In the presence of an analyte the hairpin structure is broken up. The analyte may be a complementary nucleic acid strand or an enzyme which cleaves the hairpin structure or a protein which binds to the hairpin and thus brakes up the structure. The photosensitizer group is separated from the quencher group and thus is capable of photosensibilisation. In this case, irradiation of light leads to a sensibilisation of the photographic medium and thus to the detection of analyte (cf. Fig. 27).

In this embodiment the present invention relates to a method for detecting an analyte in a sample comprising the steps:

(i) providing a sample,

(ii) providing a reporter molecule comprising a photosensitizer group or a handle group for introducing a photosensitizer group and a quencher group wherein the photosensitizer group is quenched in the absence of the analyte to be detected,

(iii) contacting the sample with the reporter molecule under conditions wherein the quenching of the photosensitizer group is at least partially reduced or terminated in the presence of the analyte,

(iv) if necessary, reacting the handle group with a reaction partner comprising a photosensitizer group,

(v) irradiating said reporter molecule in contact with a photosensitive medium under conditions wherein marker groups are formed in said photosensitive medium in the presence of unquenched photosensitizer groups in said reporter molecule, and

(vi) detecting said marker groups

Further, this embodiment refers to a reagent kit for detecting an analyte in a sample comprising

a) a reporter molecule comprising a photosentisitizer group or a handle group for introducing a photosensitizer group and a quencher group wherein the photosensitizer group is quenched in the absence of the analyte to be detected,

b) optionally a reaction partner for the handle group comprising a photosensitizer group and

c) a photosensitive medium which forms marker groups upon irradiation of unquenched photosensitizer groups

Preferred aspects of the method an the reagent kits and preferred applications are as described above.

The invention is further explained by the following Figures and Examples.

Description of Figures

Figure 1: Preferred attachment sites of functional groups (R), e.g. aldehyde functionalized groups on different nucleobases 7-dN-G, C, 7-dN-A and T for the enzymatic incorporation of marker groups into oligonucleotides.

Figure 2: Schematic representation of the synthesis of aldehyde functionalized nucleoside building blocks for the solid phase synthesis of nucleic acids.

Figure 3a: Schematic representation of the synthesis of an acetal (protected aldehyde) functionalized nucleoside triphosphate for the enzymatic synthesis of nucleic acids.
Figure 3b: An example of an alkyne functionalized nucleoside triphosphate for efficient Click chemistry in DNA, wherein n is preferably 0-4.
Figure 3c: An example of a protected aldehyde functionalized triphosphate.
The compounds shown in Figure 3 are suitable for efficient PCR incorporation into DNA.

Figure 4: The results of a metallization reaction by contacting Tollens reagent with an aldehyde-modified base: (1) sugar solution as reference, (2) DNA with one aldehyde-modified group, (3) DNA with two aldehyde groups and (4) unmodified DNA.

Figure 5: (I) Primer extension products stained with Ag (a) or using a standard fluorescence dye (b): I.1a: aldehyde-modified TTP in primer extension. I.1b: acetal-modified TTP in primer extension. I.3a: unmodified DNA. Silver staining only positive on Lane 1 and 2. I.1b-3b same gel but stained unspecifically with a fluorescence dye. (II) A 2142 bp PCR product stained with a fluorescent dye (a) or with Ag (b): II2a: acetal-modified TTP in PCR. M: marker; II1b: aldehyde-modified TTP in PCR, 2: acetal-modified

TTP in PCR, II3b: unmodified DNA.

Figure 6: The results of a dilution series with a synthetic DNA molecule containing a single aldehyde functional group. Detection by Ag-staining.

Figure 7: Examples of nucleosides with different nucleobases carrying acetal (protected aldehyde) functions, which can be converted into corresponding phosphoramidites, H-phosphonates or triesters for chemical synthesis of nucleic acids or into 5'-triphosphates for enzymatic incorporate of nucleic acids.

Figure 8: Derivatisation of aldehyde modified DNA or PNA with a fluorescence tag as an alternative to metallization via reductive amination.

Figure 9: Alkyne-modified (a,b), azide-modified (c) and protected aldehyde-modified (d,e) nucleoside and nucleotide monomers, wherein n is preferably 0-4.

Figure 10: Schematic representation of the synthesis of alkyne-functionalized nucleosides and nucleotide triphosphates.

Figure 11: Schematic representation of the synthesis of azide-functionalized dendrimers comprising protected aldehyde groups.

Figure 12: Examples of azide and alkyne azide derivatives with marker or marker precursor groups for the Click reaction with alkyne- or azide-modified nucleotides or nucleic acids.

Figure 13: On top: MALDI-TOF analysis of the Click reaction with oligonucleotides containing the modified base **2** (Figure 9b) and fluorescein azides as the clicking partner (m: 495). Below: Gel electrophoresis of Click reactions of DNA modified with monomer **2** and fluorescine azide. A1: Fluorescence image, Lane 1: starting material prior to Click reaction; 2,3:

raw reaction mixture; 4: Azide under Click conditions; A2: same gel stained with SYBR Green. B1: Lane 1,2: raw reaction mixture; 3: starting material; B2 same gel but stained stained with SYBR Green.

Figure 14: Click reaction for introducing coumarin azide into DNA results in a fluorescent product (right reaction tube).

Figure 15: An alkyne-modified phosphoramidite (a), an alkyne-modified nucleoside (b) and azide-modified galactose (c).

Figure 16: PCR assay using 200 µM of 8, dATP, dCTP and dGTP, 0.05 µg genomic DNA from *S. cerevisiae* 499, 10x polymerase buffer with magnesium, 0.3 mM each of primers and 1.25 U polymerases. Lane1) Vent, 2) Vent (exo$^-$), 3) Pwo, 4) Taq (exo$^-$) from Roche, 5) Therminator, 6) Taq from Promega and 7) marker.

Figure 17: PCR amplification of 2142 bp DNA with modified triphosphate **1** or **8** (Figure 10) replacing dTTP. Agarose Gel (2%) was used and stained with Ethidium Bromide. A total of 35 PCR cycles were run, with 45 sec used for each incubation. Lane 1) NEB 2-log DNA ladder (0.1-10.0 kb), Lane 2) Negative control (minus dTTP), Lane 3) with substrate (**1**) replacing dTTP, 4) with substrate (**8**) replacing dTTP and 5) positive control (using dTTP).

Figure 18: HPLC chromatogram of (a) the enzymatic digest of PCR fragments (318 mer) incorporating triphosphate **8** (Figure 10); (b) the enzymatic digest of PCR fragments incorporating dTTP; (c) nucleoside **7** (Fig.10).

Figure 19: Dilution series of 318 bp PCR fragments incorporating triphosphates 1 and 2 followed by "on the gel" clicking and silver staining. (a) Dilution series of PCR fragments incorporating 1 (Lane 1 7.0 ng, Lane 2 3.5 ng, Lane 3 1.3 ng, Lane 4 0.7 ng) and 2 (Lane 5 7.0 ng, Lane 6 3.5 ng, Lane 7 1.3 ng, Lane 8 0.7 ng) run on a TBE-urea PAAG gel. The gel was

subjected to "on the gel" clicking with azide 3 and subsequent silver staining. (b) Comparative detection of a dilution series of a PCR fragment incorporating 2 via (i) the selective silver staining method (as per (a)) and via (ii) SYBR green II (Lane 1 7 ng, Lane 2 3.5 ng, Lane 3 1.3 ng, Lane 4 0.9 ng, Lane 5 0.5 ng, Lane 6 0.3 ng). (c) Dilution series of PCR fragments incorporating 2 (Lane 1 7 ng, Lane 2 3.5 ng, Lane 3 1.3 ng, Lane 4 0.9 ng, Lane 5 0.5 ng, Lane 6 0.3 ng) and 2 Lane 1 7.0 ng, Lane 2 3.5 ng, Lane 3 1.3 ng, Lane 4 0.7 ng) run on TBE-urea PAAG gel. The gel was then subjected to "on the gel" clicking with aldehyde-modified azide 4 and subsequent silver staining. (d) Dilution series of PCR fragments incorporating 2 (Lane 1 7 ng, Lane 2 3.5 ng, Lane 3 1.3 ng, Lane 4 0.9 ng, Lane 5 0.5 ng, Lane 6 0.3 ng) run on TBE-urea PAAG gel. The gel was then subjected to "on the gel" clicking with aldehyde-modified azide 5 and subsequent silver staining.

Figure 20: AFM photographs of natural DNA (a) and aldehyde-modified DNA (b) after exposure to Ag staining conditions, and aldehyde-modified DNA after Ag staining without development (c), after 2 min of development (d) and after two times 2 min of development (e).

Figure 21: A schematic depiction of an analyte, e.g. DNA analyte detection method using the principles of black and white photography. Initial replication of the DNA analyte in the presence of a sequence-selective primer produces a target sequence tagged with a sensitizer (**S**). After irradiation and subsequent photographic development the analyte can be detected on a photosensitive medium, e.g. photographic paper.

Figure 22: Depiction of cyanine dyes **(1)**, **(2)** and **(3)**. Dilution series of cyanine dyes irradiated for 10 seconds using an overhead projector lamp equipped with a 520 nm cut-off filter using **(a) 1**; **(b) 2**; and **(c) 3** or irradiation for 5 minutes with an infrared lamp using **(d) 1**, **(e) 2** and **f (3)**. The spot experiments correspond to the following dilutions: Spot 1: 1×10^{-11} mol., Spot 2: 1×10^{-12} mol., Spot 3: 3×10^{-13} mol, Spot 4: 1×10^{-13} mol, Spot

5: 3 x 10^{-14} mol, Spot 6: 1 x 10^{-14} mol, Spot 7: 3 x 10^{-15} mol, Spot 8: 1 x 10^{-15} mol, Spot 9: 3 x 10^{-16} mol, Spot 10: 1 x 10^{-16} mol,

Figure 23: Spot tests of oligodeoxyribonucleotides ODN-1 [5'-GCG ATT CGT TCG TCG C-3'], ODN-2 [5'-CGC GAA TGA ACA GCG C-3'] and ODN-3 [5'-GCG ACC GAT TCG C-3'] all at 50 nmol. using **(a)** high energy irradiation and a cut-off filter (520 nm); and **(b)** low energy irradiation via prolonged exposure (5 minutes) using an infrared lamp.

Figure 24: Depiction of cyanine dyes Cy5 and Cy5.5. Dilution series of cyanine dyes tethered to ODNs irradiated for either 10 seconds using an overhead projector lamp equipped with a 520 nm cut-off filter using **(a)** ODN-**4** [5'-Cy5-GCG CTG TTC ATT CGC G-3']; **(b)** ODN-**5** [5'-Cy5.5-GCG CTG TTC ATT CGC G-3']; or irradiation for 5 minutes with an infrared lamp using **(c)** ODN-**4**; **(d)** ODN-**5**. The spot experiments correspond to the following dilutions: Spot 1: 1 x 10^{-11} mol., Spot 2: 3 x 10^{-12} mol., Spot 3: 1 x 10^{-12} mol, Spot 4: 3 x 10^{-13} mol, Spot 5: 1 x 10^{-13} mol, Spot 6: 3 x 10^{-14} mol, Spot 7: 1 x 10^{-14} mol, Spot 8: 3 x 10^{-15} mol.

Figure 25: Schematic depiction of the process of the "Click and photograph" methodology. A sequence, e.g. gene, of interest is specifically selected and amplified via PCR with alkyne-modified triphosphates (dU*TP) and gene-selective primers. These alkyne functions can be tagged via click chemistry with an appropriate photosensitizer (**S**) producing photosensitized DNA hybrids. Irradiation of the sample on photo paper and subsequent development will provide a new method for the ultra sensitive and specific detection of genes.

Figure 26: Schematic depiction of a method for identifying methylation patterns in DNA by cytosine-specific chemical modifications. A DNA analyte is reacted with a cytosine (or methylcytosine) specific modification agent, e.g. hydroxylamine, preferably in a sub-stoichiometric amounts in order to give partially modified cytosine residues (C*). A primer extension reaction

with an alkynyl-modified base is carried out. This reaction terminates at modified cytosine residues resulting in a "ladder" of extension products having a characteristic length. After separating the primer extension products e.g. on a gel, a Click reaction with an azide-modified marker group, e.g. a modified sugar and a subsequent detection of the marker group (e.g. via silver staining) is carried out. The methylation pattern of the DNA sample may be determined by comparing extension products from a methylated DNA sample with the extension products from an unmethylated DNA sample which has been subjected to the same treatment.

Figure 27: Schematic depiction of a molecular beacon detection method on a photosensitive medium. A reporter molecule having a fluorescence group (F) and a quenching group (Q) is provided. In the absence of analyte, the reporter molecule has a hairpin structure and the fluorescence is quenched. In the presence of analyte the quenching group is removed from the fluorescence group which becomes unquenchend (F*). The sample is irradiated in the presence of a photographic medium such as photographic paper or other light-sensitive material and developed.

Examples

Example 1

Synthesis of aldehyde-modified nucleosides and nucleotides

Nucleosides and nucleoside triphosphates with aldehyde-modified nucleobases were synthesized from appropriately modified nucleosides which carry a leaving group such as I, preferably either on position 5 of pyrimidine bases, e.g. T, U and C or on position 7 of purine bases, e.g. 7-desaza G, 7-desaza A, G and A as shown in Figure 1. All modifications on these positions protrude out of the DNA major groove.

The synthesis of an aldehyde-modified T (U) nucleoside phosphoramidite first via Sonogashira mediated alkynylation [20] followed by reaction with

appropriate functional groups was performed as shown in Figure 2. The aldehyde function was kept protected as an acetal group. The acetal protection group may be removed by treatment with acid. The modified nucleoside phosphoramidite may be incorporated into nucleic acids by chemical synthesis.

The synthesis of an acetal-modified nucleoside triphosphate was carried out as shown in Figure 3a. Further alkyne (for Click reaction), acetal- and hemiacetal-modified nucleoside triphosphates are shown in Figure 3b. The modified nucleoside triphosphates may be incorporated into nucleic acids by enzymatic synthesis.

The use of Pd-based C-C forming reactions such as by Sonogashira/Suzuki [20] provides a general synthetic approach for the synthesis of aldehyde-modified nucleosides and nucleotides with different aldehyde groups with different modified nucleobases. Further, aldehyde groups with different steric, electronic and functional characteristics may be synthesized.

Example 2

Incorporation of aldehyde-modified nucleosides and nucleotides into oligonucleotides

2.1 Incorporation by chemical synthesis

Incorporation of the acetal/aldehyde-modified nucleoside phosphoramidite was achieved by conventional solid phase synthesis [21]. Several DNA oligonucleotides containing one or multiple acetal/aldehyde-modified nucleobases were prepared as depicted in Table 1. Deprotection of the acetal groups afforded the aldehyde-modified DNA oligonucleotide.

The oligonucleotides were tested for their ability to form base pairs with complementary DNA strands in order to obtain double stranded DNA

molecules. It was found that the reduction of duplex stability due to the presence of the aldehyde group is low. The melting point of double strands is lowered by about only 2°C per modification. This amount of destabilisation is, however, fully acceptable for the intended applications.

Table 1: Oligodesoxynucleotides synthesised by solid phase synthesis.

		T_m [°C]	
1	TTTTTT**X**TTTTT		
2	TTTTTT**XX**TTTTT		
3	GCCGA**X**GCGC	53,8	(56,5 unmodified control)
4	GCG**X**ATA**X**ATA**X**TCGC	48,4	(53,7 unmodified control)
5	TT**X**TT**X**TT**X**TT**X**TT**X**		

2.2 Incorporation by enzymatic methods

Acetal modified triphosphate monomers were prepared according to Figure 3. The most selective method of synthesising triphosphates is the procedure following Ludwig and Eckstein [11, 12]. This procedure is slightly acidic so one obtains a mixture of aldehyde and acetal-TTP which can be separated by HPLC, if desired [13].

Studies were performed with both the acetal and aldehyde triphosphates and a variety of different DNA polymerases. They showed that all polymerases accept the modified triphosphate as substrate and they selectively incorporate the modified base. Also multiple incorporations turned out to be unproblematic. The following polymerases were tested in primer extension studies and PCR. The experiments were performed with the acetal protected thymidine and also with the deprotected aldehyde functionalized thymidine.

Primer extention PCR

Therminator (NEB)	Pfx (A)
Vent	Taq (A)
Vent (exo$^-$)	Vent (B)
Taq	

We also performed PCR studies with TPP replaced by the synthetic triphosphates (acetal and aldehyde). The PCR experiment showed that the modified base can be incorporated into a whole gene 2400 base pairs long establishing that we can create genes specifically labelled with hundreds of aldehyde derived nucleation sites.

Example 3

Detection of the labelled oligonucleotides and genes

A preferred method for the metal deposition on aldehydes is based on the Tollens test [14].

$$R\text{-}CHO + 2\ Ag[NH_3]OH \rightarrow R\text{-}COO^-NH_4^+ + 2\ Ag(s) + H_2O + NH_3$$

In this reaction a silver-ammonium complex is reduced by the aldehyde. If the concentration of the aldehyde is high, one can see a film of solid silver on the inside of the reaction tube.

