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<b>(54) Title:</b> DETECTION METHOD FOR C-RAF-1 GENES  <b>(57) Abstract</b>  The present invention relates to: (1) a method of identifying an individual at an increased risk for developing cancer, (2) a method for determining a prognosis in patients afflicted with cancer, and (3) a method for determining the proper course of treatment for a patient afflicted with cancer; comprising: amplifying a region of the c-raf-1 gene.		

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## DETECTION METHOD FOR C-RAF-1 GENES

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### Field of the Invention

10           The present invention relates to (1) a method of identifying an individual at an increased risk for developing cancer, (2) a method for determining a prognosis of patients afflicted with cancer, and (3) a method for determining the proper course of treatment for  
15 a patient afflicted with cancer.

### Background Information

          Lung cancer claims more lives in the United  
20 States than any other neoplasm (R.S. Finley, Am. Pharm. NS29, 39 (1989)), and of the various forms lung adenocarcinomas have one of the worst prognoses (T.P. Miller, Semin. Oncol. 17, 11 (1990)). The incidence of adenocarcinoma of the lung (ACL) in the United States is  
25 also quickly rising (I. Linnoila, Hematol. Oncol. North. Am. 4, 1027 (1990); J.B. Sorensen, H.H. Hansen, Cancer Surviv. 8, 671 (1989)). In order to gain insight into this complex and deadly disease, a model system for its study has been developed. For such a model to provide  
30 clinically relevant data several criteria must be met. The tumors produced should be histologically equivalent to their human counterparts, tumor induction must be reliable and reproducible, and the numbers generated must be great enough to provide statistical significance. To satisfy  
35 these conditions a system has been created which uses two inbred mouse strains (NFS/n and AKR) along with

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transplacental exposure to the potent carcinogen N-ethyl-N-nitrosourea (ENU) and promotion with the antioxidant butylated hydroxytoluene (BHT). The resulting tumors were examined for altered expression or structural mutations of

5 genes implicated in lung tumor development such as ras, myc, and raf oncogenes (C.D. Little et al., Nature 306, 194 (1983); P.E. Kiefer et al., Cancer Res., 47, 6236 (1987); E. Santos et al., Science 223, 661 (1984); S. Rodenhuis, N. Engl. J. Med. 317, 929 (1987); M. Barbacid,

10 Eur. J. Clin. Invest. 20, 225 (1990); U.R. Rapp et al., J. Int. Assoc. for the Study of Lung Cancer 4, 162 (1988); M.J. Birrer et al., Ann. Rev. Med. 40, 305 (1989); G. Sithanandam et al., Oncogene 4, 451 (1989)).

15 raf proto-oncogenes are evolutionarily highly conserved genes encoding cytoplasmic serine/threonine specific kinases, which function in mitogen signal transduction (reviewed in U.R. Rapp et al., The Oncogene Handbook, T. Curran et al., Eds. (Elsevier Science

20 Publishers, The Netherlands, 1988), pp. 115-154; U.R. Rapp, Oncogene 6, 495 (1991)). The three known active members in the raf family encode phosphoproteins of similar size (72/74 kD for Raf-1; 68 kD for A-Raf-1, and 74 kD for B-Raf (U.R. Rapp et al., in Retroviruses and

25 Human Pathology, R. Gallo et al., Eds. (Humana Press, Clifton, New Jersey 1985), pp. 449-472; T.W. Beck et al., Nucleic Acids Res. 15, 595 (1987); G. Sithanandam et al., Oncogene 5, 1775 (1990))). Raf-1 was first identified as the cellular homologue of v-raf (H.W. Jansen et al.,

30 Nature 307, 218 (1984)), the transforming gene of 3611 MSV (U.R. Rapp et al., J. Virol. 45, 914 (1983); U.R. Rapp et al., Proc. Natl. Acad. Sci. USA 80, 4218 (1983)). Amino acid comparisons of raf family genes shows three conserved regions [CR1, CR2, CR3] (T.W. Beck et al., Nucleic Acids

35 Res. 15, 595 (1987)); CR1 is a regulatory region surrounding a Cys finger consensus sequence, CR2 is a serine/threonine rich region, and CR3 represents the

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kinase domain. Raf-1 has been mapped to chromosome 3p25 in humans (S.J. O'Brien et al., Science 223, 71 (1984)), and this region has been found to be frequently altered in small cell lung carcinoma (SCLC) (J. Whang-Peng et al.,  
5 Cancer Genet. Cytogenet. 6, 119 (1982); J.M. Ibsen et al.,  
J. Cell. Biochem. 33, 267 (1987)), familial renal cell carcinoma (A.J. Cohen et al., N. Engl. J. Med. 301, 592 (1979); G. Kovacs et al., Int. J. Cancer 40, 171 (1987)),  
10 mixed parotid gland tumors (J. Mark et al., Hereditas 96,  
141 (1982)), and ovarian cancer (K. Tanaka et al., Cancer Genet. Cytogenet. 43, 1 (1989)).

Raf genes are differentially expressed in various tissues (S.M. Storm et al., Oncogene 5, 345  
15 (1990)). c-raf-1 has been found to be expressed ubiquitously, though absolute levels vary between tissues. A-raf-1 is present predominantly in the urogenital tissues, whereas B-Raf is most abundant in cerebrum and testis. The ubiquitous c-Raf-1 kinase is regulated by  
20 tyrosine and serine phosphorylations that result from activated growth factor receptor kinases (D.K. Morrison et al., Cell 58, 648 (1989); D.K. Morrison et al., Proc. Natl. Acad. Sci. USA 85, 8855 (1989); K.S. Kovacina et al., J. Biol. Chem. 265, 12115 (1990); P.J. Blackshear et al.,  
25 J. Biol. Chem. 265, 12131 (1990); M.P. Carroll et al., J. Biol. Chem. 265, 19812 (1990); J.N. Siegel et al., J. Biol. Chem. 265, 18472 (1990); B.C. Turner et al., Proc. Natl. Acad. Sci. USA 88, 1227 (1991); M. Baccarini et al., EMBO J. 9, 3649 (1990); H. App et al., Mol. Cell. Biol. 11, 913 (1991)). Raf-1 operates downstream of Ras in mitogen signal transduction as judged by experiments using antibody microinjection (M.R. Smith et al., Nature 320, 540 (1986)), c-raf-1 antisense expression constructs (W. Kolch et al., Nature 349, 426 (1991)), dominant  
35 negative mutants (W. Kolch et al., Nature 349, 426 (1991)), and Raf revertant cells. Studies with NIH3T3 cells and brain tissue demonstrated that mitogen treatment

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induces Raf-1 kinase activity and causes a transitory relocation of the active enzyme from the cytoplasm to the nucleus and perinuclear area (Z. Oláh et al., Exp. Brain Res. (in press); U.R. Rapp et al., in Cold Spring Harbor Symposia on Quantitative Biology, Vol. LIII, Eds. (Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY 1988) pp. 173-184).

Raf-1 coupling has been examined in more than a dozen receptor systems and all strong mitogens stimulated Raf-1 kinase activity (U.R. Rapp, Oncogene 6, 495 (1991); D.K. Morrison et al., Cell 58, 648 (1989); D.K. Morrison et al., Proc. Natl. Acad. Sci. USA 85, 8855 (1989); K.S. Kovacina et al., J. Biol. Chem. 265, 12115 (1990); P.J. Blackshear et al., J. Biol. Chem. 265, 12131 (1990); M.P. Carroll et al., J. Biol. Chem. 265, 19812 (1990); J.N. Siegel et al., J. Biol. Chem. 265, 18472 (1990); B.C. Turner et al., Proc. Natl. Acad. Sci. USA 88, 1227 (1991); M. Baccarini et al., EMBO J. 9, 3649 (1990); H. App et al., Mol. Cell. Biol. 11, 913 (1991)), and this stimulation correlated with an increase in Raf-1 phosphorylation leading to a shift in apparent molecular weight.

#### SUMMARY OF THE INVENTION

It is an object of this invention to provide a method of identifying an individual at an increased risk for developing cancer.

It is another object of this invention to provide a method for determining a prognosis in patients afflicted with cancer.

It is a further object of this invention to provide a method for determining the proper course of treatment for a patient afflicted with cancer.

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Further objects and advantages of the present invention will be clear from the description that follows.

In one embodiment, the present invention relates to a method of identifying an individual at an increased risk for developing cancer, comprising:

- amplifying a region of the c-raf-1 gene;
- analyzing products of the amplification for evidence of mutation; and
- classifying an individual having one or more mutations in the region as having an increased risk for developing cancer.

In another embodiment, the present invention relates to a method for determining a prognosis in patients afflicted with cancer, comprising:

- amplifying a region of the c-raf-1 gene;
- analyzing products of the amplification for evidence of mutation; and
- classifying patients having no mutation in said region as being less likely to suffer disease relapse or having an increased chance of survival than those patients having one or more mutations in said region.

In a further embodiment, the present invention relates to a method for determining the proper course of treatment for a patient afflicted with cancer, comprising:

- amplifying a region of the c-raf-1 gene;
- analyzing products of said amplification for evidence of mutation;
- identifying a patient having at least one mutation in said region, which patient may require treatment proper for patients having a lesser chance of survival or decreased time to relapse; and
- identifying a patient lacking mutations in said region, which patients may require treatment proper for

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patients having a greater chance of survival or being less likely to suffer disease relapse.