Both the aldehyde containing nucleoside and the chemically synthesised aldehyde-modified nucleic acids could be detected in a silver staining test indicative of aldehyde functions (Fig. 4). An unlabeled DNA strand gave in contrast a clearly negative result under the same conditions, showing that the aldehyde selectively introduced into specific DNA sequences allow selective detection of these modified sequences.

Detection of aldehyde-modified nucleic acids by silver staining was also carried out on gels. The aldehyde groups on the DNA were sufficient to

reduce the silver ions within a gel. The seeds formed by the process on the DNA could be developed until a clear black band made up from deposited silver can be seen on the gel.

This was demonstrated by staining aldehyde-modified nucleic acids from primer extension reactions and from PCR (Figure 5 (I) and (II) respectively).

As shown in Fig. 5, the DNA containing the modified nucleoside is exclusively Ag-stained while unmodified DNA stays unstained. This is true for the extended primer and for the PCR product. The staining procedure is based on the SilverXPress kit (Invitrogen), but with a stronger Tollens solution. Staining following other procedures is also possible.

Example 4

Determination of Sensitivity

In order to determine the sensitivity of the detection method, dilution experiments were performed (Figure 6). It was found that staining of aldehyde-functionalized DNA with a standard Ag staining kit was at least five times more sensitive than staining with ethidium bromide (~ 0.5 ng of DNA with a length of 50 bp).

This very impressive sensitivity is obtained even with coarse visual detection.

Example 5

Synthesis of azide- and alkyne-modified nucleosides and nucleotides

Nucleosides and nucleoside triphosphate with azide and alkyne-modified bases were synthesized substantially as described in Example 1.

5. 1 Synthesis of alkyne-modified nucleotides

A detailed reaction scheme for the synthesis of alkyne-modified nucleoside triphosphate is shown in Figure 10.

The preparation of nucleoside (**1**) and its corresponding triphosphate (**2**) was carried out as previously [23, 24].

To a thoroughly degassed solution of **3** (1.00 g, 1.72 mmol.),[3] $Pd(PPh_3)_4$ (0.198 g, 0.172 mmol.) and CuI (0.065 g, 0.344 mmol.) in DMF (3 mL) was added degassed N,N-diisopropylethyl amine (1.5 mL, 8.59 mmol.) and the reaction mixture stirred at room temperature for 10 minutes. A degassed solution of 4-pentyn-1-ol (320 µL, 3.44 mmol.) in DMF (1 mL) was added dropwise to the reaction mixture over 1 hour. After complete addition, the reaction mixture was stirred at room temperature overnight. After concentration *in vacuo*, the crude mixture was diluted with ethyl acetate (200 mL) and the organic layer was washed with brine (3 x 50 mL) followed by water (50 mL). The organic layer was dried ($MgSO_4$), filtered and concentrated *in vacuo*. Flash column chromatography (SiO_2) eluting with a gradient of ethyl acetate : isohexane (1 : 1) followed by ethyl acetate : isohexane (2 : 1) provided **4** (0.790 g, 86 %) as a pale yellow foam. ^1H NMR ($CDCl_3$, 300 MHz): δ 0.01 (s, 3 H, OSiC*H*$_3$), 0.00 (s, 3 H, OSiC*H*$_3$), 0.05 (s, 3 H, OSiC*H*$_3$), 0.07 (s, 3 H, OSiC*H*$_3$), 0.81 (s, 6 H, OSi(*CH*$_3$)$_3$), 0.85 (s, 6 H, OSi(*CH*$_3$)$_3$), 1.74 (m, 2 H, CH_2-C*H*$_2$$CH_2$-OH), 1.95 (m, 1H, *H*-2β), 2.20 (m, 1H, *H*-2α), 2.42 (t, 2 H, *J* = 6.0 Hz, C≡C-C*H*$_2$$CH_2$-), 3.67 (dd, 1H, *J* = 11.4, 2.1 ($CDCl_3$, 75.5 MHz): δ 5.4 (SiCH$_3$), -5.3 (SiCH$_3$), -4.8 (SiCH$_3$), -4.6 (SiCH$_3$), 16.7 (C≡C-CH$_2$CH$_2$), 18.0 (SiC(CH$_3$)$_3$), 18.5 (SiC(CH$_3$)$_3$), 26.1 (SiC(CH$_3$)$_3$), 26.4 (SiC(CH$_3$)$_3$), 31.5 (CH$_2$-CH$_2$-CH$_2$-OH), 42.3 (C-2'), 61.9 (CH$_2$-CH$_2$CH$_2$-OH), 63.3 (C-5'), 72.4 (C≡C), 72.7 (C-3'), 86.0 (C-1'), 88.7 (C-4'), 95.0 (C≡C), 100.9 (C-5), 101.0 (C≡C), 141.9 (C-6), 149.6 (C-2), 162.4 (C-4). HRMS (ESI, +ve) calcd. for $C_{26}H_{46}N_2NaO_6Si_2$ 561.2792 $[M+Na]^+$ found 561.2803.

To a stirred solution of **4** (0.300 g, 0.56 mmol.) in dichloromethane (5 mL)

was added a solution of Dess-Martin periodinane (0.378 g, 0.89 mmol.) in dichloromethane (5 mL) dropwise over 5 minutes at room temperature under a nitrogen atmosphere. The reaction mixture was stirred for 2 hours followed by quenching with saturated sodium thiosulfate solution (10 mL). The crude mixture was then diluted with dichloromethane (200 mL) and the organic layer washed with brine (2 x 30 mL) and water (2 x 30 mL). The organic layer was then dried ($MgSO_4$), filtered and concentrated *in vacuo*. Column chromatography (flash silica) eluting with 35 % ethylacetate in isohexane afforded **5** (0.193 g, 65 %) as a pale yellow foam. ^1H NMR ($CDCl_3$, 600 MHz): δ0,07 (s, 3 H, OSiC*H*$_3$), 0.00 (s, 3 H, OSiC*H*$_3$), 0.05 (s, 3 H, OSiC*H*$_3$), 0.06 (s, 3 H, OSiC*H*$_3$), 0.81 (s, 6 H, OSi(*CH*$_3$)$_3$), 0.85 (s, 6 H, OSi(*CH*$_3$)$_3$), 1.95 (m, 1H, *H*-2β), 2.21 (m, 1H, *H*-2α), 2.61 (t, 2 H, *J* = 7.2 Hz, -C*H*$_2$CH$_2$-), 2.67 (t, 2 H, *J* = 7.2 Hz, -C*H*$_2$CH$_2$-), 3.68 d(d, 1 H, *J* = 11.4, 2.4 Hz, *H*-5'), 3.81 (dd, 1 H, *J* = 11.4, 2.4 Hz, *H*-5'), 3.89 (m, 1 H, *H*-4'), 4.32 (m, 1 H, *H*-3'), 6.20 (dd, 1 H, *J* = 7.2, 6 Hz, *H*-1'), 7.84 (s, 1 H, *H*-6), 8.99 (bs, 1 H, N-*H*), 9.72 (s, 1 H, C*H*O). ^{13}C NMR ($CDCl_3$, 150.8 MHz): δ3.8 (SiCH$_3$), -3.7 (SiCH$_3$), -3.1 (SiCH$_3$), -2.9 (SiCH$_3$), 14.4 (C≡C-CH$_2$CH$_2$), 19.7 (SiC(CH$_3$)$_3$), 20.1 (SiC(CH$_3$)$_3$), 27.4 (SiC(CH$_3$)$_3$), 27.7 (SiC(CH$_3$)$_3$), 43.7 (C-2'), 44.1 (CH$_2$-CH$_2$-CHO), 64.6 (C-5'), 74.0 (C-3' and C≡C), 87.5 (C-1'), 90.0 (C-4'), 94.3 (C≡C), 101.9 (C-5), 143.8 (C-6), 150.9 (C-2), 163.7 (C-4), 201.6 (CHO). HRMS (ESI, +ve) calcd. for $C_{26}H_{44}N_2NaO_6Si_2$ 559.2635 $[M+Na]^+$ found 559.2634.

To a solution of **5** (0.530 g, 1.00 mmol.) and K_2CO_3 (0.269 g, 1.98 mmol.) in dry methanol (20 mL) was added a solution of 1-diazo-2-oxo-propyl-phosphonic acid dimethyl ester (0.261 g, 1.19 mmol.) in dry methanol (5 mL) at room temperature under a nitrogen atmosphere. The reaction mixture was stirred at room temperature overnight, filtered and concentrated *in vacuo*. The crude mixture was dissolved in ethyl acetate (200 mL) and the organic layer was washed with brine (2 x 30 mL) and water (2 x 30 mL), dried ($MgSO_4$) and concentrated *in vacuo*. Column chromatography (flash silica) eluting with 20 % ethylacetate in isohexane afforded **6** (0.290 g, 55 %) as a colourless foam. ^1H NMR ($CDCl_3$, 600 Mhz): δ 0.00 (s, 3 H, OSiC*H*$_3$), 0.01 (s, 3 H, OSiC*H*$_3$), 0.06 (s, 3 H, OSiC*H*$_3$), 0.07 (s, 3 H, OSiC*H*$_3$), 0.82 (s, 6 H, OSi

(CH$_3$)$_3$), 0.86 (s, 6 H, OSi*(CH$_3$)$_3$*), 1.93 (m, 1H, *H*-2β), 1.95 (s, 1 H, C≡C-*H*), 2.22 (m, 1H, *H*-2α), 2.39 (dt, 2 H, *J* = 8.4, 2.4 Hz, -C*H*$_2$CH$_2$-), 2.55 (t, 2 H, *J* = 8.4 Hz, -C*H*$_2$CH$_2$-), 3.68 (dd, 1 H, *J* = 11.4, 2.4 Hz, *H*-5'), 3.81 (d, 1 H, *J* = 11.4, 2.4 Hz, *H*-5'), 3.89 (m, 1 H, *H*-4'), 4.33 (m, 1 H, *H*-3'), 6.20 (dd, 1 H, *J* = 7.8, 6 Hz, *H*-1'), 7.85 (s, 1 H, *H*-6), 8.33 (bs, 1 H, N-*H*). ^{13}C NMR ($CDCl_3$, 150.8 MHz): δ7.0 (Si*C*H$_3$), -6.9 (Si*C*H$_3$), -6.4 (Si*C*H$_3$), -6.2 (Si*C*H$_3$), 16.5 (C≡C-*C*H$_2$CH$_2$), 16.9 (C≡C-*C*H$_2$CH$_2$), 17.0 (Si*C*(CH$_3$)$_3$), 18.2 (Si*C*(CH$_3$)$_3$), 24.2 (SiC(*C*H$_3$)$_3$), 24.5 (SiC(*C*H$_3$)$_3$), 40.4 (*C*-2'), 61.4 (C-5'), 67.9 (C≡*C*-H), 70.8(C-3'), 70.9 (C≡*C*), 80.9 (C≡*C*), 84.1 (C-1'), 86.8 (C-4'), 91.2 (C≡*C*), 98.7 (C-5), 140.6 (C-6), 147.5 (C-2), 159.9 (C-4). HRMS (FAB, +ve) calcd. for $C_{27}H_{43}N_2O_5Si_2$ + H 533.28670 $[M+H]^+$ found 533.26009.

To a cooled solution (0 °C) of **6** (0.270, 0.51 mmol.) in THF (5 mL) was added TBAF (1.0 M, 1.52 mL, 1.52 mmol.) under a nitrogen atmosphere. The reaction mixture was stirred for 3 hours, quenched with glacial acetic acid (1.0 mL) and concentrated *in vacuo*. Column chromatography (flash silica) eluting with 10 % methanol in ethyl acetate afforded **7** (0.127 g, 82 %) as a colourless oil. ^{1}H NMR (d_6-DMSO, 400 MHz): δ1.88 (s, 1 H, C≡C-*H*), 2.07 (m, 2 H, *H*-2'), 2.36 (dt, 2 H, *J* = 7.2, 2.4 Hz, -C*H*$_2$CH$_2$-), 2.54 (t, 2 H, *J* = 6.8 Hz, -C*H*$_2$CH$_2$-), 3.53 (dd, 1 H, *J* = 12.0, 4.0 Hz, *H*-5'), 3.58 (dd, 1 H, *J* = 12.0, 4.0 Hz, *H*-5'), 3.76 (m, 1 H, *H*-4'), 4.19 (m, 1 H, *H*-3'), 5.07 (bs, 1 H, O-*H*), 5.23 (bs, 1 H, O-*H*), 6.08 (t, 1 H, *J* = 6.4 Hz, *H*-1'), 8.11 (s, 1 H, *H*-6), 11.55 (bs, 1 H, N-*H*). ^{13}C NMR ($CDCl_3$, 150.8 MHz): δ 17.6 (C≡C-*C*H$_2$CH$_2$), 18.9 (C≡C-*C*H$_2$CH$_2$), 39.5 (*C*-2'), 60.7 (C-5'), 70.0 (C-3'), 73.7 (C≡*C*-H), 75.1 (C≡*C*), 84.6 (C-1'), 87.3 (C-4'), 89.1 (C≡*C*), 93.0 (C≡*C*), 100.2 (C-5), 144.7 (C-6), 151.0 (C-2), 163.2 (C-4). HRMS (FAB, +ve) calcd. for $C_{15}H_{16}N_2O_5$ + Na $[M+Na]^+$ 327.28771 found 327.09635. HRMS (FT-ICR MS -) calcd. for $C_{15}H_{16}N_2O_5$ + AcO^- $[M+AcO^-]^-$ 363,1198 found 363,1221, MS-MS calcd. for $C_{15}H_{15}N_2O_5^-$ $[M^-]$ 303,1 found 303,1.

To a cooled solution (0° C) of **7** (0.060 g, 0.197 mmol.) and 1,8-bis (dimethylamino)naphthalene (proton sponge, 0.068 g, 0.316 mmol.)

trimethyl phosphate (2 mL) was added phosphorous oxychloride (22 µL , 0.237 mmol.) dropwise over 5 min. under a nitrogen atmosphere. The reaction mixture was stirred for 3 hours at 0° C. A solution of tributylammonium pyrophosphate (0.080 g, 0.237 mmol.) in dry DMF (2.0 mL) was added to the reaction mixture and stirred for 1 min. followed by quenching with triethylammonium bicarbonate (1.0 M, 20 mL, pH = 8.5). The reaction mixture was stirred for 2 h and lyophilised overnight. RP-HPLC purification (0-50 % 0.1 M triethylammonium acetate → 20 : 80 H_2O : MeCN with 0.1 M triethylammonium acetate gradient over 45 min. at a flow rate of 5 mL.min.$^{-1}$) yielded **8** (17.7 min.) as the triethylammonium salt. ^{31}P NMR (D_2O, 81 MHz): δ 22.4 (t, 1 P, *J* = 19.8 Hz, P-β), -10.5 (d, 1 P, *J* = 20.3 Hz, P-α), -9.7 (d, 1 P, *J* = 19.8 Hz, P-γ). MALDI-TOF (ATT matrix, negative mode): 271 $[M + 2 H]^{2-}$, 542 $[M + 2 H]^-$.

5.2 Synthesis of dendrimeric azide-functionalized Click reactions partners

A detailed reaction scheme for the synthesis of azide-functionalized dendrimers containing a plurality of hemiacetal groups (protected aldehyde groups) is shown in Figure 11.

General procedure for the Cu(I)-catalysed triazole ligation reaction

To a solution of **9** (7.31 g, 0.0256 mol.), **10** (3.00 g, 0.0128 mol.) in THF : H_2O (3 : 1, 40 mL) was added a solution of $CuSO_4$ (0.103 g, 0.641 mmol.) in H_2O (3 mL) followed by solid sodium ascorbate (0.253 g, 1.28 mmol.). The reaction mixture was stirred overnight at room temperature. The suspension was diluted with H_2O (50 mL), cooled to 0 °C and treated with concentrated NH_4OH (5 mL) for 10 minutes. The reaction mixture was diluted with dichloromethane (500 mL) and the organic layer washed with brine (2 x 50 mL), followed by H_2O (2 x 50 mL). The organic layer was retained, dried ($MgSO_4$) and concentrated *in vacuo*. Column chromatography (flash silica) eluting with 1 : 1 ethyl acetate : petroleum spirit afforded **9** (2.76 g), mono-

Click product (**11**, 3.94 g) as a colourless foam, followed by **12** (4.92 g, 48 %). The mono-click product (**11**) was then reacted with one equivalent of **9** to afford **12** quantitatively after workup and with no further purification required.

^{1}H NMR ($CDCl_3$, 600 MHz): δ 1.29 (s, 6 H, C-C*H*$_3$), 1.35 (s, 6 H, C-C*H*$_3$), 1.38 (s, 6 H, C-C*H*$_3$), 1.49 (s, 6 H, C-C*H*$_3$), 4.19 (m, 4 H, *H*4'/*H*5'), 4.32 (dd, 2 H, *J* = 4.8, 2.4 Hz, *H* 2'), 4.46 (dd, 2 H, *J* = 14.4, 8.4 Hz, *H*6''), 4.50 (s, 2 H, -C*H*$_2$-), 4.62 (m, 2 H, *H* 3'), 4.64 (m, 2 H, *H* 6'), 5.18 (s, 4 H, -C*H*$_2$-), 5.51 (d, 2 H, *J* = 4.8 Hz, *H* 1'), 6.59 (t, 1 H, *J*= 1.8 Hz, Ar-H), 6.64 (d, 2 H, *J* = 1.8 Hz, Ar-H), 7.79 (s, 2 H, C=CH-). ^{13}C NMR ($CDCl_3$, 150.8 Mhz):δ 24.4 (C-*C*H$_3$), 24.7 (C-*C*H$_3$), 25.9 (C-*C*H$_3$), 26.0 (C-*C*H$_3$), 46.1 (*C*H$_2$-), 50.6 (-*C*H6'/H6''), 62.2 (Ar-*C*H$_2$-), 67.0 (*C*H4'), 70.1 (*C*H2'), 70.5 (*C*H3'), 70.9 (*C*H5'), 96.0 (*C*H1'), 102.0 (Ar-*C*H), 107.9, 109.1, 110.0, 124.0 (C=*C*H), 139.6, 143.4, 160.0. ESI-MS *m/z* 806 [*M* + H]$^+$.

The reaction of **13** (1.53 g, 1.88 mmol.) and **10** (0.220 g, 0.94 mmol.) in the presence of $CuSO_4$ (0.008 g, 0.047 mmol.) and sodium ascorbate (0.019 g, 0.094 mmol.) afforded **14** (1.65 g, 95 %) as a colourless foam after column chromatography (flash SiO_2; ethyl acetate : methanol 9 : 1). ^{1}H NMR ($CDCl_3$, 600 MHz): δ 1.26 (s, 12 H, C-C*H*$_3$), 1.27 (s, 6 H, C-C*H*$_3$), 1.34 (s, 12 H, C-C*H*$_3$), 1.35 (s, 12 H, C-C*H*$_3$), 1.48 (s, 6 H, C-C*H*$_3$), 4.19 (m, 8 H, *H*4'/*H*5'), 4.32 (m, 4 H, *H* 2'), 4.46 (m, 4 H, *H*6''), 4.47 (s, 2 H, -C*H*$_2$-), 4.62 (m, 4 H, *H* 3'), 4.64 (m, 4 H, *H* 6'), 5.12 (s, 8 H, -C*H*$_2$-), 5.15 (s, 4 H, -C*H*$_2$-), 5.40 (s, 4 H, -C*H*$_2$-), 5.49 (bd, 4 H, *J* = 4.8 Hz, *H* 1'), 6.50 (m, 4 H, Ar-H), 6.55 (m, 2 H, Ar-H), 6.58 (m, 1 H, Ar-H), 6.61 (m, 2 H, Ar-H), 7.59 (s, 2 H, C=CH-), 7.78 (s, 4 H, C=CH-). ^{13}C NMR ($CDCl_3$, 150.8 MHz): δ 24.4 (C-*C*H$_3$), 24.9 (C-*C*H$_3$), 25.9 (C-*C*H$_3$), 26.0 (C-*C*H$_3$), 45.9 (*C*H$_2$-), 50.4 (-*C*H6'/H6''), 53.9 (Ar-*C*H$_2$-), 61.8 (Ar-*C*H$_2$-), 61.9 (Ar-*C*H$_2$-), 67.0 (*C*H4'), 70.1 (*C*H2'), 70.5 (*C*H3'), 71.1 (*C*H5'), 96.1 (*C*H1'), 101.6, 101.7, 107.2, 108.0, 109.0, 109.9, 122.9, 124.2, 136.7, 140.0, 143.2, 144.1, 159.5, 160.0. MALDI-TOF (ATT, positive mode): *m/z* 1859 [*M* + H]$^+$.

General procedure for the conversion of dendritic chlorides to azides

To a solution of **12** (4.84 g, 6.01 mmol.) in acetone : water (4 : 1, 100 mL) was added NaN_3 (0.586 g, 9.01 mmol.) and heated to reflux under a nitrogen atmosphere for 3 hours. The reaction mixture was diluted with ethyl acetate (600 mL) and the organic layer washed with brine (2 x 50 mL) followed by water (2 x 50 mL). The organic layer was retained, dried ($MgSO_4$) and concentrated *in vacuo* to yield **13** (4.72 g, 97 %) as a white amorphous solid.

^{1}H NMR (d_6-acetone, 400 MHz): δ 1.28 (s, 6 H, C-C*H*$_3$), 1.35 (s, 6 H, C-C*H*$_3$), 1.36 (s, 6 H, C-C*H*$_3$), 1.44 (s, 6 H, C-C*H*$_3$), 4.30 (dd, 2 H, *J* = 3.6, 2.0 Hz, *H* 6'/6"), 4.32 (dd, 2 H, *J* = 3.2, 1.6 Hz, *H* 5'), 4.36 (dd, 2 H, *J* = 7.6, 1.6 Hz, *H* 4'), 4.39 (dd, 2 H, *J* = 4.8, 2.4 Hz, *H* 2'), 4.61 (d, 2 H, *J* = 3.6 Hz, *H* 6'/6"), 4.64 (s, 2 H, -C*H*$_2$), 4.70 (dd, 2 H, *J* = 7.6, 2.4 Hz, *H* 3'), 5.20 (s, 4 H, -C*H*$_2$-), 5.47 (d, 2 H, *J* = 4.8 Hz, *H* 1 '), 6.73 (m, 3 H, Ar-*H*), 8.07 (s, 2 H, C=C-*H*). ^{13}C NMR (d_6-acetone, 150.8 MHz): δ 25.7 (C-*C*H$_3$), 26.1 (C-*C*H$_3$), 27.2 (C-*C*H$_3$), 27.4 (C-*C*H$_3$), 47.6 (*C*H$_2$-), 52.0 (-*C*H6'/H6"), 63.4 (Ar-*C*H$_2$-), 68.8 (*C*H4'), 72.0 (*C*H2'), 72.5 (*C*H3'), 72.9 (*C*H5'), 98.2 (*C*H1'), 103.3 (Ar-*C*H), 109.9 (Ar-*C*H), 110.4, 111.2, 126.3 (C=*C*H), 141.9, 144.8, 161.8. HRMS (ESI, +ve) calcd for $C_{37}H_{49}N_9O_{12}Na$ 834.3398 $[M+Na]^+$ found 834.3404.

The reaction of **14** (1.51 g, 0.81 mmol.) and NaN_3 (0.079 g, 1.22 mmol.) afforded **15** (1.45 g, 96 %) as a white amorphous solid. ^{1}H NMR ($CDCl_3$, 600 MHz): δ1.27 (s, 12 H, C-C*H*$_3$), 1.34 (s, 12 H, C-C*H*$_3$), 1.37 (s, 12 H, C-C*H*$_3$), 1.48 (s, 12 H, C-C*H*$_3$), 4.19 (m, 8 H, *H*4'/*H*5'), 4.24 (s, 2 H, -C*H*$_2$-), 4.32 (m, 4 H, *H* 2'), 4.46 (dd, 4 H, *J* = 13.8, 8.4 Hz, *H*6"), 4.62 (m, 4 H, *H* 3'), 4.64 (m, 4 H, *H* 6'), 5.12 (s, 4 H, -C*H*$_2$-), 5.18 (s, 8 H, -C*H*$_2$-), 5.43 (s, 4 H, -C*H*$_2$-), 5.49 (bd, 4 H, *J* = 4.8 Hz, *H* 1'), 6.50 (m, 2 H, Ar-H), 6.55 (m, 4 H, Ar-H), 6.58 (m, 1 H, Ar-H), 6.60 (m, 2 H, Ar-H), 7.78 (s, 2 H, C=CH-), 7.79 (s, 4 H, C=CH-). ^{13}C NMR ($CDCl_3$, 150.8 MHz): δ 24.4 (C-*C*H$_3$), 24.8 (C-*C*H$_3$), 25.8(C-*C*H$_3$), 25.9 (C-*C*H$_3$), 45.9 (*C*H$_2$-), 50.4 (-*C*H6'/H6"), 54.6 (Ar-*C*H$_2$-), 62.0 (Ar-*C*H$_2$-), 62.1 (Ar-*C*H$_2$-), 67.1 (*C*H4'), 70.3 (*C*H2'), 70.7 (*C*H3'), 71.1 (*C*H5'), 96.2 (*C*H1'), 101.7, 101.8, 107.4, 107.7, 109.0, 109.9, 124.0, 124.2, 137.8, 143.1, 143.4, 144.1, 159.7, 159.9. HRMS (ESI, +ve) calcd for $C_{87}H_{110}N_{21}O_{26}Na$

1886.7829 $[M+Na+H]^+$ found 1887.7862.

General procedure for the dendritic isopropylidene deprotection

To a mixture of TFA : water (1 : 1; 10 mL) was added **13** (0.020 g, 24.7 µmol.) under a nitrogen atmosphere. The reaction mixture was heated to 50 °C for 4 hours followed by concentration *in vacuo*. Water (20 mL) was added to the mixture and the aqueous layer was washed several times with DCM (3 x 20 mL), retained and lyophilized overnight to afford **16** (0.015 g, 63 %) as a pale yellow foam. MALDI-TOF (ATT, positive mode): *m/z* 652 $[M+H]^+$.

The reaction of **15** (1.40 g, 0.75 mmol.) with TFA : water (1 : 1; 20 mL) afforded **17** (1.05 g, 90 %) as a pale yellow amorphous solid. MALDI-TOF (ATT, positive mode): *m/z* 1545 $[M + H]^+$.

Example 6

Incorporating of azide- and alkyne-modified nucleosides and nucleotides into nucleic acids

Azide- and alkyne modified nucleosides and nucleotides are efficiently incorporated into nucleic acids by chemical or enzymatic synthesis substantially as described in Example 2. The resulting modified nucleic acids can be specifically labelled according to the desired application e.g. by fluorescent labelling or metal deposition.

This labelling strategy is a fast and represents extremely sensitive method for the detection of nucleic acids, nucleic acid sequences and genes even without the need for PCR amplification.

In a first experiment, to investigate the performance of the Click reaction within a DNA architecture, the nucleosides **1** and **2** (Figure 9a and b) were prepared and incorporated into oligonucleotides via standard solid phase synthetic protocols. The efficiency of the Click reaction was investigated

using benzyl azide, $CuSO_4$, reductant (ascorbate or TCEP) and a copper(I) stabilising ligand. The results of these are summarised in Table 2. Oligonucleotides comprising the rigid base **1** consistently afforded lower yields of the Click product compared with the flexible alkyne **2**. Temperature (10 to 40°C) did not affect yields of the Click reactions.

The efficiency of the Click reaction was then assayed as a function of azide type exhibiting suitable properties for detection (Figure 12). Fluorescein azides are extremely sensitive fluorescent markers (fluorescent quantum yield almost unity), whereas the coumarin azide provides a proof of Click marker as fluorescence is switched on upon triazole formation [19].

Table 2: Summary of Click reactions using benzyl azide, $CuSO_4$ and TCEP.

ODN sequence	X = 1			X = 2		
	Yield (%)					
	Starting Material	Desired Product	Other Products	Starting Material	Desired Product	Other Products
3'-GCG CTT ACX TGT CGC G-5'	3	97	-	-	100	Azide reduction
3'-GCG CTT ACX XGT CGC G-5'		84	16 (monoclick)	-	100	Azide reduction
3'-GCG CTT ACX TGX CGC G-5'		94	6 (monoclick)	-	100	Azide reduction
3'-GCG CTX ACX TGX CGC G-5'		84	16 (bisclick)	NA	NA	NA

Consistent with the experiments involving the use of benzyl azide, oligodeoxy-nucleotides comprising the rigid alkyne afforded lower Click conversion yields. The flexible alkyne-containing oligonucleotides provided in contrast almost quantitative conversion according to HPLC and MALDI-TOF. Labelling of DNA was again possible directly on the gel. The DNA containing the modified nucleobase was separated from other DNA strands by gel electrophoresis and the gel was then treated with the fluorescein azide and Cu(I) to perform the Click. Washing of the gel removed excess fluorescein leaving behind the stained DNA in the gel (Figure 13).

From these experiments is can be clearly deduced that DNA containing the alkyne modified bases can be selective labelled with fluorescein. CYBR green dyes DNA unspecifically and therefore marks also unmodified DNA prior to the click reaction as in lane 1 of A2 and lane 3 of B2 (Figure 13).

Fluorescein is a molecule which fluoresces strongly both as a monomer and after clicking to DNA. After the click reaction with fluorescein, the gel has therefore to be washed in order to remove excess fluorescein which leaved behind the stained DNA.

Coumarin is an alternative fluorescing molecule, which is however not fluorescing as a monomer. It starts to emit fluorescence only after the Click reaction, when the azide is converted into the triazole. The fluorescence of the coumarin switches effectively on after the click as seen in the below experiment in reaction tubes (Figure 14). A similar experiment can be made on the gel.

In a further experiment, the efficiency of the Click reaction was investigated with oligodeoxynucleotides (ODN) incorporating the nucleoside 2 (Figure 15). This nucleoside was incorporated into oligonucleotides via standard solid phase synthetic protocols using the corresponding phosphoramidite 1 (Figure 15). The oligonucleotides comprising a single or multiple alkyne reporter groups are shown in Table 3.

Table 3

ODN Sequences	X = 19	
	Mass	
	Starting Material	Product
3'-GCG CTT ACX TGT CGC G-5'	ODN1 4952 (calc) 4955 (obs)	ODN1-P 5157 (calc) 5157 (obs)
3'-GCG CTT ACX XGT CGC G-5'	ODN2 5042 (calc) 5042 (obs)	ODN2-P 5452 (calc) 5455 (obs)
3'-GCG CTT XXX XXX CGC G-5'	ODN6 5407 (calc) 5413 (obs)	ODN6-P 6637 (calc) 6646 (obs)

The Click procedure involved the sequential addition of azide **3** (Figure 15) (DMSO solution, 10 mM, 50 equiv.), $CuSO_4$/ligand[29] complex (DMSO solution, 0.05 M, 20 equiv.) and TCEP (aqueous solution, 0.1 M, 40 equiv.) solutions to a 0.2 mM solution of the corresponding ODN. The reaction mixture was shaken at room temperature overnight. The samples were then desalted by membrane and their mass determined by MALDI-TOF (HPA matrix).

Example 7

PCR amplification of DNA templates with modified dNTPs)

7.1 PCR amplification of pol η from yeast

Template and primers employed for PCR experiments:

Forward primer 5′-GATTTGGGCCGGATTTGTTTC

Reverse primer 3′-TTTTATGCTATCTCTGATACCCTTG

Template: sequence of 318 bp (nt483-800 of *Rad30*) of yeast:

GGGCCGGATTTGTTTCAATATGCTAATGTTTGATAATGAGTACGAGCTT
ACAGGCGACTTGAAACTGAAAGATGCATTAAGCAATATTCGTGAGGCTT
TTATAGGGGGCAACTATGATATAAATTCCCATCTACCTCTTATACCCGAA
AAGATAAAGTCTCTGAAGTTTGAAGGCGATGTTTTCAATCCAGAGGGCA
GAGATCTGATCACAGATTGGGACGATGTAATACTTGCACTAGGATCTCA
GGTATGCAAGGGTATCAGAGATAGCATAAAAGATATTCTCGGTTATACT
ACTTCGTGTGGTTTGTCTAGCAC

The 318 bp template contains 59.75% [A+T] and 40.25% [C+G].

A series of commercially available thermostabile polymerases were assessed for the ability to incorporate the modified deoxyuridine

triphosphates **2** and **6** (Figure 10) using the PCR reaction. DNA polymerases used were:

Pwo and Taq (exo$^-$) DNA polymerase (Roche)
Vent, Vent (exo$^-$), therminator polymerase (from New England Biolabs)
Taq (promega).

A typical PCR reaction contained 0.05 µg genomic *S. cerevisiae YPH 499* or 0.5 µg DNA template (pDest17-Poleta yeast[1-1889]), 0.3 mM each of the forward and reverse primers, 1.25 U polymerase and 10x polymerase buffer with magnesium, 200µM of each unmodified dNTPs (dATP, dCTP and dGTP; NEB) and 200µM modified dUTP. For the control were natural triphosphates (dATP, dCTP, dGTP and dTTP) used. The reactions were done in an overall volume of 50 µL. PCR experiments were performed on an Eppendorf Mastercycler Personal.