#### BRIEF DESCRIPTION OF THE DRAWINGS

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Figure 1. Effect of BHT promotion on ENU tumorigenesis in NFS/n x AKR mice. The X-axis represents percent tumor induced mortality within each group, and the Y-axis reflects age in weeks. All animals were exposed to ENU transplacentally at a dose of 0.5mM/Kg of mother's body weight on day 16 of gestation (presence of vaginal plug was scored as day one). At two weeks of age mice were weaned into two separate groups and separated by sex. Both groups were housed in identical cages and supplied with food (Purina Lab Chow) and water ad libitum. Beginning at three weeks of age, group 2A (O) was given weekly intraperitoneal (i.p.) injection of corn oil (0.1 ml), and group 2B (◊) received weekly i.p. injections of BHT (20 mg/Kg of body weight) dissolved in corn oil. Administration of BHT reduces the mean age of mortality from approximately 20 weeks to 13, and decreases the initial age of mortality. These curves are significantly different ( $p \leq 0.001$ ) as judged by a 2-tailed Cox test. In both groups the rate of tumorigenesis was identical for males and females.

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Figure 2. Northern blot analysis of proto-oncogene expression levels in ENU induced tumors.

Figure 3. Diagnostic digestion of PCR amplified Ki-ras genes from ENU induced tumors. Genomic DNA was isolated from a cesium chloride gradient during RNA preparations. In each case 10 ng was amplified via PCR (95°C, 5 min. followed by 35 cycles of 95°C, 1 min. → 55°C, 1 min. → 72°, 1 min.) with 2 units of Taq I polymerase. The primers used (K1; 5'-AACTTGTGGTGGTTGGACCT-3' → (SEQ ID NO:6) and K2; ← 3'-

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GTCTTAGTGAAACACCTACT-5' (SEQ ID NO:7)) generate a 79 b.p. product. The primer K1 ends at codon 12 and contains a mismatch from normal mouse (Ki-ras sequence its 18th nucleotide (G → C) creating a BstNI site (CCTGG) in conjunction with a normal codon 12 (GGT). Digestion of amplified product from a normal allele with BstNI produces two products of 19 and 60 b.p., whereas a mutation in one of the first two positions of codon 12 will eliminate the BstNI site. The presence of two normal alleles results in all of the product being cleaved and the presence of one mutant and one normal allele will result in only half of the product cut. In the three panels each sample was run in duplicate, uncut and cut with BstNI. F1 is DNA from an untreated NFS/n X AKR F1 mouse, and MCA5 is a murine cell line known to harbor a mutant K-ras codon 12 allele. One lymphoma (24Ly) and one cell line (117; derived from a lung adenocarcinoma) display a mutated Ki-ras codon 12 allele; however, 24Ly was a passaged tumor and examination of the original tumor showed two normal alleles indicating that this mutation was acquired during passaging.

Figure 4. c-raf-1 RNase protection analysis of ENU induced tumors. The probe used was a <sup>32</sup>P labeled antisense transcript from the 3' non-coding region of a mouse c-raf-1 cDNA to the 3' most StuI site. Hybridization of this probe with normal RNA results in a protected fragment of 1.2kb covering the region encoding the Raf-1 kinase domain. One µg of poly(A)+ RNA from each tumor and 5 µg of F1 RNA (in order to get comparable signals) was hybridized for 12 hours at 52°C with 200,000 cpm of <sup>32</sup>P labeled mouse c-raf antisense transcript. Hybrids were then digested for 30 minutes with 25 µg RNase A and 33 units of RNase T1 at room temperature. Digested hybrids were then incubated with 50 µg of proteinase K, phenol/chloroform extracted, ethanol precipitated, and resuspended in loading dye containing 80% formamide. Samples were then run on 6% polyacrylamide denaturing

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sequencing gels at 65 watts. Gels were vacuum dried at 80 degrees C and exposed to X-ray film. Probe is undigested probe alone; tRNA is probe hybridized to non-specific RNA; v-raf is probe hybridized to RNA from a v-raf transformed cell line and the bands detected represent single base mismatches between murine c-raf and v-raf; NFS/AKR F1 is probe hybridized with RNA from a normal (untreated) mouse; 24 LY is probe hybridized with RNA from a lymphoma; and the remaining lanes are probe hybridized with RNA isolated from lung tumors.

Figure 5. Schematic of Raf-1 protein showing sites of ENU induced mutations. CR1, CR2, and CR3 represent conserved regions 1, 2 and 3. cDNAs were made from tumor derived poly(A)+ RNA using MoMuLV reverse transcriptase. Primers (MR1 sequence and MR2 sequence) encompassing a 435 base pair region c-raf were then used to amplify this region via PCR. The amplification mixture was then run on 1.7% agarose gels and the 435 bp product isolated. This isolated fragment was then treated with T4 polymerase and cloned into the HincII site of M13mp18 for sequencing. Another set of primers (EMR1 sequence and EMR2 sequence) was designed containing EcoRI sites at the termini and used to amplify a 609 base pair region (encompassing the original 435 base pair region). Isolated products from these reactions were then digested with EcoRI and cloned into the EcoRI site of KS. Sequencing reactions were carried out using the Sequenase kit (USB) according to the recommended protocols for single and double stranded sequencing. Sequencing reactions were run on 6% polyacrylamide denaturing gels at 65 watts. Gels were vacuum dried at 80 degrees C and exposed to X-ray film. In each case a normal allele was also sequenced along with the mutant allele.

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Figure 6. Schematic for Identifying c-raf-1 mutations. Primers 1 and 2 are shown in SEQ ID NO:8 and SEQ ID NO:9, respectively.

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#### DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to methods that involve amplifying a region of the c-raf-1 gene (the sequence of a mouse c-raf-1 gene is shown in SEQ ID NO:10; 10 the nucleotide and corresponding amino acid sequence of a human c-raf-1 gene is shown in SEQ ID NO:11 and SEQ ID NO:12, respectively).

In one embodiment, the present invention relates 15 to a method of identifying an individual at an increased risk for developing cancer (preferably, lung cancer, T-cell lymphomas, renal cell carcinoma, ovarian carcinoma, and mixed parotid gland tumors) comprising: amplifying a region (preferably by using the polymerase chain reaction 20 method(PCR) or by cloning techniques) of the c-raf-1 gene of the individual (SEQ ID NO:11)(in one preferred embodiment, the region encodes amino acids 514 to 535 of SEQ ID NO:12); analyzing products of the amplification for evidence of mutation (preferably by DNA sequencing of the 25 region) and classifying an individual having one or more mutations in the region as having an increased risk for developing cancer. In one preferred embodiment, the region encodes amino acids 500 to 550 of SEQ ID NO:12 or amino acids 450 to 630 of SEQ ID NO:12. In another preferred 30 embodiment, the PCR method employs a primer comprising the sequence shown in SEQ ID NO:7 and a primer comprising the sequence shown in SEQ ID NO:8. In another preferred embodiment, the method comprises the steps shown in Figure 6.

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In another embodiment, the present invention relates to a method for determining a prognosis in a patient afflicted with cancer (preferably, those cancers

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listed above). The method comprises: amplifying the region of the c-raf-1 gene as described above; analyzing products of the amplification for evidence of mutation as described above; and classifying a patient having no  
5 mutation in the region as being less likely to suffer disease relapse or having an increased chance of survival than a patient having one or more mutations in the region.

In another embodiment, the present invention  
10 relates to a method for determining the proper course of treatment for a patient afflicted with cancer (preferably, those cancers listed above), comprising: amplifying a region (described above) of the c-raf-1 gene as described  
15 above; analyzing products of the amplification for evidence of mutation as described above; identifying a patient having at least one mutation in the region, which patient may require treatment proper for patients having a  
lesser chance of survival or decreased time to relapse; and identifying a patient lacking mutations in the region,  
20 which patients may require treatment proper for patients having a greater chance of survival or being less likely to suffer disease relapse.

Administration of therapeutic agents (cytotoxic  
25 or cytostatic) tailored to recognize the mutant Raf-1 protein but not normal Raf-1 could specifically target tumor cells for death of growth inhibition. Such agents could be comprised of cytotoxic T-cells, antibodies, and/or specifically designed chemical compounds.

30

The following Examples demonstrate consistent point mutations of the c-raf-1 proto-oncogene, within a small region of the kinase domain, in a mouse model for chemical tumor induction. This is the first demonstration  
35 of point mutated raf genes in vivo, and the first isolation of activating in vivo point mutations in the kinase domain of a proto-oncogene. The tumors examined

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show a selective specificity for Raf-1 mutations as another family of genes, the ras proto-oncogenes which are frequently activated by point mutation in both animal and human tumors (S. Rodenhuis et al., Am. Rev. Respir. Dis. 5 142, S27-30; T.R. Devereux et al., Carcinogenesis 12, 299 (1991)), is not involved.

The present invention is described in further detail in the following non-limiting examples.

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#### EXAMPLES

The following protocols and experimental details are referenced in the examples that follow:

15 RNA Isolation. Tumors were excised, a small portion minced in PBS (phosphate buffered saline solution) for passaging in nude mice, frozen immediately in a dry ice/ethanol bath, and stored at -70° until RNA extraction. Frozen tissues were minced on wet ice in a guanidine  
20 thiocyanate buffer (4M guanidine thiocyanate 10mM EDTA, 2% N-lauryl sarcosine, 2% beta-mercaptoethanol, 10mM Tris (pH=7.6)), disrupted in a Dounce homogenizer, and extracted three times with phenol: chloroform: isoamyl alcohol (24:24:2). Supernatants were then transferred to  
25 SW41 tubes, 100 µg of cesium chloride per ml was added to the supernatant which was then underlayered with one half saturated cesium chloride in 10mM EDTA (pH=7.0; index of refraction 1.3995-1.4000), and centrifuged at 25,000 rpm for 20 hours in a Sorvall SW-41TI rotor using a Beckman  
30 model L5-50 ultracentrifuge. Supernatants were removed and RNA pellets dissolved in 4 ml resuspension buffer (10 mM Tris-HCl pH=7.6, 5% beta-mercaptoethanol, 0.5% N-lauryl sarcosine, 10 mM EDTA), extracted once with  
35 phenol:chloroform:isoamyl alcohol, sodium acetate added to 0.12M and RNA precipitated with two volumes ethanol at -20°C overnight. Precipitates were centrifuged at 9,000 rpm in a Sorvall SS-34 rotor for 30 minutes, and pellets

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redissolved in RNA sample buffer (10 mM Tris pH=7.4, 1mM EDTA, 0.05% sodium dodecyl sulfate) and concentrations determined by absorbance at 260 nm. Poly (A)<sup>+</sup> RNA was isolated by binding to oligo dT cellulose columns in high salt (10mM Tris pH=7.4, 1mM EDTA, 0.05% SDS, 500mM NaCl), and eluting with RNA sample buffer heated to 40°C.

Northern Blotting. 5 µg poly(A)<sup>+</sup> RNA per lane was ethanol precipitated, desiccated, resuspended in loading buffer (20mM MOPS pH=6.8, 5mM sodium acetate, 1mM EDTA, 50% formamide, 6% formaldehyde), heated at 65°C for 5 min., quick chilled on wet ice for 10 min., and electrophoresed through a 0.7% agarose gel containing 2.2 M formaldehyde, 20mM MOPS [pH=6.8], 5mM sodium acetate, and 1mM EDTA. Gels were then blotted overnight onto nitrocellulose filters via capillary transfer in 20X SSC, filters were washed in 3X SSC for 10 min. and baked at 80°C for 2 hours.

Hybridizations. Filters were prehybridized at 42°C in 5X SSC, 50% formamide, 20mM sodium phosphate pH=6.8, 200 µg/ml PVP-40, 200 µg/ml ficoll 400, 200 µg/ml bovine serum albumin, and 200 µg/ml sonicated sheared salmon sperm DNA. Blots were then hybridized with 500,000 cpm/ml of random primed <sup>32</sup>P labeled probes overnight at 42°C in prehybridization solution with 5% dextran sulfate. Blots were washed with agitation in 2X SSC, 0.1% SDS at room temperature six times for 20 minutes each wash, then washed once at 45°C in 0.1X SSC for 15 minutes. Filters were exposed to X-AR 5 film at -70°C.

#### EXAMPLE 1

##### Tumor Induction

NFS female mice were mated with AKR males and pregnant females given a transplacental injection of 1-ethyl-1-nitrosourea (ENU) at a dosage of 0.5 mM/Kg

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mother's body weight on day 16 of gestation, counting plug date as day one. ENU was chosen for tumor induction since it is a very potent direct acting carcinogen capable of modifying any base in vivo (Singer, B. et al., 1983.

5 Molecular Biology of Mutagens and Carcinogens, Plenum Press, New York). ENU alkylates all tissues with roughly the same efficiency (E. Scherer et al., Cancer Lett. 46, 21 (1989)) and has a very short half life in vivo (E.M. Faustman et al., Teratology 40, 199 (1989)) allowing

10 specific mutagenesis of tissues which are mitotically active at a particular time. NFS and AKR were chosen as parental strains based on earlier studies which showed them to be particularly susceptible to lung tumors following ENU exposure (B.A. Diwan et al., Cancer Res. 34,

15 764 (1974); S.L. Kauffman, JNCI 57, 821 (1976)). With this procedure nearly 100% of the offspring develop lung adenocarcinomas and approximately 70% develop, in addition, T-cell lymphomas with a mean latency of approximately 20 weeks. In order to achieve more rapid

20 tumor development, weanling mice were treated with weekly injections of a tumor promoter, the antioxidant butylated hydroxytoluene or BHT (20mg/kg body weight dissolved in corn oil). BHT was used as it has been demonstrated to cause lung lesions and hyperplasia when injected into mice

25 (A.A. Marino et al., Proc. Soc. Exp. Biol. Med. 140, 122 (1972); H. Witschi et al., Proc. Soc. Exp. Biol. Med., 147, 690 (1974); N. Ito et al., CRC Crit. Rev. Toxicol. 15, 109 (1984)). In the present system it nearly doubles the rate at which tumors develop. Figure 1 compares tumor

30 induced mortality with age of animals for those receiving ENU alone, and those receiving ENU and promoted with BHT. These curves demonstrate that when BHT is given the mean age of tumor induced mortality decreases from approximately 20 weeks to around 12, and there is also a

35 decrease in initial latency. These curves are significantly different with a confidence limit greater than 99.99% using a 2-tailed Cox test. In addition, BHT

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promotion, while increasing the rate at which tumors develop, does not affect the tumor spectrum.

#### EXAMPLE 2

##### Oncogene Expression

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Northern blot analysis revealed elevated levels of c-raf-1, as compared to normal tissue, in every tumor examined (Figure 2), and Western blot analysis showed that protein levels correlated with message levels (U.R. Rapp et al., in Oncogenes and Cancer, S.A. Aaronson et al., Eds. (Tokyo/VNU Scientific Press, Tokyo, 1987) pp. 55-74). In addition, in cell lines derived from primary tumors, Raf-1 protein kinase activity was shown by immune-complex kinase assays to be constitutive. Further analysis of other oncogenes revealed no consistent pattern of expression except for ras and myc family genes. In the case of the myc family, one member (either c-, N-, or L-myc) was overexpressed but never more than one. For the ras genes, at least one member (Ki-, Ha-, or N-ras), and often more than one, was expressed at high levels when compared with the normal tissue. In addition all oncogenes examined via Northern analysis exhibited full length, normal sized transcripts.

25

ras genes were considered likely candidates for mutational activation since oncogenic forms of Ki-ras have previously been observed in lung tumors (S. Rodenhuis et al., Am. Rev. Respir. Dis. 142, S27-30; T.R. Devereux et al., Carcinogenesis 12, 299 (1991)) and ENU is a point mutagen (Singer, B. et al., 1983. Molecular Biology of Mutagens and Carcinogens, Plenum Press, New York). A systematic analysis of various ras codons known to be involved in oncogenic activation was therefore performed. Ha-, Ki-, and N- ras were examined at codons 12, 13, and 61 for potential mutations via RNase protection assays (R.M. Myers et al., Science 230, 1242 (1985); E. Winter et

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al., Proc. Natl. Acad. Sci. USA 82, 7575 (1985)), PCR amplification followed by subsequent sequencing (F. Sanger et al., J. Mol. Biol. 13, 373 (1975)), and PCR amplification followed by diagnostic restriction digests

5 (W. Jiang et al., Oncogene 4, 923 (1989)). PCR amplification creating diagnostic enzyme sites is a very efficient way of examining alleles for mutations at known sites and involves designing a PCR primer whose 3' end

10 lies next to and produces a novel restriction site encompassing the codon of interest. Following amplification, PCR products from normal alleles will contain the new restriction site, while mutant alleles will not. Digestion of the product from tissue with two

15 normal alleles results in all product being cut; however, if one allele contains a mutation, only half of the product will be digested. Figure 3 shows the results of amplification and diagnostic digestion applied to Ki-ras codon 12 in several tumors and cell lines. The first

20 panel is from a set of lymphomas. F1 is DNA from a normal untreated mouse and both alleles are cut by BstNI, indicating the presence of two normal alleles. MCA5 is a murine cell line known to contain a Ki-ras codon 12

25 mutation (L.F. Parada et al., Mol. Cell. Biol. 3, 2298 (1983)), and only the amplified normal allele is cleaved. Of the five tumors shown in the second panel, one shows a mutant Ki-ras allele. The next panel shows some of the lung tumors tested and none of them exhibit a mutant

30 allele, and the final panel shows tumor derived cell lines. The first three are from lymphomas and the last three from lung adenocarcinomas. One lung tumor line (#117) has a Ki-ras 12 mutation that was not present in the primary tumor but came up upon transplantation. This analysis has been performed with Ki, Ha and N-ras genes at codons 12 and 61. Of all the tumors and cell lines

35 examined by this method for mutations of the three ras genes at codons 12 and 61, the two shown here were the only ones detected. Examination of codon 13 was done by

PCR amplification of genomic DNA surrounding codon 13 followed by cloning into KS+ (Stratagene) and double stranded sequencing. Table I summarizes the ras mutation data. The most notable point from this table is the  
 5 conspicuous lack of ras mutations in these tumors. In fact the number of ras mutations is much lower than would be expected for a sampling of spontaneous tumors (S. Rodenhuis et al., Am. Rev. Respir. Dis. 142, S27-30; T.R. Devereux et al., Carcinogenesis 12, 299 (1991); J.L. Bos,  
 10 Cancer Res. 49, 4682 (1989)). Having eliminated ras genes as playing a primary role in the genesis of these ENU induced tumors, c-raf-1 was investigated for possible small or point mutations.