For amplification hotstart (2 min at 94°C) was used, followed by 10 cycles of amplification (15 sec at 94°C, 30 sec at 53°C, 45 sec at 72°C), 25 cycles (15 sec at 94°C, 30 sec at 56°C, 45 sec at 72°C) and a final incubation for 2 min at 72°C. PCR products were analyzed on a 2% agarose gel by staining with ethidium bromide (Figure 16). PCR products were purified on a QIAquick PCR purification kit (Qiagen), and used for silver staining, sequencing or digestion. The products of PCR reaction were separated by 2% agarose gel electrophoresis containing ethidium bromide. The products were recorded with a Ultra-Violet Products CCD camera.

7.2 PCR amplification of polH from human

A typical PCR reaction contained 0.5 µg DNA template (pDest17-plH human [1-2142], 0.3 mM each of the forward and reverse primers, 1.25 U Pwo polymerase and 10x polymerase buffer with magnesium, 200µM of each unmodified dNTPs (dATP, dCTP and dGTP; NEB) and 200µM modified dUTP. For the control were natural triphosphates (dATP, dCTP, dGTP and

dTTP) used. The reactions were done in an overall volume of 50 µL. PCR experiments were performed on an Eppendorf Mastercycler Personal.

For amplification hotstart (2min at 94°C) was used, followed by 10 cycles of amplification (15 sec at 94°C, 30 sec at 53°C, 210 sec at 72°C), 30cycles (15 sec at 94°C, 30 sec at 56°C, 210 sec at 72°C) and a final incubation for 7 min at 72°C. PCR products were analyzed on a 1% agarose gel by staining with ethidium bromide. PCR products were purified on a QIAquick PCR purification kit (Qiagen), and used for digestion or sequencing.

The products of PCR reaction were separated by 1% agarose gel electrophoresis containing ethidium bromide. The products were recorded with a Ultra-Violet Products CCD camera. The results are shown in Fig. 17.

For workup 6 µL of 0.1 M HCl was added and the probes centrifuged (6000 rpm, 5 min). The digest was analysed by HPLC (interchim Interchrom Uptisphere 3 HDO column (150 x 2.1 mm), Buffer A: 2 mM TEA/HOAc in H_2O; Buffer B: 2 mM TEA/HOAc H_2O:MeCN 1:4; 0 → 30 min; 0 % → 30 % B; 30 → 32 min; 30 % → 100 % B; 32 → 36 min; 100 %B; 36 → 38 min; 100 % → 0 % B; 38 → 60 min; 0% B; flow 0.2 mL/min) (Figure 18). The different peaks were assigned by co-injection, UV and FT-ICR-HPLC-MS-MS using the same conditions

7.3 Enzymatic digestion of PCR fragments (318 mer) incorporating an alkyne-mediated nucleotide

For the enzymatic digestion the 318 bp DNA template containing the modified nucleotide 8 (Figure 10) (ca. 10 µg in 100 µL water) was incubated in 10 µL Buffer A (300 mM ammonium acetate, 100 mM $CaCl_2$, 1 mM $ZnSO_4$, pH 5.7), 22 units Nuclease P1 (Penicilinum citrium) and 0.05 unit Calf Spleen Phosphodiesterase II. The sample was shaken at 37°C for 3 h. The digest was completed by adding 12 µL Buffer B (500 mM Tris-HCl, 1 mM EDTA), 10 units Alkaline Phosphatase (CIP) and 0.1 unit Snake venom

phosphodiesterase I (*Crotalus adamanteus venom*). The sample was shaken for another 3 h at 37 °C.

7.4 General procedure for the Cu(I)-catalysed triazole ligation reaction of sugar azides with modified ds DNA on polyacrylamide gels

All click experiments were run on 318 bp PCR fragments comprising either **2** or **8** (Figure 10) in place of dTTP. The modified PCR fragments were separated on 5 % polyacrylamide gels then each gel was placed in a bath comprising 1 : 1 MeOH : H_2O (25 mL). A solution of sugar azide (0.1 M, 3 mL) was added to the bath followed by a solution of $CuSO_4$ (0.1 M, 600 µL and finally TCEP (0.1 M, 1.2 mL). These solutions were gently shaken at room temperature overnight.

7.5 General procedure for the silver staining of sugar azides linked to double-stranded DNA

The click solution was decanted and each gel was washed with 1 : 1 MeOH : H_2O (3 x 50 mL, 10 min. each wash), followed by H_2O (3 x 50 mL, 10 min. each wash). Each gel was then incubated with the Tollens reagent* (40 mL) for 30 min. After subsequent washing with H_2O (3 x 50 mL, 10 min. each wash) the gels were developed with a developing solution comprising 100 mL H_2O, citric acid (1 %, 250 µL) and formaldehyde (35%, 80-200 µL). Depending on the formaldehyde concentration, the development process can vary from 2 min. to 20 min.

Conclusion

The current invention proposed involves a new and modular method for the site specific labelling of nucleic acids by via the efficient incorporation of modified triphosphates. These modified triphosphates comprise groups that can be further functionalized, marked or stained according to the needs of

* Preparation of the Tollens reagent:
To 80 mL H_2O was added $AgNO_3$ (0.5 M, 5 mL), followed by NaOH (3.0 M, 1.0 mL) and finally NH_4OH (1 :1 conc. NH_4OH : H_2O, 2.2 mL).

the user. It is foreseeable that RNA labelling could be achieved via these methods as well using RNA polymerases and reverse transcriptase respectively. Therefore an early and efficient detection of viral genomes within a host could be effected. The reported novel nucleic acid labelling protocol is simple, efficient, sensitive and highly-selective.

Example 8

Detection of nucleic acids using photographic processes

The black and white photographic process is one of the most sensitive chemical methods known. Photons captured on photographic paper initiate the formation of small Ag-nuclei which catalyse further silver deposition during a subsequent development process [22]. This gives rise to signal amplification factors between 10^5 for Ag^+ chemical reduction and 10^{11} for Ag^+ photochemical reduction that are similar to that obtained using the PCR.

We have developed a sensitive method that utilizes photosensitizing dyes tethered to nucleic acids, which enables one to potentially detect a particular gene at subfemtomolar sensitivity (Figure 21). This new method is simple (can use conventional photographic materials), fast (detection in minutes), efficient (only one photosensitising molecule is required per biomolecule) and sensitive (current unoptimised sensitivity levels are ~10^{-14} -10^{-15} mol). Coupling this methodology with gene specific biochemical tools such as primer extension and PCR technologies provides a new and powerful method for the detection of nucleic acids and other analytes.

A number of fluorescent cyanine indoline (**1** and **2**) and quinoline dye derivatives (**3**) were investigated for their ability to act as photosensitizers in a photographic process (Figure 22). The visible absorption maxima for **1-3** are 546 nm, 646 nm and 607 nm, respectively.

The indoline dye (**1**) was readily detected down to the 3 x 10^{-14} mol. (30 fmol), whereas the limit of detection of (**2**) was approximately 1-3 fmol

(Figure 22a and 22b). The detection of the quinoline cyanine dye (**3**) was found to be more sensitive (detection limit ~ 0.3 fmol) than the indoline dyes (Figure 22c). Background fog may occur upon irradiation with intense light, however, fog can be suppressed by using a low intensity infrared light source, although sensitivity is somewhat lower (Figure 22d-f).

Control experiments (Figure 23) using unmodified oligodeoxyribonucleotides (ODN-**1**, ODN-**2**, ODN-**3**) produced a small background negative photographic response upon high-energy irradiation at levels of 50 nmol. (i.e. three orders of magnitude difference). The negative background levels can be suppressed completely if irradiation is conducted with an infrared lamp for 5 minutes (Figure 23b). In summary, unmodified DNA gives no staining.

A dilution series of commercially available dyes Cy5 (λ_{max} = 646 nm, ODN-**4**) and Cy5.5 (λ_{max} = 646 nm, ODN-**5**) tethered ODNs were then tested (Figure **16**). The detection limit of ODN-**4** was found to be 100 fmol, whereas the sensitivity of Cy5.5 ODN-**5** detection was a factor of ten higher (detection limit 10 fmol). Therefore, although a slight decrease in sensitivity was observed with cyanine dye conjugated ODNs compared with their non-tethered controls (Figure 24), the results clearly demonstrate that the photography of photosensitizer-conjugated biomolecules such as ODNs can be used at a highly sensitive analytical tool.

Photosensitive dyes, e.g. compounds 4 or 5 also may be introduced into nucleic acids via Click chemistry (Figure 25).

Conclusion

A photographic methodology can be coupled with photosensitized dye-nucleic acids to create a fast, simple, efficient and sensitive method for analyte, e.g. nucleic acid, detection.

Suitable examples of photosensitizer groups are quinoline-based cyanine dyes (e.g. **3**) or indoline dyes (e.g. **1** or **2**) as shown in Figure 22, which offer sensitives of at least 10 fmol (**1**), 1 fmol (**2**) or 0.1 fmol (**3**).

Indoline-based dyes such as Cy5 and Cy5.5 tethered to oligodeoxyribonucleotides may be detected at levels of 100 fmol and 10 fmol, respectively.

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Claims

1. A method for detecting an analyte in a sample comprising the steps:
   (i) providing a sample;
   (ii) contacting the sample with a functionalized compound comprising at least one functional group selected from an aldehyde group, a protected aldehyde group, an aldehyde precursor group or a handle group for introducing an aldehyde group, a protected aldehyde group or an aldehyde precursor group, under conditions wherein said compound forms an association product with the analyte to be detected;
   (iii) if necessary, reacting the handle group with a reaction partner, comprising an aldehyde group, a protected aldehyde group or an aldehyde precursor group,
   (iv) if necessary, converting protected aldehyde groups and aldehyde precursor groups to aldehyde groups,
   (v) contacting said association product having aldehyde groups with a marker reagent under conditions wherein marker groups are formed around aldehyde groups in said association product, and
   (vi) detecting said marker groups.

2. The method of claim 1, comprising a qualitative detection.

3. The method of claims 1 or 2, comprising a quantitative detection.

4. The method of any one of claims 1-3 wherein the analyte is selected from nucleic acids and nucleoside-, nucleotide- or nucleic acid-binding molecules.

5. The method of any one of claims 1 to 4, wherein the analyte to be detected is a nucleic acid selected from DNA and RNA.

6. The method of any one of claims 1 to 5, wherein the sample is a

biological sample.

7. The method of claim 6, wherein the sample is an agricultural or nutritional sample.

8. The method of claim 6, wherein the sample is a clinical sample.

9. The method of any one of claims 1 to 8, wherein the detection is carried out directly without amplification.

10. The method of any one of claims 1 to 8, wherein the detection is carried out in combination with an amplification step.

11. The method of any one of claim 1 to 10, wherein a sequence-specific detection of a nucleic acid analyte is carried out.

12. The method of claim 11, wherein the forming of said association product comprises a sequence-specific hybridization reaction.

13. The method of any one of claims 1 to 12, wherein the functionalized compound comprises
    (i) an aliphatic or cycloaliphatic aldehyde group, a protected aliphatic or cycloaliphatic aldehyde group or an aliphatic or cycloaliphatic aldehyde precursor group,
    (ii) an aromatic or heteroaromatic aldehyde group or an aromatic or heteroaromatic aldehyde precursor group, and/or
    (iii) an alkyne aldehyde group, a protected alkyne aldehyde group or an alkyne aldehyde precursor group.

14. The method of any one of claims 1 to 13, wherein the protected aldehyde groups are selected from acetal groups, hemiacetal groups, e.g. hemiacetal groups in a sugar or a sugar-related compound, thio and dithioacetal groups, imidazolone groups and benzothiazol groups.

15. The method of any one of claims 1 to 14, wherein the aldehyde precursor groups are selected from carboxylic acids and carboxylic acid derivatives such as nitriles and primary alcohols.

16. The method of any one of claims 1 to 15, wherein the handle groups are selected from azide and alkyne groups.

17. The method of claim 16, wherein said azide or alkyne groups are reacted by performing a Click reaction with a reaction partner comprising an aldehyde, protected aldehyde or aldehyde precursor group.

18. The method of any one of claims 1 to 17, wherein the functional group is attached to a nucleobase of a nucleosidic or nucleotidic compound or an oligomer or polymer thereof.

19. The method of claim 18, wherein the nucleobase is selected from naturally occurring and non-naturally occurring purine and pyrimidine bases.

20. The method of claim 19, wherein the functional group is attached to position 5 and 6, preferably position 5, of a pyrimidine nucleobase or to positions 7 and 8, preferably position 7, of a purine nucleobase.

21. The method of any one of claims 1 to 20, wherein the functional group is attached to the compound via a direct bond or spacer.

22. The method of claim 21 wherein said spacer is a flexible spacer or an at least partially rigid spacer.

23. The method of claim 22, wherein the spacer comprises at least one group selected from alkene groups, alkyne groups, cyclic

groups,particularly aromatic and heteroaromatic groups, and combinations thereof.

24. The method of any one of claims 1 to 23, wherein said functionalized compound is selected from:
    (i) a functionalized nucleic acid or nucleic acid analogue building block and/or
    (ii) a functionalized nucleic acid or nucleic acid analogue.

25. The method of claim 24, wherein the forming of said association product comprises incorporating said functionalized building block into a nucleic acid or nucleic acid analogue molecule.

26. The method of claim 25, wherein said functionalized nucleotide or nucleotide analogue is enzymatically incorporated into a nucleic acid molecule.

27. The method of claim 25, wherein the forming of said association product comprises binding said functionalized nucleic acid or nucleic acid analogue to the analyte to be detected.

28. The method of claim 27, wherein the binding comprises hybridization to a nucleic acid analyte.

29. The method of any one of claims 24-28, comprising a primer extension reaction optionally in combination with a nucleic acid amplification reaction.

30. The method of claim 29 comprising:
    providing at least one primer molecule which hybridizes under the assay conditions with the nucleic acid analyte to be detected or the complement thereof and
    extending said primer,

wherein at least one functionalized nucleotide or nucleotide analogue is incorporated into the extension product.

31. The method of claim 29 or 30 comprising:
providing at least one functionalized primer molecule which hybridizes under the assay conditions with the nucleic acid analyte to be detected or the complement thereof,
extending said primer molecule,
wherein an extended primer molecule is formed.

32. The method of any one of claims 28-31 comprising:
providing a functionalized hybridization probe which hybridizes under the assay conditions with the nucleic acid analyte to be detected or the complement thereof,
wherein a hybridization product is formed.

33. The method of any one of claims 26-32 comprising:
providing a functionalized hybridization probe which hybridizes under the assay conditions with the nucleic acid analyte to be detected or the complement thereof, and
subjecting the hybridization product to a treatment wherein a hybridization product containing at least one mismatch is dissolved,
wherein the presence of an undissolved hybridization product is indicative for the presence and/or amount of a nucleic acid which has a fully complementary sequence to the hybridization probe.

34. The method of claim 33, wherein the treatment comprises a mismatch digestion treatment.

35. The method of claim 34, wherein the mismatch digestion treatment comprises contacting the hybridization product with a mismatch-glycosylase.

36. The method of claim 33, wherein the treatment comprises a differential hybridization treatment.

37. The method of claims 1-36, wherein said marker reagent comprisesfluorescent or redox active groups.

38. The method of claims 1-37 wherein said marker reagent comprisesmetal groups.

39. The method of claims 1 to 38, wherein said groups are selected from metal atoms and/or ions such as Ag, Au, Bi, Cu, Pd, Pt which can be selectively deposited around aldehyde groups in said association product.

40. The method of claims 38 or 39, wherein said marker reagent comprises an Ag-ammonium complex.

41. The method of claims 1 to 40, wherein the detection is carried out by optical means.

42. The method of claims 1 to 41, wherein the detection is carried out by electrical means.

43. The method of any one of claims 1 to 42 comprising a parallel detection of a plurality of nucleic acids.

44. The method of any one of claims 1 to 43, wherein the detection is carried out on a solid surface, e.g. on a microarray chip.

45. A reagent kit for detecting an analyte in a sample, comprising:

(a) a functionalized compound comprising a functional group selected from an aldehyde group, a protected aldehyde group or an aldehyde

precursor group, or a handle group for introducing an aldehyde group, a protected aldehyde group or an aldehyde precursor group,

(b) optionally a reaction partner for the handle group comprising an aldehyde group,a protected aldehyde group or an aldehyde precursor group,

(c) optionally an aldehyde-forming reagent capable of converting protected aldehyde groups and aldehyde precursor groups to aldehyde groups, and

(d) a marker reagent.

46. Use of the reagent kit of claim 45 in a method according to any one of claims 1 to 44.

47. A compound of the formula (I):

$$A - S - N$$

wherein A is a functional group selected from an aldehyde group, a protected aldehyde group or an aldehyde precursor group,

S is a spacer or a bond, and

N is a nucleic acid or nucleic acid analogue building block such as a nucleosidic or nucleotidic compound.

48. The compound of claim 47, wherein the protected aldehyde groups are selected from acetal groups, hemiacetal groups, thio- and dithioacetal groups, imidazolone groups and benzothiazole groups.