15 TABLE I

Tumors and Cell Lines Positive for ras Mutations

	Codon 12		Codon 13		Codon 61	
	Tumors	Cell Lines	Tumors	Cell Lines	Tumors	Cell Lines
20 Ha-ras	0/10	0/6	0/6	0/2	0/10	0/6
Ki-ras	1*/10	1/6	0/6	0/2	0/6	0/2
N-ras	0/10	0/6	0/6	0/2	0/10	0/6

\* This was a second passage tumor in which the original  
 25 tumor did not contain a Ki-ras mutation.

Table I: Summary of mutation analysis for Ha-, Ki-, and N-ras at codons 12, 13, and 61. Each box displays the number of mutations detected, over the number of tumors  
 30 and tumor derived cell lines examined via RNase protection, sequencing or diagnostic digestion, for each of the nine codons.

EXAMPLE 3

Mutations in Raf-1

35

Since no point mutations had been described for raf genes in vivo, as had been for the ras genes (E.

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Santos et al., Science 223, 661 (1984); S. Rodenhuis, N. Engl. J. Med. 317, 929 (1987); M. Barbacid, Eur. J. Clin. Invest. 20, 225 (1990); F. Sanger et al., J. Mol. Biol. 13, 373 (1975)), point mutations were screened for  
5 using RNase protection assays (R.M. Myers et al., Science 230, 1242 (1985); E. Winter et al., Proc. Natl. Acad. Sci. USA 82, 7575 (1985)). Figure 4 shows a  
typical protection assay using a c-raf-1 probe. In this  
10 experiment the probe used covered the 3' end of raf-1  
from the 3' most StuI site to the end of the coding  
sequence. The first lane is a marker (pBR322 digested  
with HaeIII), the second shows the probe alone  
undigested, the third lane shows the probe hybridized to  
unrelated RNA in this case tRNA, the fourth lane shows  
15 hybridization with v-raf transformed cells and the lower  
bands represent cleavage at points where the mouse c-raf-1  
gene differs from v-raf. The fifth lane shows  
hybridization with RNA isolated from a normal lung of an  
untreated F1 mouse, the next lanes are RNA isolated from  
20 several tumors. In the case of the normal RNA, only  
one, fully protected, band is detected while in the case  
of the tumors two major bands are seen after digestion.  
20 out of 20 tumors analyzed in this fashion showed this  
extra band. These data demonstrate the following major  
25 points: 1) there is a tumor specific alteration in c-raf-1  
that results in a region of non-homology  
recognizable by either RNase A or T1; 2) The alterations  
are confined to the same region of one allele as two  
bands of equal size are present in the tumor lanes, and;  
30 3) both alleles were expressed at comparable levels as  
both bands are of approximately equal intensity. In the  
assay shown 5 µg of poly(A)+ RNA was hybridized from  
normal tissue, and 1 µg was used from the tumors. This  
was necessary to get signals that could be compared on  
35 the same gel due to the overexpression of c-raf-1 in the  
tumors. By running these assays with various markers it  
was possible to estimate the approximate site of the

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alteration(s) to be in the vicinity of the exon 14/exon 15 junction. In order to define the precise genetic alteration or alterations, PCR primers were designed which would generate a 600 bp fragment encompassing this region. cDNAs from tumor derived RNA were then amplified and cloned into KS+ (Stratagene) for double stranded sequencing. The sequencing results from several tumors are shown in Figure 5. The top portion of Figure 5 presents a cartoon of the mouse Raf-1 protein. There are three conserved regions CR1, CR2 and CR3 with CR3 representing the kinase domain. The probe used in the RNase protection assays covers the indicated area, and the PCR primers amplified the bracketed region. Sequencing through this area revealed a variety of mutations just downstream of the APE site. These mutants are shown in an expanded version at the bottom of Figure 5 (See also SEQ ID NO:1 for normal mouse sequence and SEQ ID NO:2, 3, 4, and 5 for mutant sequences). These mutants were isolated from four separate tumors, and in each case a normal allele (SEQ ID NO:1) was also sequenced. Repeating the cDNA synthesis, PCR amplification, cloning and sequencing gives the same sequence and normal tissue shows no mutations demonstrating that these alterations are not artifactual. Sequence covering the amplified region has been examined and it is interesting that all of these changes occur within a very small region of the raf protein. In fact the region where these mutations occur overlaps an epitope shared by monoclonal antibodies generated against raf (W. Kolch et al., Oncogene 5, 713 (1990)), and computer modeling of the protein shows this to be a hydrophilic domain, the structure of which is predicted to be altered by these mutations. This indicates a biologically important region for the molecule and indeed the first of these mutation tested in NIH3T3 cell assays, after cloning into a retroviral expression vector (E1-neo, (G. Heidecker et al., Mol.

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Cell. Biol. 10, 2503 (1990)), was found to be weakly transforming when driven by a Moloney LTR. The transformation efficiency was comparable to EC2, a previously characterized mutation of human c-raf-1 cDNA (G. Heidecker et al., Mol. Cell. Biol. 10, 2503 (1990); C. Wasylyk et al., Mol. Cell. Biol. 9, 2247 (1989)) and ~20 fold lower than the v-raf oncogene.

\* \* \* \* \*

10 All publications mentioned hereinabove are hereby incorporated in their entirety by reference.

15 While the foregoing invention has been described in some detail for purposes of clarity and understanding, it will be appreciated by one skilled in the art from a reading of this disclosure that various changes in form and detail can be made without departing from the true scope of the invention and appended claims.

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## SEQUENCE LISTING

## (1) GENERAL INFORMATION:

- (i) APPLICANT: Rapp, Ulf R.  
Storm, Stephen M.
- (ii) TITLE OF INVENTION: DETECTION METHOD FOR C-RAF-1 GENES
- (iii) NUMBER OF SEQUENCES: 12
- (iv) CORRESPONDENCE ADDRESS:
  - (A) ADDRESSEE: NEEDLE & ROSENBERG, P.C.
  - (B) STREET: Suite 400, 133 Carnegie Way, N.W.
  - (C) CITY: Atlanta
  - (D) STATE: Georgia
  - (E) COUNTRY: USA
  - (F) ZIP: 30303-1031
- (v) COMPUTER READABLE FORM:
  - (A) MEDIUM TYPE: Floppy disk
  - (B) COMPUTER: IBM PC compatible
  - (C) OPERATING SYSTEM: PC-DOS/MS-DOS
  - (D) SOFTWARE: PatentIn Release #1.0, Version #1.25
- (vi) CURRENT APPLICATION DATA:
  - (A) APPLICATION NUMBER:
  - (B) FILING DATE:
  - (C) CLASSIFICATION:
- (viii) ATTORNEY/AGENT INFORMATION:
  - (A) NAME: Perryman, David G.
  - (B) REGISTRATION NUMBER: 33,438
  - (C) REFERENCE/DOCKET NUMBER: 1414.0421
- (ix) TELECOMMUNICATION INFORMATION:
  - (A) TELEPHONE: (404) 688-0770
  - (B) TELEFAX: (404) 688-9880

## (2) INFORMATION FOR SEQ ID NO:1:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 648 amino acids
  - (B) TYPE: amino acid
  - (D) TOPOLOGY: linear
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:
 

Met	Glu	His	Ile	Gln	Gly	Ala	Trp	Lys	Thr	Ile	Ser	Asn	Gly	Phe	Gly
1				5					10					15	

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Leu Lys Asp Ala Val Phe Asp Gly Ser Ser Cys Ile Ser Pro Thr Ile  
 20 25 30  
 Val Gln Gln Phe Gly Tyr Gln Arg Arg Ala Ser Asp Asp Gly Lys Leu  
 35 40 45  
 Thr Asp Ser Ser Lys Thr Ser Asn Thr Ile Arg Val Phe Leu Pro Asn  
 50 55 60  
 Lys Gln Arg Thr Val Val Asn Val Arg Asn Gly Met Ser Leu His Asp  
 65 70 75 80  
 Cys Leu Met Lys Ala Leu Lys Val Arg Gly Leu Gln Pro Glu Cys Cys  
 85 90 95  
 Ala Val Phe Arg Leu Leu Gln Glu His Lys Gly Lys Lys Ala Arg Leu  
 100 105 110  
 Asp Trp Asn Thr Asp Ala Ala Ser Leu Ile Gly Glu Glu Leu Gln Val  
 115 120 125  
 Asp Phe Leu Asp His Val Pro Ile Thr Thr His Asn Phe Ala Arg Lys  
 130 135 140  
 Thr Phe Leu Lys Leu Ala Phe Cys Asp Ile Cys Gln Lys Phe Leu Leu  
 145 150 155 160  
 Asn Gly Phe Arg Cys Gln Thr Cys Gly Tyr Lys Phe His Glu His Cys  
 165 170 175  
 Ser Thr Lys Val Pro Thr Met Cys Val Asp Trp Ser Asn Ile Arg Gln  
 180 185 190  
 Leu Leu Leu Phe Pro Asn Ser Thr Val Gly Asp Ser Gly Val Pro Ala  
 195 200 205  
 Pro Pro Ser Phe Pro Met Arg Arg Met Arg Glu Ser Val Ser Arg Met  
 210 215 220  
 Pro Ala Ser Ser Gln His Arg Tyr Ser Thr Pro His Ala Phe Thr Phe  
 225 230 235 240  
 Asn Thr Ser Ser Pro Ser Ser Glu Gly Ser Leu Ser Gln Arg Gln Arg  
 245 250 255  
 Ser Thr Ser Thr Pro Asn Val His Met Val Ser Thr Thr Leu His Val  
 260 265 270  
 Asp Ser Arg Met Ile Glu Asp Ala Ile Arg Ser His Ser Glu Ser Ala  
 275 280 285  
 Ser Pro Ser Ala Leu Ser Ser Ser Pro Asn Asn Leu Ser Pro Thr Gly  
 290 295 300