49. The compound of claim 47, wherein the aldehyde precursor groups are selected from carboxylic acids and carboxylic acid derivatives such as nitriles and primary alcohols.

50. The compound of any one of claims 47-49, wherein the functional group is attached to a nucleobase.

51. The compound of claim 50, wherein the nucleobase is selected from naturally occurring and non-naturally purine and pyrimidine bases.

52. The compound of claims 50 or 51, wherein the nucleobase is selected from adenine, 7-deazaadenine, guanine, 7-deazaguanine, cytosine, thymidine, uracil, inosine and xanthine.

53. The compound of claims 51 to 52, wherein the functional group is attached to positions 5 and 6, preferably position 5, of a pyrimidine nucleobase, or to positions 7 and 8, preferably position 7 of a purine nucleobase.

54. The compound of any one of claims 47 to 53, wherein said spacer is an at least partially rigid spacer.

55. The compound of claim 54, wherein the spacer comprises at least one group selected from alkene groups, alkyne groups, cyclic groups, particularly aromatic and heteroaromatic groups, and combinations thereof.

56. The compound of any one of claims 47 to 55 which is a building block for the chemical or enzymatic synthesis of nucleic acids or nucleic acid analogues or a precursor thereof.

57. The compound of any one of claims 47 to 56 which is a nucleoside triphosphate, particularly a ribose, 2'-deoxyribose or 2',3'-dideoxyribose nucleoside triphosphate or a nucleoside phosphoramidite, H-phosphonate or phosphotriester.

58. The compound of any one of claims 46 to 56 which is a building block for the synthesis of peptide nucleic acids, morpholino nucleic acids or locked nucleic acids.

59. A nucleic acid or a nucleic acid analogue molecule having incorporated therein at least one compound of formula (I) according to any one of claims 47 to 58.

60. The molecule of claim 59 which is a nucleic acid selected from DNA and RNA, or a nucleic acid analogue selected from peptidic nucleic acids, morpholino nucleic acids or locked nucleic acids.

61. A method of synthesizing a nucleic acid or nucleic acid analogue molecule comprising incorporating at least one nucleotide or nucleotide analogue building block comprising a compound (I) of any one of claims 47 to 58 into a nucleic acid or nucleic acid analogue molecule.

62. The method of claim 61 comprising a chemical synthesis and/or an enzymatic synthesis.

63. A metallization product of the nucleic acid or nucleic acid analogue molecule of any one of claims 59 to 60.

64. An association product of the nucleic acid or nucleic acid analogue molecule of any one of claims 59 to 60 or the metallization product of claim 63 with an analyte.

65. The product of claim 64 which is a hybridization product with a complementary nucleic acid.

66. A method for detecting a nucleic acid in a sample comprising the steps:
    (i) providing a sample;
    (ii) contacting the sample with a functionalized compound comprising at least one functional group which is a first reaction partner for a Click reaction under conditions wherein said compound forms an association product with the nucleic acid to be detected or the

complement thereof,

(iii) contacting the association product with a second reaction partner for a Click reaction under conditions wherein a Click reaction between the first and second reaction partner occurs, wherein the second reaction partner further comprises a marker group or a marker precursor group,

(iv) if necessary, converting marker precursor groups to marker groups, and

(v) detecting said marker groups.

67. The method of claim 66 comprising the features as defined in any one of claims 2 to 12 and 18 to 44.

68. The method of claims 66 or 67, wherein the functional group is selected from azide groups or alkyne groups.

69. The method of claims 66 to 68, wherein the Click reaction comprises a (3+2) cycloaddition.

70. The method of claim 69, wherein a 5-membered heterocycle is formed by the Click reaction.

71. The method of any one of claims 66 to 68, wherein the second reaction partner comprises a marker group selected from optically detectable marker groups, particularly fluorescence marker groups or from redox active marker groups.

72. The method of any one of claims 66 to 71, wherein the second reaction partner comprises a marker precursor group selected from aldehyde groups and protected aldehyde groups and aldehyde precursor groups.

73. The method of claim 72, wherein converting the marker precursor groups to marker groups comprises forming metal depositions around

aldehyde groups.

74. A reagent kit for detecting an analyte in a sample, comprising:
(a) a functionalized compound comprising at least one functional group which is a first reaction partner for a Click reaction,
(b) a second reaction partner for a Click reaction, wherein the second reaction partner further comprises a marker group or a marker precursor group, and
(c) optionally a marker forming reagent capable of converting marker precursor groups to marker groups.

75. Use of a reagent kit of claim 74 in a method according to any one of claims 66 to 73.

76. A compound of the formula (II):

C – S – N

wherein C is a functional group which is a first reaction partner for a Click reaction,
S is a spacer or a bond, and
N is a nucleic acid or nucleic acid analogue building block such as a nucleosidic or nucleotidic compound.

77. The compound of claim 76 having the features as defined in any one of claims 50 to 58.

78. The compound of claims 76 to 77, wherein the functional group is attached to the nucleobase via a spacer having a chain length of up to 10 atoms.

79. The compound of claim 78, wherein the chain length is of up to 3 atoms.

80. A nucleic acid or a nucleic acid analogue molecule having incorporated therein at least one compound of formula (II) according to any one of claims 76 to 79.

81. The nucleic acid or a nucleic acid analogue molecule of claim 80 which is a nucleic acid selected from DNA and RNA, or a nucleic acid analogue molecule selected from peptidic nucleic acids, morpholino nucleic acids or locked nucleic acids.

82. A method of synthesizing a nucleic acid or nucleic acid analogue molecule comprising incorporating a nucleotide or nucleotide analogue building block comprising a compound (II) of any one of claims 76 to 79 into a nucleic acid or nucleic acid analogue molecule.

83. The method of claim 82 comprising a chemical synthesis and/or an enzymatic synthesis.

84. The method of any one of claims 82 to 83 further comprising contacting the nucleic acid or nucleic acid analogue molecule with a second reaction partner of compound (II) and performing a Click reaction between the first and second reaction partners.

85. An association product of the nucleic acid or nucleic acid analogue molecule of any one of claims 80 to 81 with an analyte.

86. The product of claim 85 which is a hybridization product with a complementary nucleic acid.

87. A method for detecting an analyte in a sample comprising the steps:
(i) providing a sample
(ii) contacting the sample with a functionalized compound comprising at least one functional group selected from a photosensitizer group or a handle group for introducing a photosensitizer group under

conditions wherein said compound forms an association product with the analyte to be detected;

(iii) if necessary, reacting the handle group with a reaction partner comprising a photosensitizer group;

(iv) irradiating said association product in contact with a photosensitive medium under conditions wherein marker groups are formed in said photosensitive medium in the presence of photosensitizer groups in said association product, and

(v) detecting said marker groups.

88. The method of claim 87 comprising the features as defined in any one of claims 2-12 and 16-44.

89. The method of claim 87 or 88 wherein the photosensitizer groups are selected from fluorescent dye groups.

90. The method of claim 89 wherein the photosensitizer groups are selected from cyanine-based indoline groups and quinoline groups.

91. The method of any one of claims 87-90 wherein the photosensitive medium comprises metal atoms or ions capable of forming metal nuclei.

92. The method of claim 91 wherein the metal is Ag.

93. The method of any one of claims 87-92 wherein the photosensitive medium is a light sensitive paper such as photographic paper or a light sensitive emulsion or gel on a supportive material.

94. The method of any one of claims 87-93 wherein the irradiating step (iv) is carried out with long wave visible light and/or with infrared light.

95. A reagent kit for detecting an analyte in a sample comprising:

(a) a functionalized compound comprising at least one functional group

selected from a photosensitizer group or a handle group for introducing a photosensitizer group;

(b) optionally a reaction partner for the handle group comprising a photosensitizer group, and

(c) a photosensitive medium which forms marker groups upon irradiation in the presence of photosensitizer groups.

96. Use of a reagent kit of claim 95 in a method of any one of claims 87-94.

97. Use of the method of any one of claims 1 to 44, 66 to 73 or 87 to 94 or the reagent kit of claim 45, 74 or 95 for agricultural applications.

98. The use of claim 97 for detecting nucleic acids from plants, plant pathogens or plant pests such as insects.

99. The use of claims 97 or 98 for detecting genetic variabilities, e.g. SNPs in plants, plant pathogens or plant pests.

100. The use of any one of claims 97 to 99 for detecting or monitoring herbicide, fungizide or pesticide resistances, tolerances or intolerances, e.g. pesticide resistances, tolerances or intolerances in fungi, insects or plants.

101. The use of any one of claims 97 to 100 for genotyping, e.g. for detecting and/or differentiating species or strains of fungi, insects or plants.

102. The use of any one of claims 97 to 101 for detecting and/or differentiating genetically modified organisms or strains, e.g. organisms or strains of fungi, insects or plants.

103. Use of the method of any one of claims 1 to 44, 66 to 73 or 87 to 94 or the reagent kit of claim 45, 74 or 95 for medical, diagnostic and forensic

applications.

104. The use of the method of claim 103 in human or veterinary medicine.

105. The use of claim 104 for detecting nucleic acids from pathogens, e.g human pathogens.

106. The use of any one of claims 103 to 105 for detecting genetic variabilities, e.g. SNPs in humans.

107. The use of any one of claims 103 to 106 for detecting medicament resistances, tolerances, or intolerances, or allergies.

108. The use of any one of claims 103 to 107 for genotyping.

109. The use of any one of claims 103 to 108 for detecting genetically modified organisms or strains, e.g. organisms or strains of bacteria or viruses.

110. The use of any one of claims 103 to 109 for diagnosing diseases, e.g genetic diseases, allergic diseases, autoimmune diseases or infectious diseases.

111. Use of the method of any one of claims 1 to 44, 66 to 73 or 87 to 94 or the reagent kit of claim 45, 74 or 95 for detecting function and/or expression of genes.

112. Use of the method of any one of claims 1 to 44, 66 to 73 or 87 to 94 or the reagent kit of claim 45, 74 or 95 for brand protection.

113. The use of claim 112 for detecting specific information encoded in products.

114. The use of the method of any one of claims 1 to 4, 66 to 73 or 87 to 94 or the reagent kit of claim 45, 74 or 95 for nutritional applications, particularly in the feed area.

115. The use of the method of any one of claims 1 to 44, 66 to 73 or 87 to 94 or the reagent kit of claim 45, 74 or 95 for an epigenetic analysis.

116. The use of claim 115 for the analysis of a DNA methylation pattern.

117. A method for detecting an analyte in a sample comprising the steps:

(i) providing a sample,

(ii) providing a reporter molecule comprising a photosensitizer group or a handle group for introducing a photosensitizer group and a quencher group wherein the photosensitizer group is quenched in the absence of the analyte to be detected,

(iii) contacting the sample with the reporter molecule under conditions wherein the quenching of the photosensitizer group is at least partially reduced or terminated in the presence of the analyte,

(iv) if necessary, reacting the handle group with a reaction partner comprising a photosensitizer group

(v) irradiating said reporter molecule in contact with a photosensitive medium under conditions wherein marker groups are formed in said photosensitive medium in the presence of unquenched photosensitizer groups in said reporter molecule and

(vi) detecting said marker groups

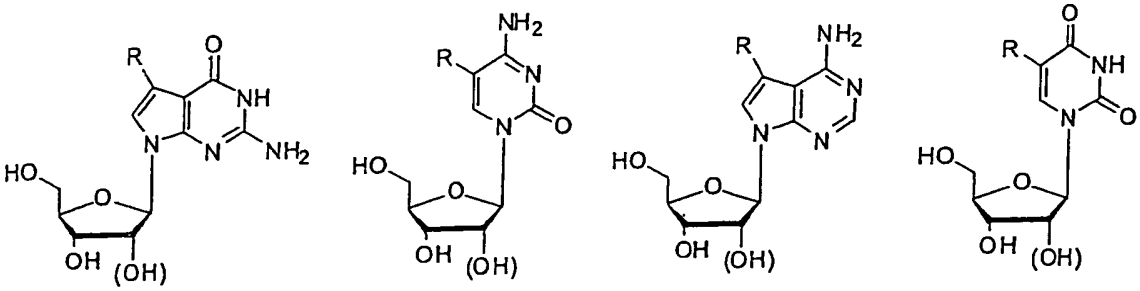
118. A reagent kit for detecting an analyte in a sample comprising:

(a) a reporter molecule comprising a photosensitizer group or a handle group for introducing a photosensitizer group and a quencher group wherein the photosensitizer group is quenched in the absence of the analyte to be detected,

(b) optionally a reaction parker for the handle group comprising a photosensitizer group and

(c) a photosensitive medium which forms marker groups upon irradiation of unquenched photosensitizer groups.

Figure 1



7-dN-G^{mod} C^{mod} 7-dN-A^{mod} T^{mod}

Figure 2

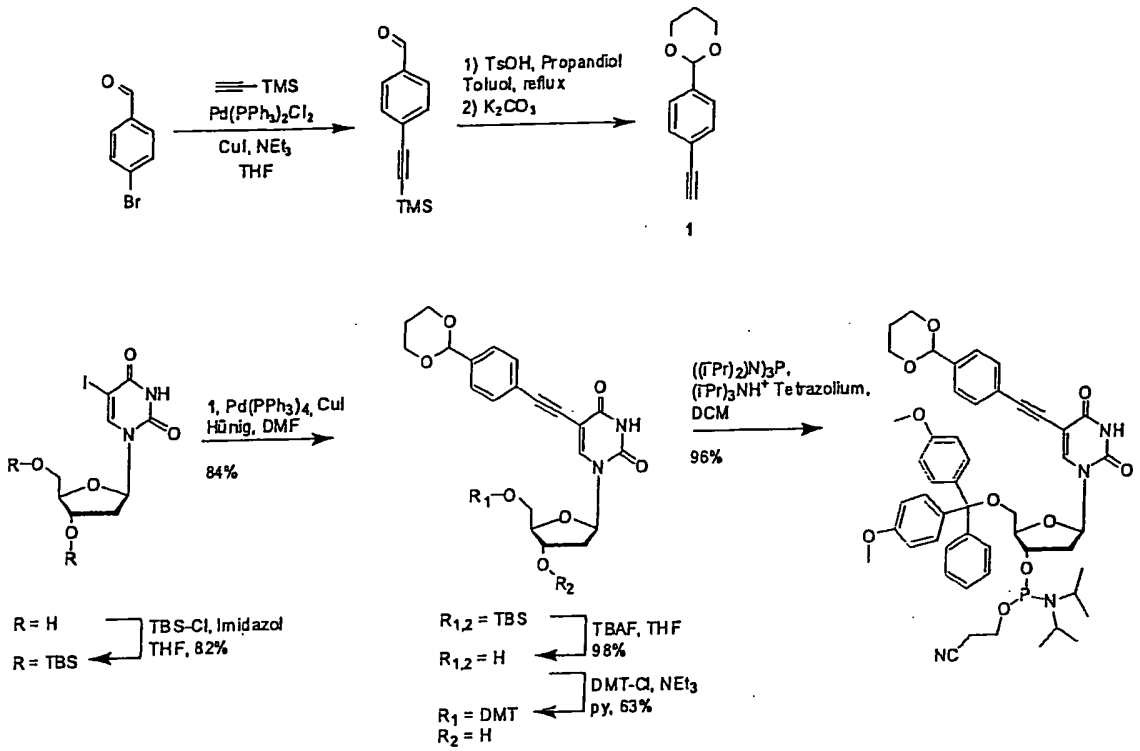

TMS
Pd(PPh3)2Cl2
CuI, NEt3
THF
Br
TMS
1) TsOH, Propandiol
Toluol, reflux
2) K2CO3
1
1, Pd(PPh3)4, CuI
Hünig, DMF
84%
R = H
R = TBS
TBS-Cl, Imidazol
THF, 82%
R1,2 = TBS
R1,2 = H
TBAF, THF
98%
R1 = DMT
R2 = H
DMT-Cl, NEt3
py, 63%
((iPr)2)N)3P,
(iPr)3NH+ Tetrazolium,
DCM
96%
NC

Figure 3a

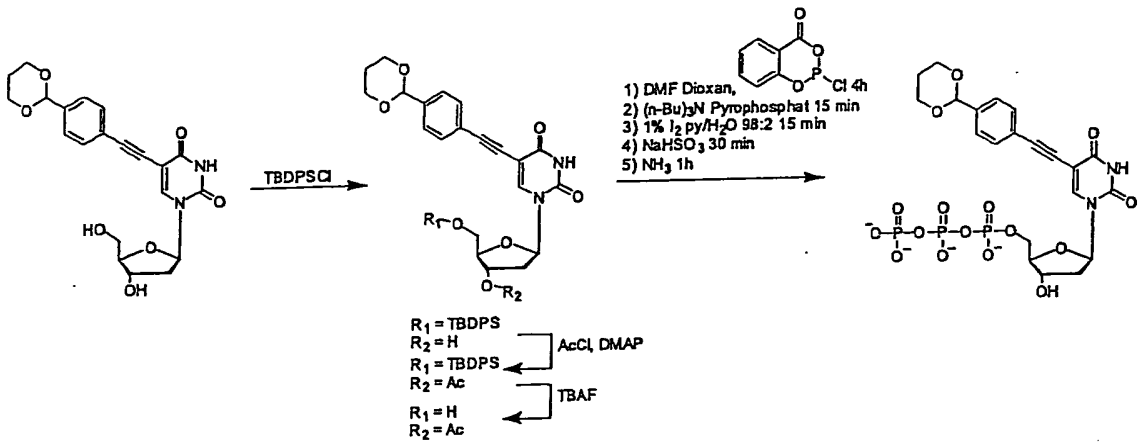


Figure 3b

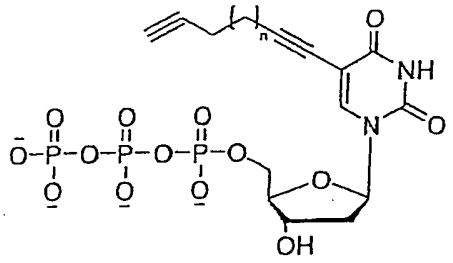


Figure 3c

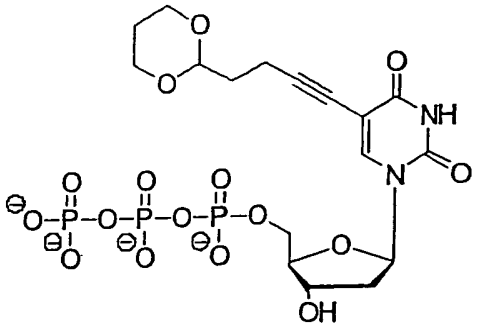


Figure 4

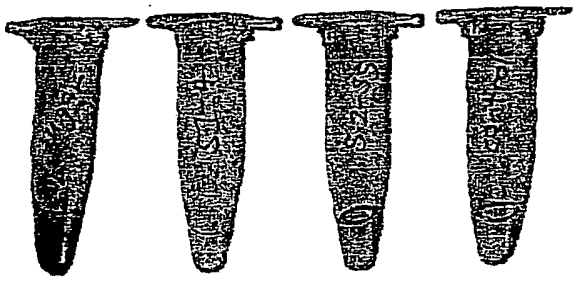


Figure 5

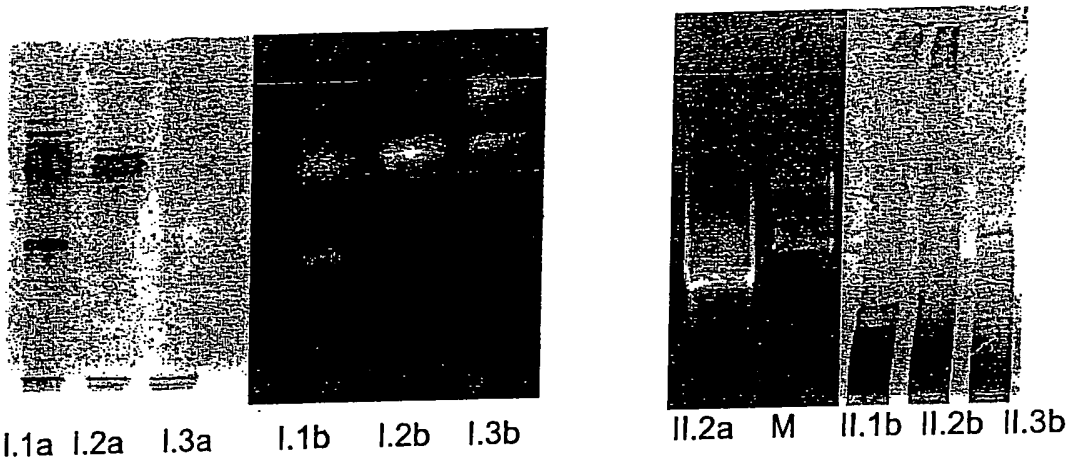


Figure 6

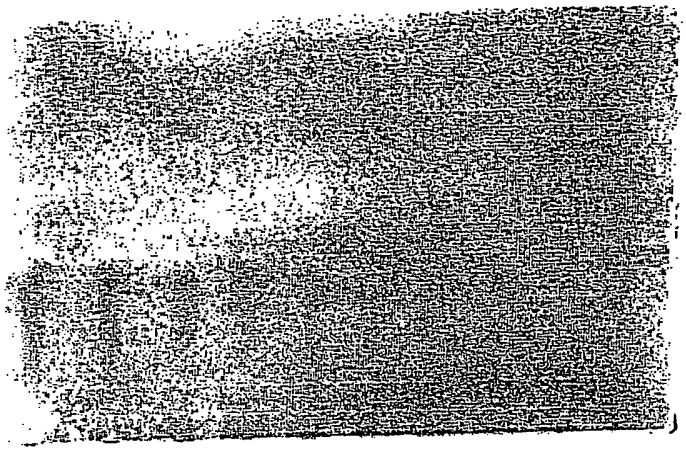


Figure 7

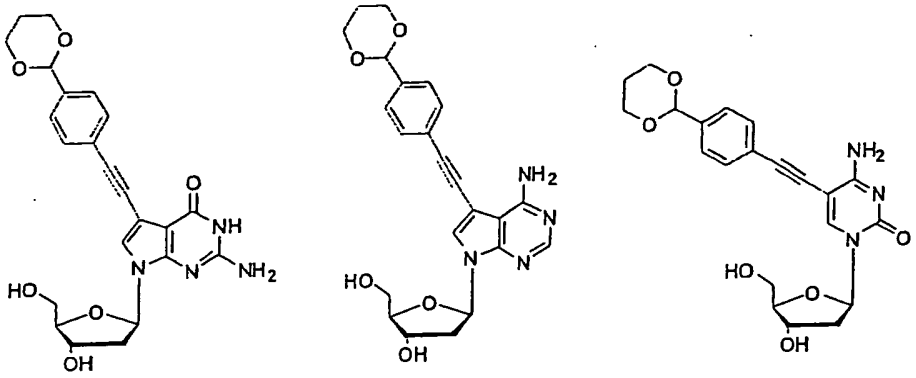


Figure 8

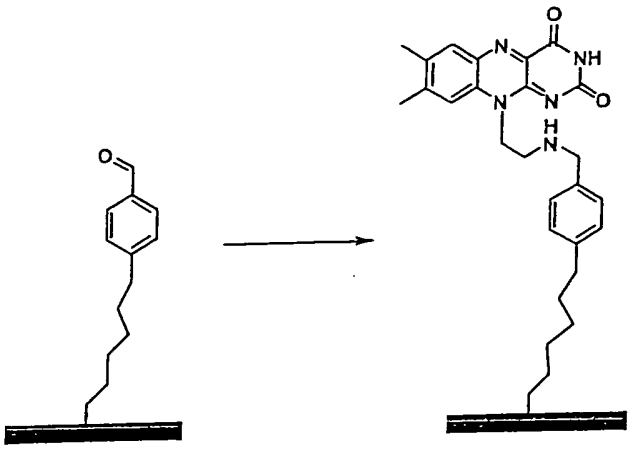
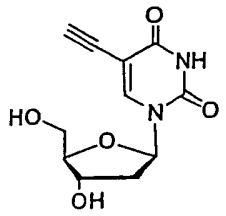
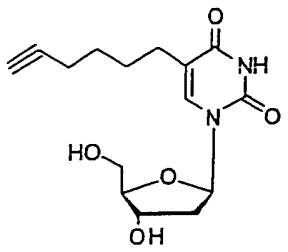


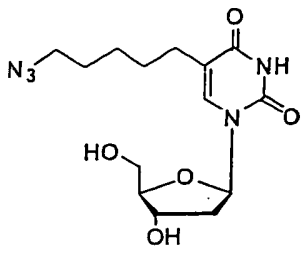
Figure 9



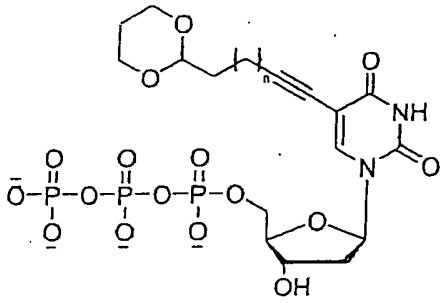
a



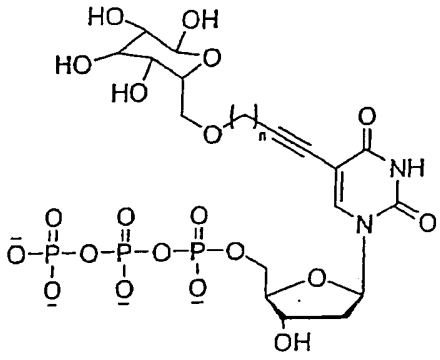
b



c

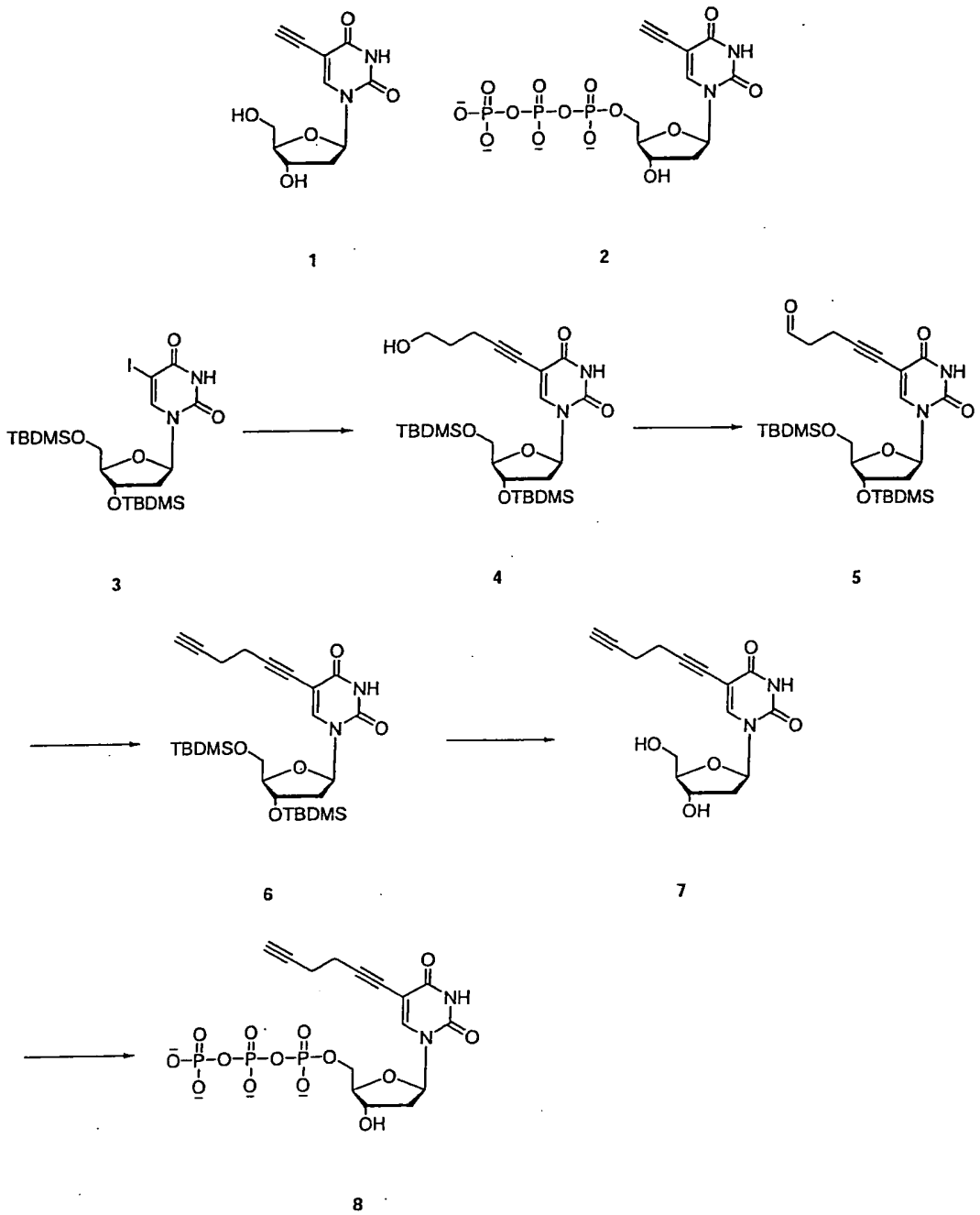


d



e

Figure 10

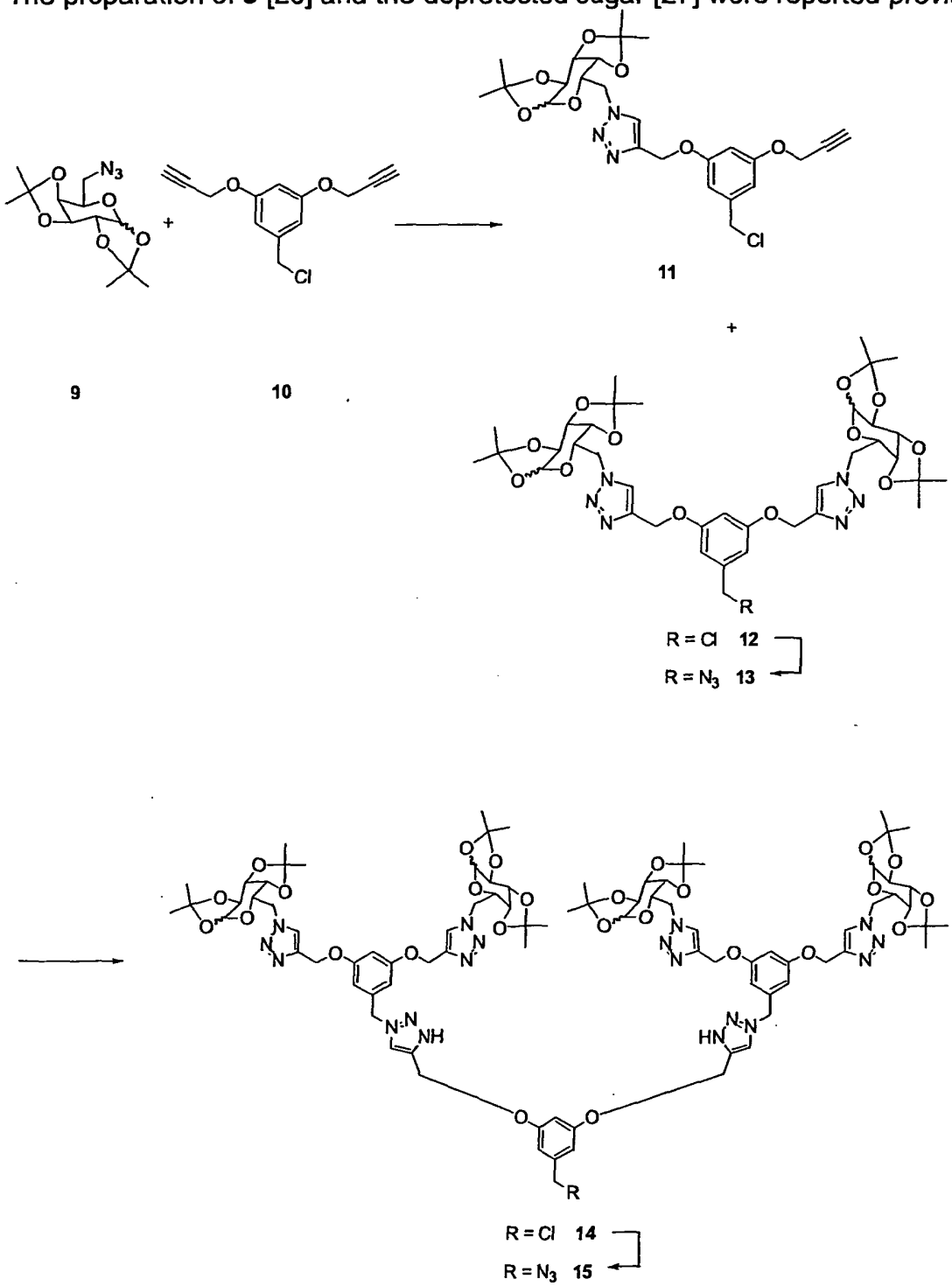


Scheme 1

Figure 11

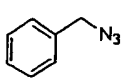
Dendrimer synthesis

The preparation of **9** [26] and the deprotected sugar [27] were reported previously.