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Trp Ser Gln Pro Lys Thr Pro Val Pro Ala Gln Arg Glu Arg Ala Pro  
 305 310 315 320  
 Gly Ser Gly Thr Gln Gln Lys Asn Lys Ile Arg Pro Arg Gly Gln Arg  
 325 330 335  
 Asp Ser Ser Tyr Tyr Trp Glu Ile Glu Ala Ser Glu Val Met Leu Ser  
 340 345 350  
 Thr Arg Ile Gly Ser Gly Ser Phe Gly Thr Val Tyr Lys Gly Lys Trp  
 355 360 365  
 His Gly Asp Val Ala Val Lys Ile Leu Lys Val Val Asp Pro Thr Pro  
 370 375 380  
 Glu Gln Leu Gln Ala Phe Arg Asn Glu Val Ala Val Leu Arg Lys Thr  
 385 390 395 400  
 Arg His Val Asn Ile Leu Leu Phe Met Gly Tyr Met Thr Lys Asp Asn  
 405 410 415  
 Leu Ala Ile Val Thr Gln Trp Cys Glu Gly Ser Ser Leu Tyr Lys His  
 420 425 430  
 Leu His Val Gln Glu Thr Lys Phe Gln Met Phe Gln Leu Ile Asp Ile  
 435 440 445  
 Ala Arg Gln Thr Ala Gln Gly Met Asp Tyr Leu His Ala Lys Asn Ile  
 450 455 460  
 Ile His Arg Asp Met Lys Ser Asn Asn Ile Phe Leu His Glu Gly Leu  
 465 470 475 480  
 Thr Val Lys Ile Gly Asp Phe Gly Leu Ala Thr Val Lys Ser Arg Trp  
 485 490 495  
 Ser Gly Ser Gln Gln Val Glu Gln Pro Thr Gly Ser Val Leu Trp Met  
 500 505 510  
 Ala Pro Glu Val Ile Arg Met Gln Asp Asp Asn Pro Phe Ser Phe Gln  
 515 520 525  
 Ser Asp Val Tyr Ser Tyr Gly Ile Val Leu Tyr Glu Leu Met Ala Gly  
 530 535 540  
 Glu Leu Pro Tyr Ala His Ile Asn Asn Arg Asp Gln Ile Ile Phe Met  
 545 550 555 560  
 Val Gly Arg Gly Tyr Ala Ser Pro Asp Leu Ser Arg Leu Tyr Lys Asn  
 565 570 575  
 Cys Pro Lys Ala Met Lys Arg Leu Val Ala Asp Cys Val Lys Lys Val  
 580 585 590

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Lys Glu Glu Arg Pro Leu Phe Pro Gln Ile Leu Ser Ser Ile Glu Leu  
                   595                                  600                                  605

Leu Gln His Ser Leu Pro Lys Ile Asn Arg Ser Ala Ser Glu Pro Ser  
       610                                  615                                  620

Leu His Arg Ala Ala His Thr Glu Asp Ile Asn Ala Cys Thr Leu Thr  
   625                                  630                                  635                                  640

Thr Ser Pro Arg Leu Pro Val Phe  
                                   645

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

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 648 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

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

Met Glu His Ile Gln Gly Ala Trp Lys Thr Ile Ser Asn Gly Phe Gly  
   1                                  5                                  10                                  15

Leu Lys Asp Ala Val Phe Asp Gly Ser Ser Cys Ile Ser Pro Thr Ile  
                                   20                                  25                                  30

Val Gln Gln Phe Gly Tyr Gln Arg Arg Ala Ser Asp Asp Gly Lys Leu  
                                   35                                  40                                  45

Thr Asp Ser Ser Lys Thr Ser Asn Thr Ile Arg Val Phe Leu Pro Asn  
   50                                  55                                  60

Lys Gln Arg Thr Val Val Asn Val Arg Asn Gly Met Ser Leu His Asp  
   65                                  70                                  75                                  80

Cys Leu Met Lys Ala Leu Lys Val Arg Gly Leu Gln Pro Glu Cys Cys  
                                   85                                  90                                  95

Ala Val Phe Arg Leu Leu Gln Glu His Lys Gly Lys Lys Ala Arg Leu  
                                   100                                  105                                  110

Asp Trp Asn Thr Asp Ala Ala Ser Leu Ile Gly Glu Glu Leu Gln Val  
                                   115                                  120                                  125

Asp Phe Leu Asp His Val Pro Ile Thr Thr His Asn Phe Ala Arg Lys  
   130                                  135                                  140

Thr Phe Leu Lys Leu Ala Phe Cys Asp Ile Cys Gln Lys Phe Leu Leu  
   145                                  150                                  155                                  160

Asn Gly Phe Arg Cys Gln Thr Cys Gly Tyr Lys Phe His Glu His Cys  
                                   165                                  170                                  175

Ser Thr Lys Val Pro Thr Met Cys Val Asp Trp Ser Asn Ile Arg Gln  
 180 185 190

Leu Leu Leu Phe Pro Asn Ser Thr Val Gly Asp Ser Gly Val Pro Ala  
 195 200 205

Pro Pro Ser Phe Pro Met Arg Arg Met Arg Glu Ser Val Ser Arg Met  
 210 215 220

Pro Ala Ser Ser Gln His Arg Tyr Ser Thr Pro His Ala Phe Thr Phe  
 225 230 235 240

Asn Thr Ser Ser Pro Ser Ser Glu Gly Ser Leu Ser Gln Arg Gln Arg  
 245 250 255

Ser Thr Ser Thr Pro Asn Val His Met Val Ser Thr Thr Leu His Val  
 260 265 270

Asp Ser Arg Met Ile Glu Asp Ala Ile Arg Ser His Ser Glu Ser Ala  
 275 280 285

Ser Pro Ser Ala Leu Ser Ser Ser Pro Asn Asn Leu Ser Pro Thr Gly  
 290 295 300

Trp Ser Gln Pro Lys Thr Pro Val Pro Ala Gln Arg Glu Arg Ala Pro  
 305 310 315 320

Gly Ser Gly Thr Gln Gln Lys Asn Lys Ile Arg Pro Arg Gly Gln Arg  
 325 330 335

Asp Ser Ser Tyr Tyr Trp Glu Ile Glu Ala Ser Glu Val Met Leu Ser  
 340 345 350

Thr Arg Ile Gly Ser Gly Ser Phe Gly Thr Val Tyr Lys Gly Lys Trp  
 355 360 365

His Gly Asp Val Ala Val Lys Ile Leu Lys Val Val Asp Pro Thr Pro  
 370 375 380

Glu Gln Leu Gln Ala Phe Arg Asn Glu Val Ala Val Leu Arg Lys Thr  
 385 390 400

Arg His Val Asn Ile Leu Leu Phe Met Gly Tyr Met Thr Lys Asp Asn  
 405 410 415

Leu Ala Ile Val Thr Gln Trp Cys Glu Gly Ser Ser Leu Tyr Lys His  
 420 425 430

Leu His Val Gln Glu Thr Lys Phe Gln Met Phe Gln Leu Ile Asp Ile  
 435 440 445

Ala Arg Gln Thr Ala Gln Gly Met Asp Tyr Leu His Ala Lys Asn Ile  
 450 455 460

Ile His Arg Asp Met Lys Ser Asn Asn Ile Phe Leu His Glu Gly Leu  
 465 470 475 480

Thr Val Lys Ile Gly Asp Phe Gly Leu Ala Thr Val Lys Ser Arg Trp  
 485 490 495

Ser Gly Ser Gln Gln Val Glu Gln Pro Thr Gly Ser Val Leu Trp Met  
 500 505 510

Ala Pro Glu Val Val Arg Met Gln Asp Asp Asn Pro Phe Ser Phe Gln  
 515 520 525

Ser Asp Val Tyr Ser Tyr Gly Ile Val Leu Tyr Glu Leu Met Ala Gly  
 530 535 540

Glu Leu Pro Tyr Ala His Ile Asn Asn Arg Asp Gln Ile Ile Phe Met  
 545 550 555 560

Val Gly Arg Gly Tyr Ala Ser Pro Asp Leu Ser Arg Leu Tyr Lys Asn  
 565 570 575

Cys Pro Lys Ala Met Lys Arg Leu Val Ala Asp Cys Val Lys Lys Val  
 580 585 590

Lys Glu Glu Arg Pro Leu Phe Pro Gln Ile Leu Ser Ser Ile Glu Leu  
 595 600 605

Leu Gln His Ser Leu Pro Lys Ile Asn Arg Ser Ala Ser Glu Pro Ser  
 610 615 620

Leu His Arg Ala Ala His Thr Glu Asp Ile Asn Ala Cys Thr Leu Thr  
 625 630 635 640

Thr Ser Pro Arg Leu Pro Val Phe  
 645

(2) INFORMATION FOR SEQ ID NO:3:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 648 amino acids
  - (B) TYPE: amino acid
  - (D) TOPOLOGY: linear

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

Met Glu His Ile Gln Gly Ala Trp Lys Thr Ile Ser Asn Gly Phe Gly  
 1 5 10 15

Leu Lys Asp Ala Val Phe Asp Gly Ser Ser Cys Ile Ser Pro Thr Ile  
 20 25 30

Val Gln Gln Phe Gly Tyr Gln Arg Arg Ala Ser Asp Asp Gly Lys Leu  
 35 40 45

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Thr Asp Ser Ser Lys Thr Ser Asn Thr Ile Arg Val Phe Leu Pro Asn  
 50 55 60

Lys Gln Arg Thr Val Val Asn Val Arg Asn Gly Met Ser Leu His Asp  
 65 70 75 80

Cys Leu Met Lys Ala Leu Lys Val Arg Gly Leu Gln Pro Glu Cys Cys  
 85 90 95

Ala Val Phe Arg Leu Leu Gln Glu His Lys Gly Lys Lys Ala Arg Leu  
 100 105 110

Asp Trp Asn Thr Asp Ala Ala Ser Leu Ile Gly Glu Glu Leu Gln Val  
 115 120 125

Asp Phe Leu Asp His Val Pro Ile Thr Thr His Asn Phe Ala Arg Lys  
 130 135 140

Thr Phe Leu Lys Leu Ala Phe Cys Asp Ile Cys Gln Lys Phe Leu Leu  
 145 150 155 160

Asn Gly Phe Arg Cys Gln Thr Cys Gly Tyr Lys Phe His Glu His Cys  
 165 170 175

Ser Thr Lys Val Pro Thr Met Cys Val Asp Trp Ser Asn Ile Arg Gln  
 180 185 190

Leu Leu Leu Phe Pro Asn Ser Thr Val Gly Asp Ser Gly Val Pro Ala  
 195 200 205

Pro Pro Ser Phe Pro Met Arg Arg Met Arg Glu Ser Val Ser Arg Met  
 210 215 220

Pro Ala Ser Ser Gln His Arg Tyr Ser Thr Pro His Ala Phe Thr Phe  
 225 230 235 240

Asn Thr Ser Ser Pro Ser Ser Glu Gly Ser Leu Ser Gln Arg Gln Arg  
 245 250 255

Ser Thr Ser Thr Pro Asn Val His Met Val Ser Thr Thr Leu His Val  
 260 265 270

Asp Ser Arg Met Ile Glu Asp Ala Ile Arg Ser His Ser Glu Ser Ala  
 275 280 285

Ser Pro Ser Ala Leu Ser Ser Ser Pro Asn Asn Leu Ser Pro Thr Gly  
 290 295 300

Trp Ser Gln Pro Lys Thr Pro Val Pro Ala Gln Arg Glu Arg Ala Pro  
 305 310 315 320

Gly Ser Gly Thr Gln Gln Lys Asn Lys Ile Arg Pro Arg Gly Gln Arg  
 325 330 335

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Asp Ser Ser Tyr Tyr Trp Glu Ile Glu Ala Ser Glu Val Met Leu Ser  
 340 345 350

Thr Arg Ile Gly Ser Gly Ser Phe Gly Thr Val Tyr Lys Gly Lys Trp  
 355 360 365

His Gly Asp Val Ala Val Lys Ile Leu Lys Val Val Asp Pro Thr Pro  
 370 375 380

Glu Gln Leu Gln Ala Phe Arg Asn Glu Val Ala Val Leu Arg Lys Thr  
 385 390 395 400

Arg His Val Asn Ile Leu Leu Phe Met Gly Tyr Met Thr Lys Asp Asn  
 405 410 415

Leu Ala Ile Val Thr Gln Trp Cys Glu Gly Ser Ser Leu Tyr Lys His  
 420 425 430

Leu His Val Gln Glu Thr Lys Phe Gln Met Phe Gln Leu Ile Asp Ile  
 435 440 445

Ala Arg Gln Thr Ala Gln Gly Met Asp Tyr Leu His Ala Lys Asn Ile  
 450 455 460

Ile His Arg Asp Met Lys Ser Asn Asn Ile Phe Leu His Glu Gly Leu  
 465 470 475 480

Thr Val Lys Ile Gly Asp Phe Gly Leu Ala Thr Val Lys Ser Arg Trp  
 485 490 495

Ser Gly Ser Gln Gln Val Glu Gln Pro Thr Gly Ser Val Leu Trp Met  
 500 505 510

Ala Pro Glu Val Ile Arg Met Gln Asp Asn Asn Pro Phe Ser Phe Gln  
 515 520 525

Ser Asp Val Tyr Ser Tyr Gly Ile Val Leu Tyr Glu Leu Met Ala Gly  
 530 535 540

Glu Leu Pro Tyr Ala His Ile Asn Asn Arg Asp Gln Ile Ile Phe Met  
 545 550 555 560

Val Gly Arg Gly Tyr Ala Ser Pro Asp Leu Ser Arg Leu Tyr Lys Asn  
 565 570 575

Cys Pro Lys Ala Met Lys Arg Leu Val Ala Asp Cys Val Lys Lys Val  
 580 585 590

Lys Glu Glu Arg Pro Leu Phe Pro Gln Ile Leu Ser Ser Ile Glu Leu  
 595 600 605

Leu Gln His Ser Leu Pro Lys Ile Asn Arg Ser Ala Ser Glu Pro Ser  
 610 615 620

Leu His Arg Ala Ala His Thr Glu Asp Ile Asn Ala Cys Thr Leu Thr  
 625 630 635 640

Thr Ser Pro Arg Leu Pro Val Phe  
 645

(2) INFORMATION FOR SEQ ID NO:4:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 648 amino acids
  - (B) TYPE: amino acid
  - (D) TOPOLOGY: linear

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

Met Glu His Ile Gln Gly Ala Trp Lys Thr Ile Ser Asn Gly Phe Gly  
 1 5 10 15  
 Leu Lys Asp Ala Val Phe Asp Gly Ser Ser Cys Ile Ser Pro Thr Ile  
 20 25 30  
 Val Gln Gln Phe Gly Tyr Gln Arg Arg Ala Ser Asp Asp Gly Lys Leu  
 35 40 45  
 Thr Asp Ser Ser Lys Thr Ser Asn Thr Ile Arg Val Phe Leu Pro Asn  
 50 55 60  
 Lys Gln Arg Thr Val Val Asn Val Arg Asn Gly Met Ser Leu His Asp  
 65 70 75 80  
 Cys Leu Met Lys Ala Leu Lys Val Arg Gly Leu Gln Pro Glu Cys Cys  
 85 90 95  
 Ala Val Phe Arg Leu Leu Gln Glu His Lys Gly Lys Lys Ala Arg Leu  
 100 105 110  
 Asp Trp Asn Thr Asp Ala Ala Ser Leu Ile Gly Glu Glu Leu Gln Val  
 115 120 125  
 Asp Phe Leu Asp His Val Pro Ile Thr Thr His Asn Phe Ala Arg Lys  
 130 135 140  
 Thr Phe Leu Lys Leu Ala Phe Cys Asp Ile Cys Gln Lys Phe Leu Leu  
 145 150 155 160  
 Asn Gly Phe Arg Cys Gln Thr Cys Gly Tyr Lys Phe His Glu His Cys  
 165 170 175  
 Ser Thr Lys Val Pro Thr Met Cys Val Asp Trp Ser Asn Ile Arg Gln  
 180 185 190  
 Leu Leu Leu Phe Pro Asn Ser Thr Val Gly Asp Ser Gly Val Pro Ala  
 195 200 205

Pro Pro Ser Phe Pro Met Arg Arg Met Arg Glu Ser Val Ser Arg Met  
 210 215 220

Pro Ala Ser Ser Gln His Arg Tyr Ser Thr Pro His Ala Phe Thr Phe  
 225 230 235 240

Asn Thr Ser Ser Pro Ser Ser Glu Gly Ser Leu Ser Gln Arg Gln Arg  
 245 250 255

Ser Thr Ser Thr Pro Asn Val His Met Val Ser Thr Thr Leu His Val  
 260 265 270

Asp Ser Arg Met Ile Glu Asp Ala Ile Arg Ser His Ser Glu Ser Ala  
 275 280 285

Ser Pro Ser Ala Leu Ser Ser Ser Pro Asn Asn Leu Ser Pro Thr Gly  
 290 295 300

Trp Ser Gln Pro Lys Thr Pro Val Pro Ala Gln Arg Glu Arg Ala Pro  
 305 310 315 320