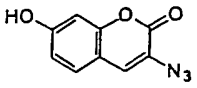


Scheme 2

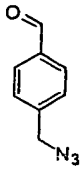
Figure 12



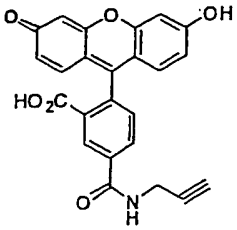
Benzyl azide



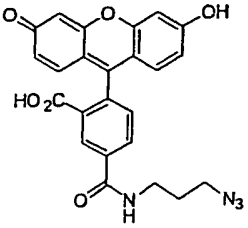
Coumarin azide



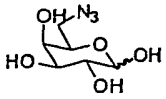
Aldehyde azide



Fluorescin alkyne

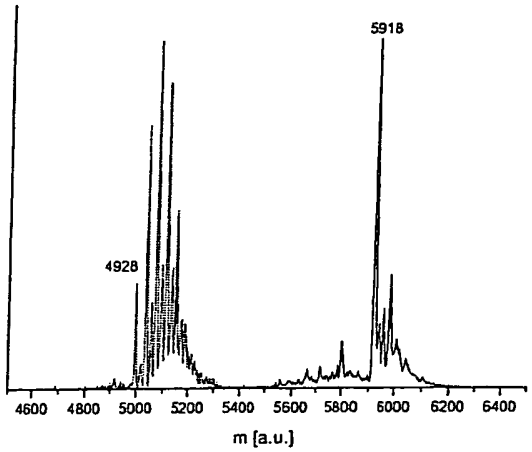


Fluorescin azide



Galactose azide

Figure 13


5918
4928
4600 4800 5000 5200 5400 5600 5800 6000 6200 6400
m [a.u.]

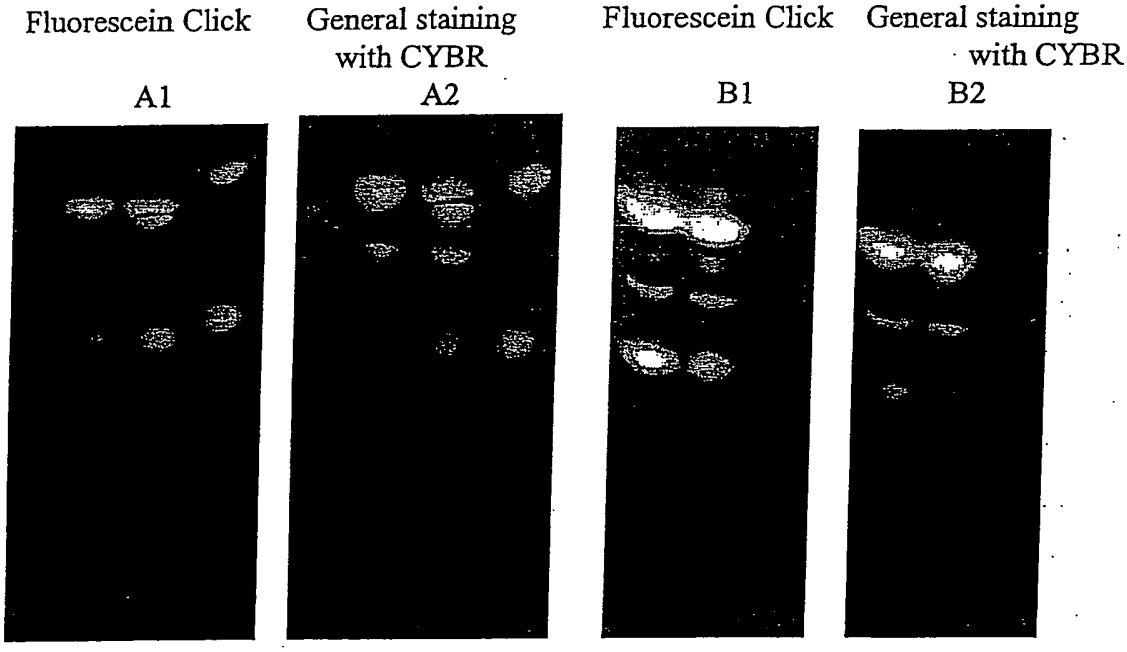

Fluorescein Click
General staining with CYBR
Fluorescein Click
General staining with CYBR
A1
A2
B1
B2

Figure 14

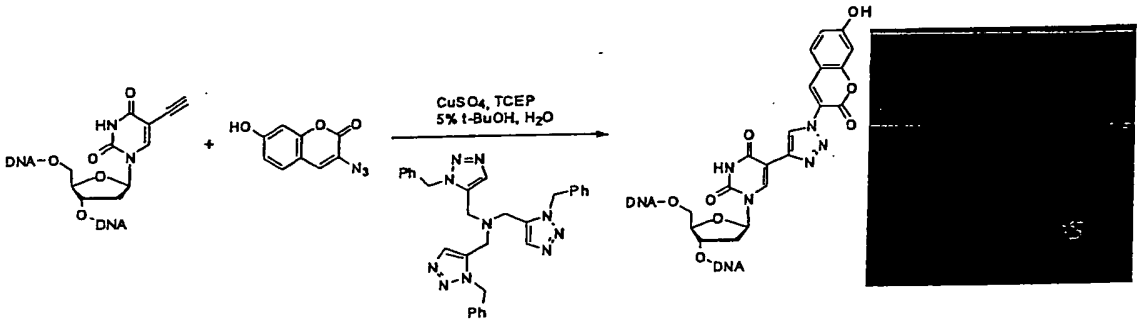
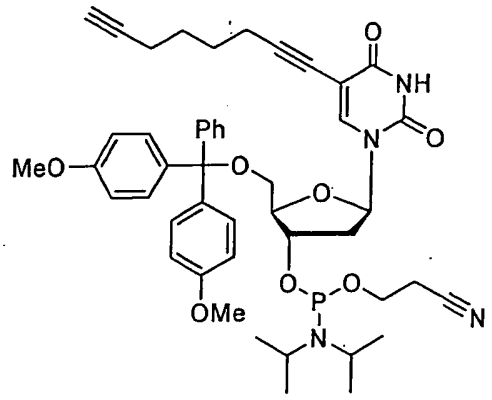
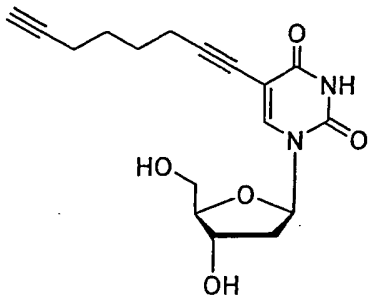

DNA-O
HN
O
N
O
O-DNA
HO
O
O
N3
+
CuSO4, TCEP
5% t-BuOH, H2O
N=N
Ph
Ph
Ph
N
N
N
N
N
N
OH
O
O
HN
O
N
DNA-O
O-DNA
N
N
N

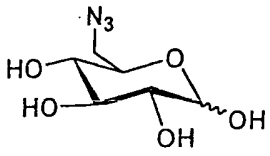
Figure 15



a



b



c

Figure 16

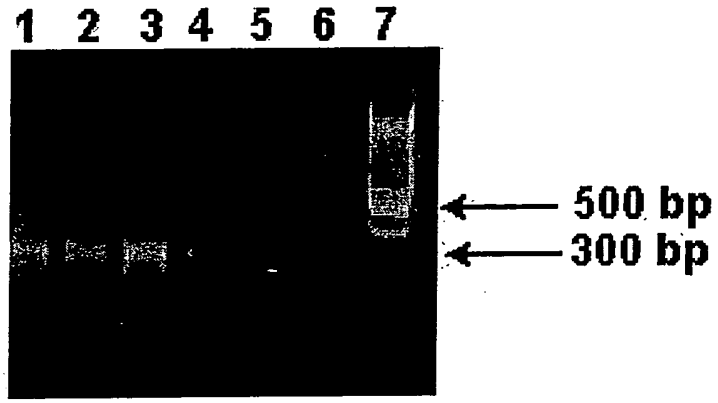


Figure 17

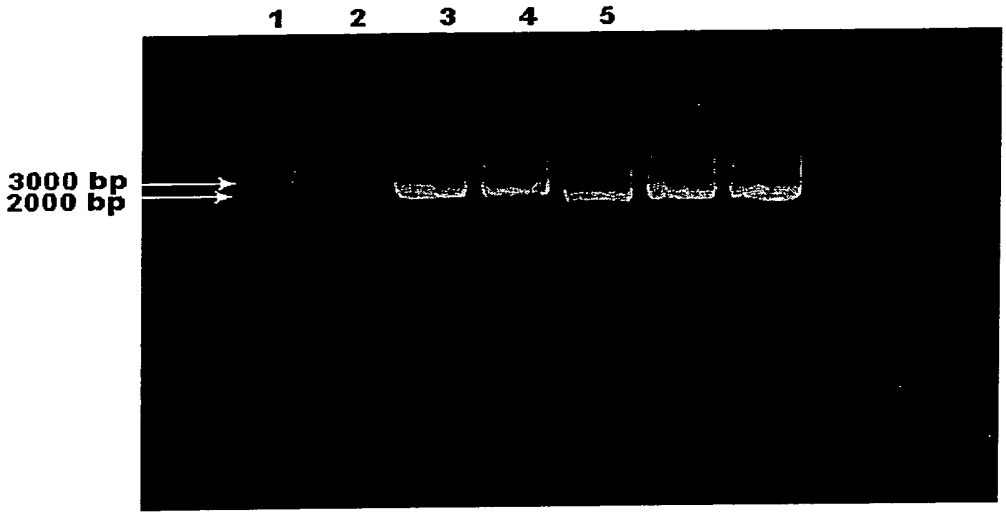


Figure 18

HPLC

Peak assignments:

9.5 min Cytidine
13.1 min Inosine (as a side product of snake venom)
13.6 min Guanosine
14.6 min Thymidine
16.7 min Adenosine
26.3 min. **7**

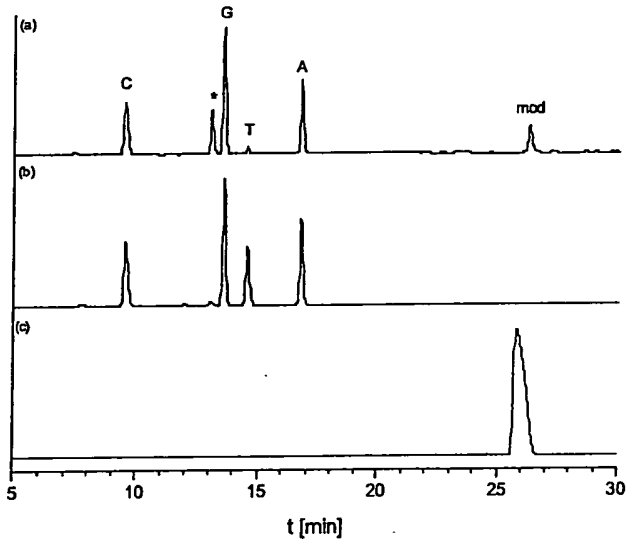
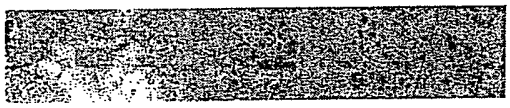


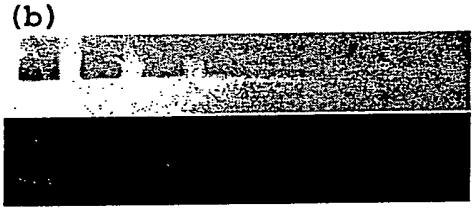
Figure 19

Dilution series.

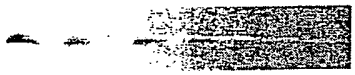
(a)



(b)



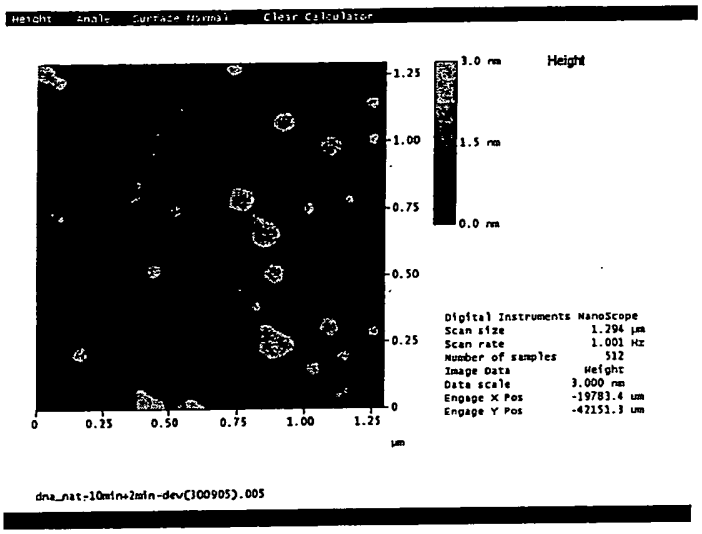
(c)



(d)

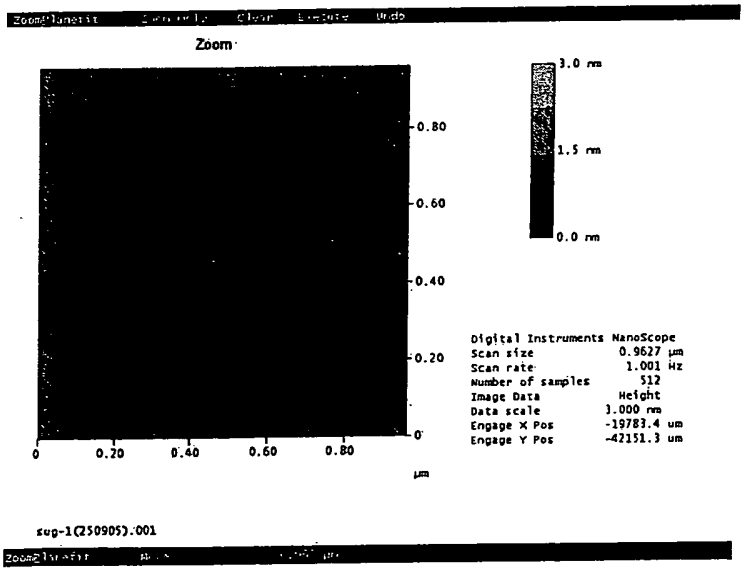


Figure 20a



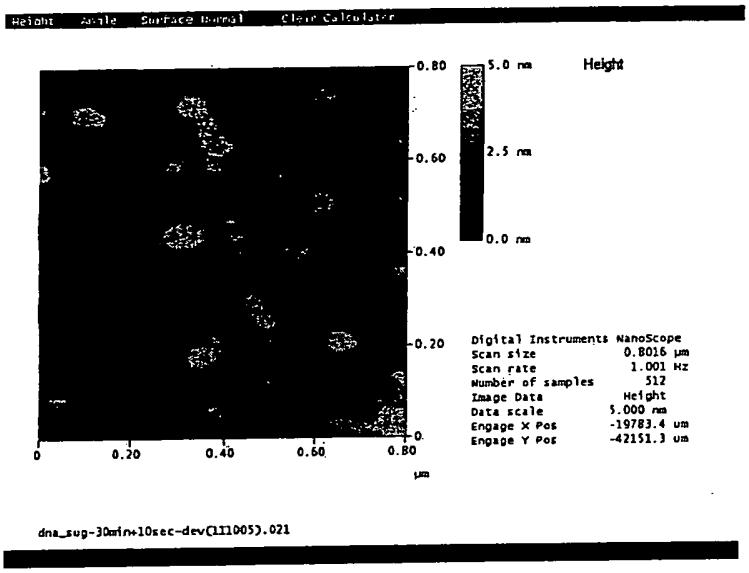
Natural DNA after exposing the DNA to the Ag staining conditions.