Gly Ser Gly Thr Gln Gln Lys Asn Lys Ile Arg Pro Arg Gly Gln Arg  
 325 330 335

Asp Ser Ser Tyr Tyr Trp Glu Ile Glu Ala Ser Glu Val Met Leu Ser  
 340 345 350

Thr Arg Ile Gly Ser Gly Ser Phe Gly Thr Val Tyr Lys Gly Lys Trp  
 355 360 365

His Gly Asp Val Ala Val Lys Ile Leu Lys Val Val Asp Pro Thr Pro  
 370 375 380

Glu Gln Leu Gln Ala Phe Arg Asn Glu Val Ala Val Leu Arg Lys Thr  
 385 390 395 400

Arg His Val Asn Ile Leu Leu Phe Met Gly Tyr Met Thr Lys Asp Asn  
 405 410 415

Leu Ala Ile Val Thr Gln Trp Cys Glu Gly Ser Ser Leu Tyr Lys His  
 420 425 430

Leu His Val Gln Glu Thr Lys Phe Gln Met Phe Gln Leu Ile Asp Ile  
 435 440 445

Ala Arg Gln Thr Ala Gln Gly Met Asp Tyr Leu His Ala Lys Asn Ile  
 450 455 460

Ile His Arg Asp Met Lys Ser Asn Asn Ile Phe Leu His Glu Gly Leu  
 465 470 475 480

Thr Val Lys Ile Gly Asp Phe Gly Leu Ala Thr Val Lys Ser Arg Trp  
 485 490 495

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Ser Gly Ser Gln Gln Val Glu Gln Pro Thr Gly Ser Val Leu Trp Met  
 500 505 510

Ala Pro Glu Val Ile Arg Met Gln Asp Asp Asn Pro Phe Ser Ser Gln  
 515 520 525

Ser Asp Val Tyr Ser Tyr Gly Ile Val Leu Tyr Glu Leu Met Ala Gly  
 530 535 540

Glu Leu Pro Tyr Ala His Ile Asn Asn Arg Asp Gln Ile Ile Phe Met  
 545 550 555 560

Val Gly Arg Gly Tyr Ala Ser Pro Asp Leu Ser Arg Leu Tyr Lys Asn  
 565 570 575

Cys Pro Lys Ala Met Lys Arg Leu Val Ala Asp Cys Val Lys Lys Val  
 580 585 590

Lys Glu Glu Arg Pro Leu Phe Pro Gln Ile Leu Ser Ser Ile Glu Leu  
 595 600 605

Leu Gln His Ser Leu Pro Lys Ile Asn Arg Ser Ala Ser Glu Pro Ser  
 610 615 620

Leu His Arg Ala Ala His Thr Glu Asp Ile Asn Ala Cys Thr Leu Thr  
 625 630 635 640

Thr Ser Pro Arg Leu Pro Val Phe  
 645

(2) INFORMATION FOR SEQ ID NO:5:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 648 amino acids
  - (B) TYPE: amino acid
  - (D) TOPOLOGY: linear

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

Met Glu His Ile Gln Gly Ala Trp Lys Thr Ile Ser Asn Gly Phe Gly  
 1 5 10 15

Leu Lys Asp Ala Val Phe Asp Gly Ser Ser Cys Ile Ser Pro Thr Ile  
 20 25 30

Val Gln Gln Phe Gly Tyr Gln Arg Arg Ala Ser Asp Asp Gly Lys Leu  
 35 40 45

Thr Asp Ser Ser Lys Thr Ser Asn Thr Ile Arg Val Phe Leu Pro Asn  
 50 55 60

Lys Gln Arg Thr Val Val Asn Val Arg Asn Gly Met Ser Leu His Asp  
 65 70 75 80



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His Gly Asp Val Ala Val Lys Ile Leu Lys Val Val Asp Pro Thr Pro  
 370 375 380

Glu Gln Leu Gln Ala Phe Arg Asn Glu Val Ala Val Leu Arg Lys Thr  
 385 390 395 400

Arg His Val Asn Ile Leu Leu Phe Met Gly Tyr Met Thr Lys Asp Asn  
 405 410 415

Leu Ala Ile Val Thr Gln Trp Cys Glu Gly Ser Ser Leu Tyr Lys His  
 420 425 430

Leu His Val Gln Glu Thr Lys Phe Gln Met Phe Gln Leu Ile Asp Ile  
 435 440 445

Ala Arg Gln Thr Ala Gln Gly Met Asp Tyr Leu His Ala Lys Asn Ile  
 450 455 460

Ile His Arg Asp Met Lys Ser Asn Asn Ile Phe Leu His Glu Gly Leu  
 465 470 475 480

Thr Val Lys Ile Gly Asp Phe Gly Leu Ala Thr Val Lys Ser Arg Trp  
 485 490 495

Ser Gly Ser Gln Gln Val Glu Gln Pro Thr Gly Ser Val Leu Trp Met  
 500 505 510

Ala Pro Glu Val Ile Arg Met Gln Asp Asp Asn Pro Phe Ser Phe Gln  
 515 520 525

Ser Thr Cys Thr Phe Tyr Gly Ile Val Leu Tyr Glu Leu Met Ala Gly  
 530 535 540

Glu Leu Pro Tyr Ala His Ile Asn Asn Arg Asp Gln Ile Ile Phe Met  
 545 550 555 560

Val Gly Arg Gly Tyr Ala Ser Pro Asp Leu Ser Arg Leu Tyr Lys Asn  
 565 570 575

Cys Pro Lys Ala Met Lys Arg Leu Val Ala Asp Cys Val Lys Lys Val  
 580 585 590

Lys Glu Glu Arg Pro Leu Phe Pro Gln Ile Leu Ser Ser Ile Glu Leu  
 595 600 605

Leu Gln His Ser Leu Pro Lys Ile Asn Arg Ser Ala Ser Glu Pro Ser  
 610 615 620

Leu His Arg Ala Ala His Thr Glu Asp Ile Asn Ala Cys Thr Leu Thr  
 625 630 635 640

Thr Ser Pro Arg Leu Pro Val Phe  
 645

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## (2) INFORMATION FOR SEQ ID NO:6:

- (i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 20 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear

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

AACTTGTGGT GGTGGACCT 20

## (2) INFORMATION FOR SEQ ID NO:7:

- (i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 20 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear

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

TCATCCACAA AGTGATTCTG 20

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

- (i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 20 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear

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

AGGAGACCAA GTTTCAGATG 20

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

- (i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 20 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear

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

GCGTGCAAGC ATTGATATCC 20

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

- (i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 1947 base pairs

-34-

(B) TYPE: nucleic acid  
 (C) STRANDEDNESS: double  
 (D) TOPOLOGY: linear

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

ATGGAGCACA	TACAGGGAGC	TTGGAAGACG	ATCAGCAATG	GCTTTGGACT	CAAAGATGCG	60
GTGTTTGATG	GCTCCAGCTG	CATCTCCCCT	ACCATTGTTC	AGCAGTTTGG	CTATCAGCGC	120
CGGGCCTCAG	ATGATGGCAA	GCTCACGGAT	TCTTCTAAGA	CAAGCAATAC	TATCCGGGTT	180
TTCTTGCCGA	ATAAGCAAAG	GACTGTGGTC	AATGTGCCGA	ATGGAATGAG	CTTACATGAC	240
TGCCTTATGA	AAGCTCTGAA	GGTGAGAGGC	CTGCAGCCAG	AGTGCTGTGC	AGTGTTCAGA	300
CTTCTCCAGG	AACACAAAGG	TAAGAAAGCA	CGCTTAGATT	GGAACACCGA	TGCCGCCTCT	360
CTGATTGGAG	AAGAACTGCA	AGTGGATTTT	TTGGATCATG	TTCCCATCAC	AACTCACAAC	420
TTTGCTCGGA	AAACGTTCTT	GAAGCTTGCA	TTCTGTGACA	TCTGTCAGAA	GTTCTGCTA	480
AATGGATTTT	GATGTCAGAC	TTGTGGCTAC	AAGTTTCATG	AGCACTGTAG	CACCAAAGTA	540
CCTACTATGT	GTGTGGACTG	GAGTAATATC	AGACAGCTCT	TGCTGTTTCC	AAATTCCACT	600
GTTGGTGACA	GTGGAGTCCC	AGCACCACCT	TCTTTCCCAA	TGCGTCGGAT	GCGAGAATCT	660
GTTTCCCGGA	TGCCTGCTAG	TTCCACGAC	AGATACTCTA	CACCCCATGC	CTTCACTTTC	720
AACACCTCCA	GCCCTTCTC	AGAAGTTCC	CTCTCCAGA	GGCAGAGGTC	AACGTCCACT	780
CCCAATGTCC	ACATGGTCAG	CACCACCCTG	CATGTGGACA	GCAGGATGAT	TGAGGATGCA	840
ATTCGAAGTC	ACAGTGAATC	AGCCTCACCT	TCAGCCCTGT	CCAGCAGCCC	AAACAACCTG	900
GGTCCAACAG	GCTGGTCACA	GCCCAAACC	CCCGTGCCAG	CACAAAGAGA	GCGGGCACCA	960
GGATCTGGGA	CCCAGCAAAA	AAACAAAATT	AGGCCTCGTG	GGCAGAGAGA	CTCGAGTTAT	1020
TACTGGGAAA	TAGAAGCCAG	TGAGGTGATG	CTGTCTACTC	GGATCGGGTC	AGGTTCTTTT	1080
GGCACTGTGT	ACAAGGGCAA	GTGGCATGGA	GATGTTGCAG	TAAAGATCCT	AAAGGTGGTT	1140
GACCCAATC	CAGAGCAACT	TCAGGCCTTC	AGGAACGAGG	TGGCTGTTTT	GCGCAAAACA	1200
CGGCATGTTA	ACATCCTGCT	GTTTATGGGG	TACATGACAA	AGGACAACCT	GGCGATTGTG	1260
ACTCAGTGGT	GTGAAGGCAG	CAGTCTCTAC	AAACACCTGC	ATGTCCAGGA	GACCAAATTC	1320
CAGATGTTCC	AGCTAATTGA	CATTGCCCGA	CAGACAGCTC	AGGGAATGGA	CTATTTGCAT	1380
GCAAAGAACA	TCATCCACAG	AGACATGAAA	TCCAACAATA	TATTTCTCCA	TGAAGGCCTC	1440
ACGGTGAAAA	TTGGAGATTT	TGGTTTGGCA	ACAGTGAAGT	CACGCTGGAG	TGGTTCTCAG	1500
CAGGTTGAAC	AGCCCACTGG	CTCTGTGCTG	TGGATGGCCC	CAGAAGTAAT	CCGGATGCAG	1560