Figure 20b



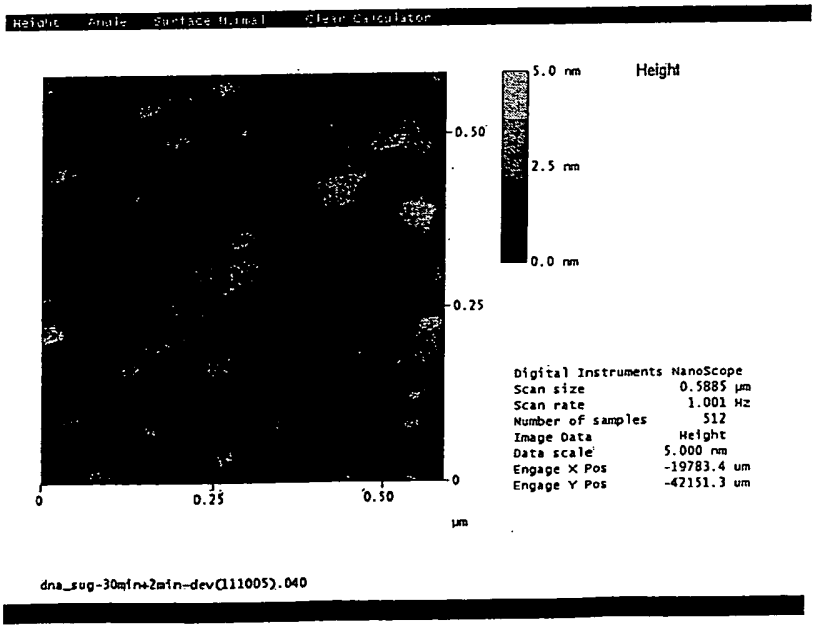
Sugar modified DNA

Figure 20c



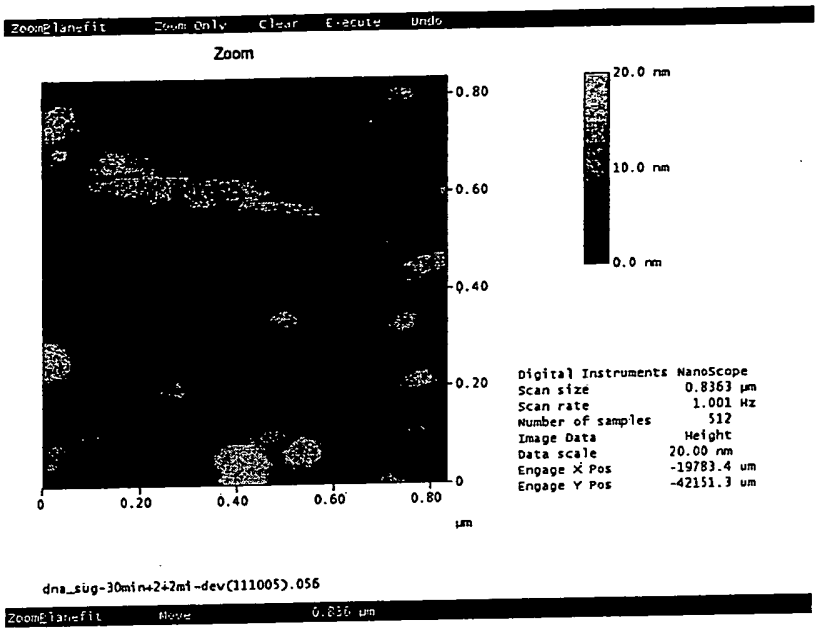
Sugar modified DNA after Ag staining without development

Figure 20d



Sugar modified DNA after Ag staining and with 2 min of development

Figure 20e



Sugar modified DNA after Ag staining and with two times 2 min of development

Figure 21

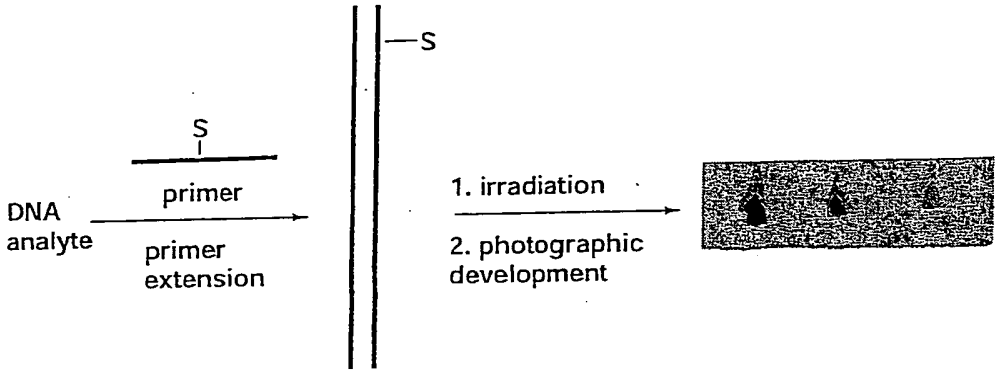
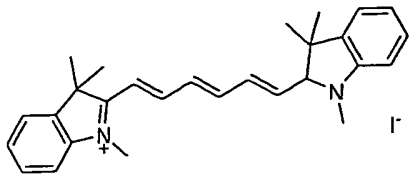
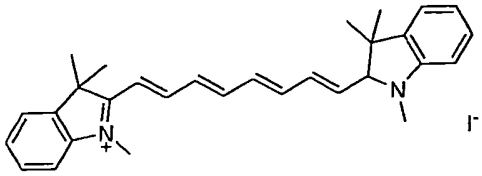

S
S
primer
DNA
analyte
primer
extension
1. irradiation
2. photographic
development

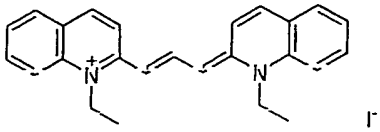
Figure 22



1



2



3

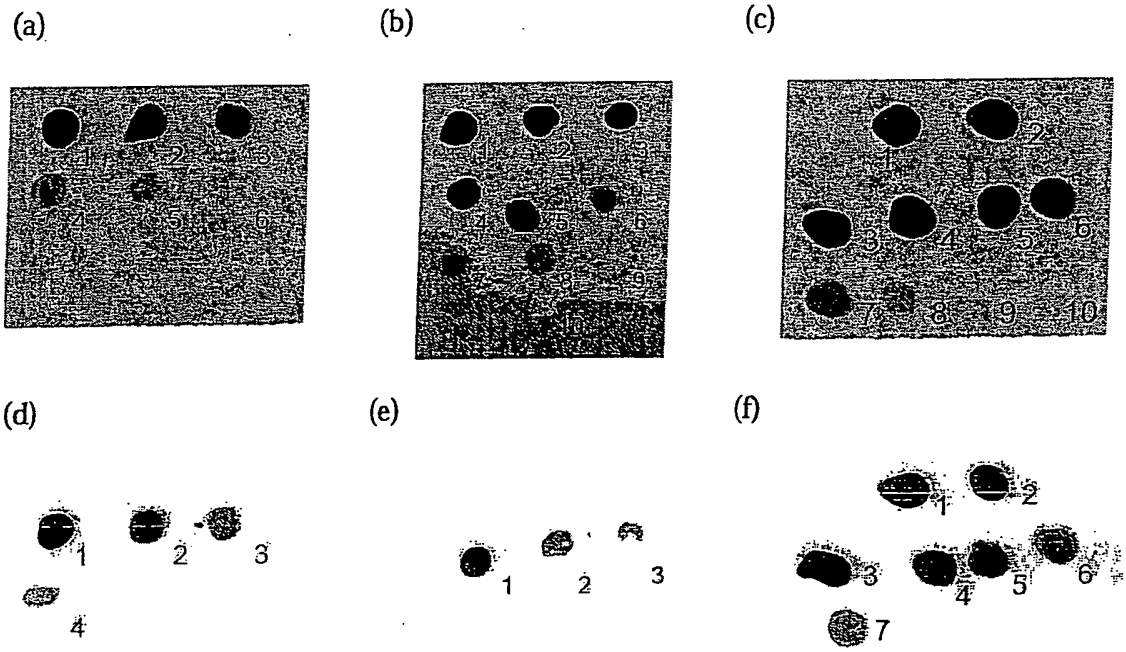


Figure 23

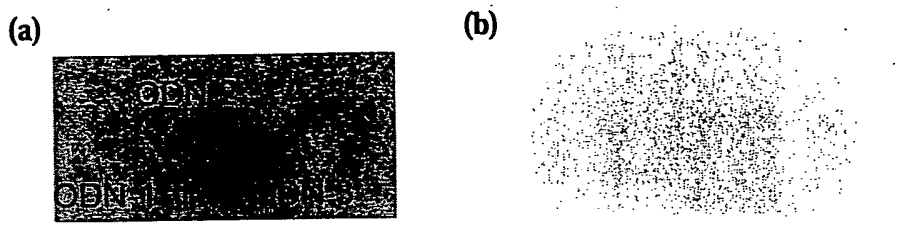
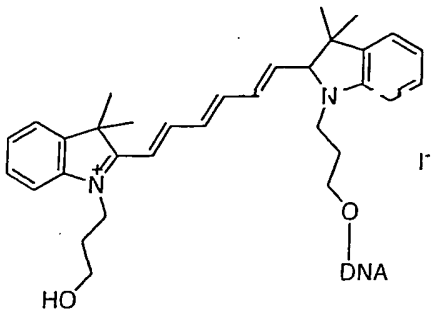
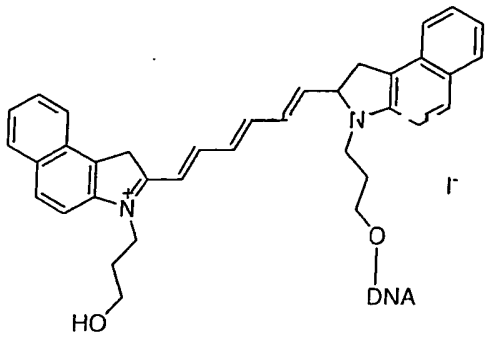


Figure 24

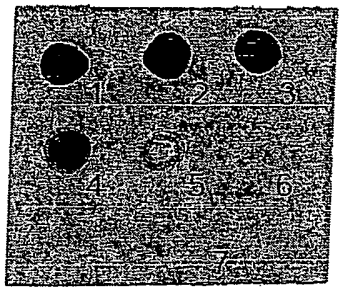


ODN-4

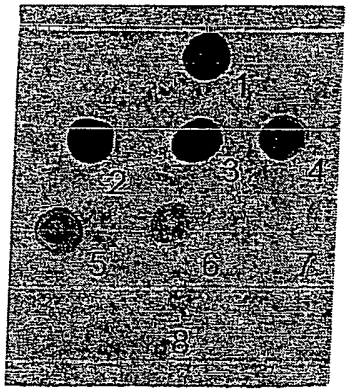


ODN-5

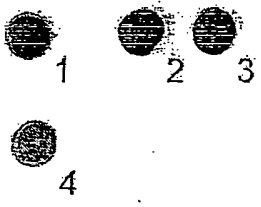
(a)



(b)



(c)



(d)

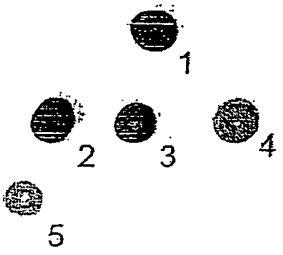
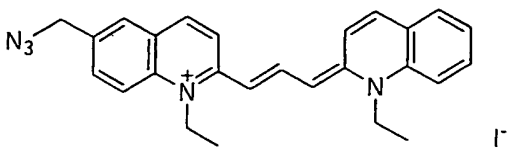


Figure 25


N3
N
N
I-

4

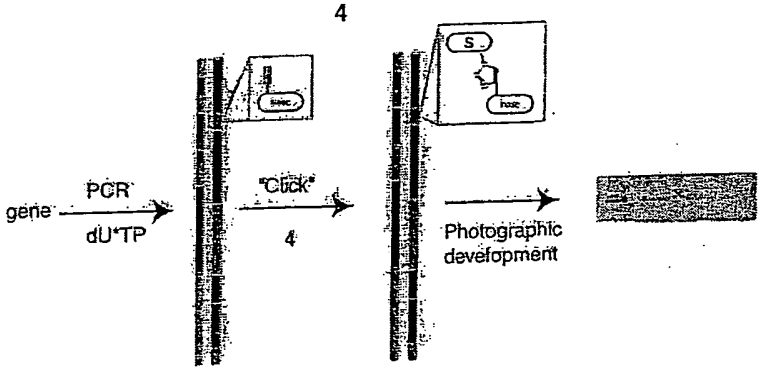

S
base
PCR
gene
dU*TP
"Click"
4
Photographic
development

Figure 26

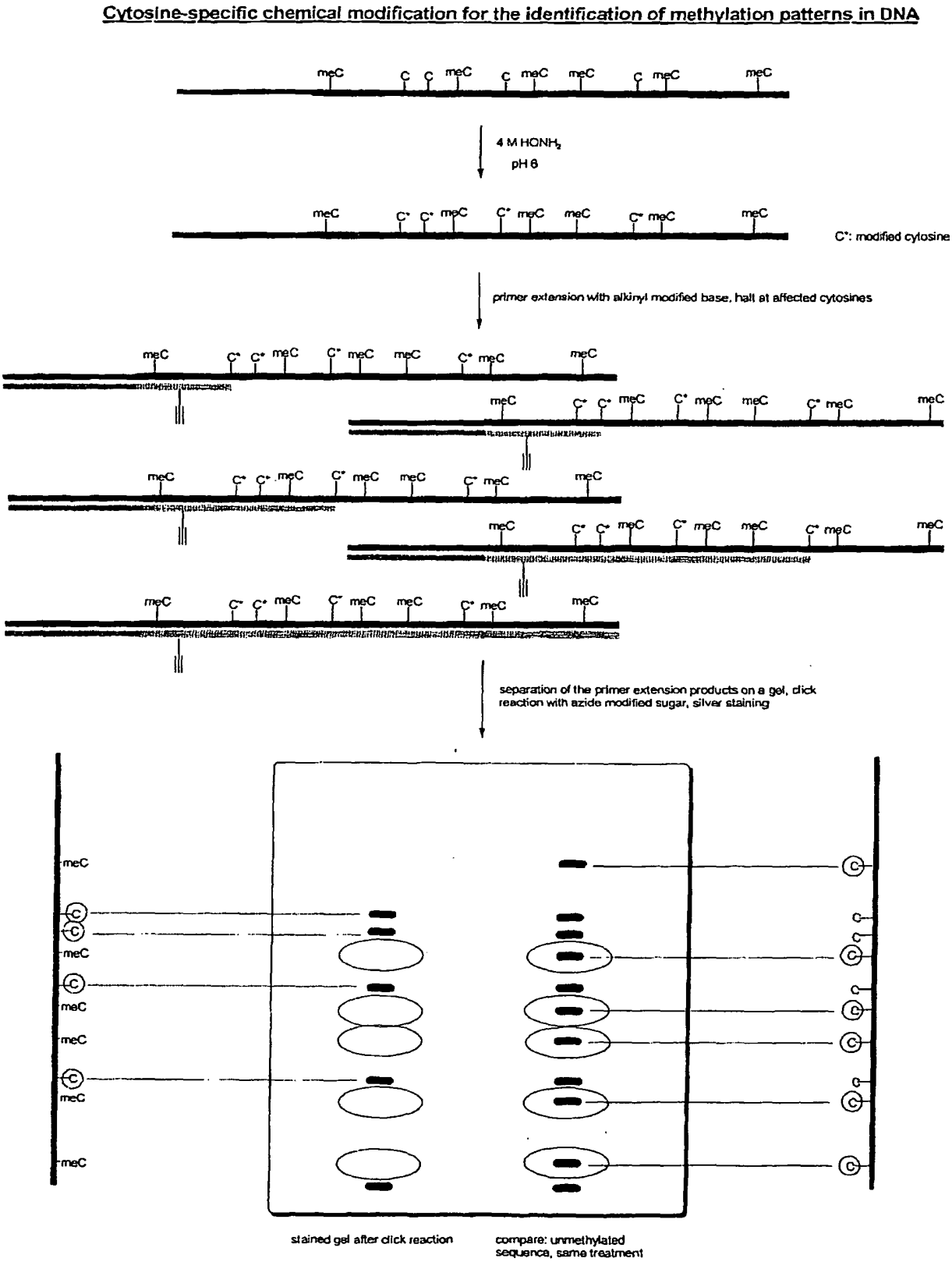
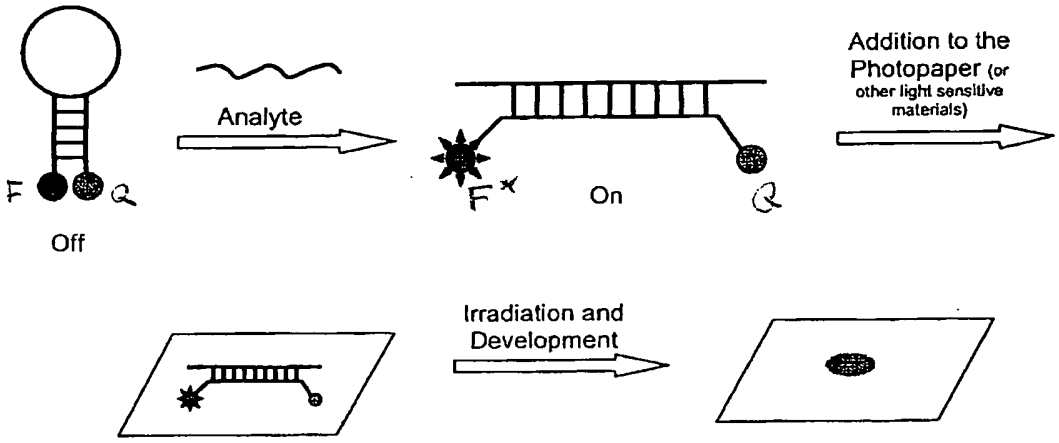

Cytosine-specific chemical modification for the identification of methylation patterns in DNA
meC
4 M HONH2
pH 6
C*: modified cytosine
primer extension with alkinyl modified base, halt at affected cytosines
separation of the primer extension products on a gel, click reaction with azide modified sugar, silver staining
stained gel after click reaction
compare: unmethylated sequence, same treatment

Figure 27


Analyte
Addition to the Photopaper (or other light sensitive materials)
F
Q
Off
F*
On
Q
Irradiation and Development