-35-

GATGACAACC CGTTCAGCTT CCAGTCCGAC GTGTACTCGT ACGGCATCGT GCTGTACGAG 1620  
 CTGATGGCTG GGGAGCTTCC CTACGCCAC ATCAACAACC GAGACCAGAT CATCTTCATG 1680  
 GTAGGCCGTG GGTATGCATC CCCTGATCTC AGCAGGCTCT ACAAGAACTG CCCCAAGGCA 1740  
 ATGAAGAGGT TGGTGGCTGA CTGTGTGAAG AAAGTCAAAG AAGAGAGACC TTTGTTTCCC 1800  
 CAGATCCTGT CTTCCATCGA GCTGCTTCA GACTCTCTGC CGAAAATCAA CAGGAGCGCC 1860  
 TCTGAGCCTT CCCTGCATCG GGCAGCTCAC ACTGAGGACA TCAATGCTTG CACGCTGACT 1920  
 ACATCCCCAA GGCTACCAGT CTTCTAG 1947

## (2) INFORMATION FOR SEQ ID NO:11:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1947 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

## (ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 1..1944

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:11:

ATG GAG CAC ATA CAG GGA GCT TGG AAG ACG ATC AGC AAT GGT TTT GGA 48  
 Met Glu His Ile Gln Gly Ala Trp Lys Thr Ile Ser Asn Gly Phe Gly  
 1 5 10 15  
 TTC AAA GAT GCC GTG TTT GAT GGC TCC AGC TGC ATC TCT CCT ACA ATA 96  
 Phe Lys Asp Ala Val Phe Asp Gly Ser Ser Cys Ile Ser Pro Thr Ile  
 20 25 30  
 GTT CAG CAG TTT GGC TAT CAG CGC CGG GCA TCA GAT GAT GGC AAA CTC 144  
 Val Gln Gln Phe Gly Tyr Gln Arg Arg Ala Ser Asp Asp Gly Lys Leu  
 35 40 45  
 ACA GAT CCT TCT AAG ACA AGC AAC ACT ATC CGT GTT TTC TTG CCG AAC 192  
 Thr Asp Pro Ser Lys Thr Ser Asn Thr Ile Arg Val Phe Leu Pro Asn  
 50 55 60  
 AAG CAA AGA ACA GTG GTC AAT GTG CGA AAT GGA ATG AGC TTG CAT GAC 240  
 Lys Gln Arg Thr Val Val Asn Val Arg Asn Gly Met Ser Leu His Asp  
 65 70 75 80

-36-

TGC CTT ATG AAA GCA CTC AAG GTG AGG GGC CTG CAA CCA GAG TGC TGT 288  
 Cys Leu Met Lys Ala Leu Lys Val Arg Gly Leu Gln Pro Glu Cys Cys  
                   85                                  90                                  95

GCA GTG TTC AGA CTT CTC CAC GAA CAC AAA GGT AAA AAA GCA CGC TTA 336  
 Ala Val Phe Arg Leu Leu His Glu His Lys Gly Lys Lys Ala Arg Leu  
                   100                                  105                                  110

GAT TGG AAT ACT GAT GCT GCG TCT TTG ATT GGA GAA GAA CTT CAA GTA 384  
 Asp Trp Asn Thr Asp Ala Ala Ser Leu Ile Gly Glu Glu Leu Gln Val  
                   115                                  120                                  125

GAT TTC CTG GAT CAT GTT CCC CTC ACA ACA CAC AAC TTT GCT CGG AAG 432  
 Asp Phe Leu Asp His Val Pro Leu Thr Thr His Asn Phe Ala Arg Lys  
                   130                                  135                                  140

ACG TTC CTG AAG CTT GCC TTC TGT GAC ATC TGT CAG AAA TTC CTG CTC 480  
 Thr Phe Leu Lys Leu Ala Phe Cys Asp Ile Cys Gln Lys Phe Leu Leu  
                   145                                  150                                  155                                  160

AAT GGA TTT CGA TGT CAG ACT TGT GGC TAC AAA TTT CAT GAG CAC TGT 528  
 Asn Gly Phe Arg Cys Gln Thr Cys Gly Tyr Lys Phe His Glu His Cys  
                   165                                  170                                  175

AGC ACC AAA GTA CCT ACT ATG TGT GTG GAC TGG AGT AAC ATC AGA CAA 576  
 Ser Thr Lys Val Pro Thr Met Cys Val Asp Trp Ser Asn Ile Arg Gln  
                   180                                  185                                  190

CTC TTA TTG TTT CCA AAT TCC ACT ATT GGT GAT AGT GGA GTC CCA GCA 624  
 Leu Leu Leu Phe Pro Asn Ser Thr Ile Gly Asp Ser Gly Val Pro Ala  
                   195                                  200                                  205

CTA CCT TCT TTG ACT ATG CGT CGT ATG CGA GAG TCT GTT TCC AGG ATG 672  
 Leu Pro Ser Leu Thr Met Arg Arg Met Arg Glu Ser Val Ser Arg Met  
                   210                                  215                                  220

CCT GTT AGT TCT CAG CAC AGA TAT TCT ACA CCT CAC GCC TTC ACC TTT 720  
 Pro Val Ser Ser Gln His Arg Tyr Ser Thr Pro His Ala Phe Thr Phe  
                   225                                  230                                  235                                  240

AAC ACC TCC AGT CCC TCA TCT GAA GGT TCC CTC TCC CAG AGG CAG AGG 768  
 Asn Thr Ser Ser Pro Ser Ser Glu Gly Ser Leu Ser Gln Arg Gln Arg  
                   245                                  250                                  255

TCG ACA TCC ACA CCT AAT GTC CAC ATG GTC AGC ACC ACG CTG CCT GTG 816

-37-

Ser Thr Ser Thr Pro Asn Val His Met Val Ser Thr Thr Leu Pro Val  
 260 265 270  
 GAC AGC AGG ATG ATT GAG GAT GCA ATT CGA AGT CAC AGC GAA TCA GCC 864  
 Asp Ser Arg Met Ile Glu Asp Ala Ile Arg Ser His Ser Glu Ser Ala  
 275 280 285  
 TCA CCT TCA GCC CTG TCC AGT AGC CCC AAC AAT CTG AGC CCA ACA GGC 912  
 Ser Pro Ser Ala Leu Ser Ser Ser Pro Asn Asn Leu Ser Pro Thr Gly  
 290 295 300  
 TGG TCA CAG CCG AAA ACC CCC GTG CCA GCA CAA AGA GAG CGG GCA CCA 960  
 Trp Ser Gln Pro Lys Thr Pro Val Pro Ala Gln Arg Glu Arg Ala Pro  
 305 310 315 320  
 GTA TCT GGG ACC CAG GAG AAA AAC AAA ATT AGG CCT CGT GGA CAG AGA 1008  
 Val Ser Gly Thr Gln Glu Lys Asn Lys Ile Arg Pro Arg Gly Gln Arg  
 325 330 335  
 GAT TCA AGC TAT TAT TGG GAA ATA GAA GCC AGT GAA GTG ATG CTG TCC 1056  
 Asp Ser Ser Tyr Tyr Trp Glu Ile Glu Ala Ser Glu Val Met Leu Ser  
 340 345 350  
 ACT CGG ATT GGG TCA GGC TCT TTT GGA ACT GTT TAT AAG GGT AAA TGG 1104  
 Thr Arg Ile Gly Ser Gly Ser Phe Gly Thr Val Tyr Lys Gly Lys Trp  
 355 360 365  
 CAC GGA GAT GTT GCA GTA AAG ATC CTA AAG GTT GTC GAC CCA ACC CCA 1152  
 His Gly Asp Val Ala Val Lys Ile Leu Lys Val Val Asp Pro Thr Pro  
 370 375 380  
 GAG CAA TTC CAG GCC TTC AGG AAT GAG GTG GCT GTT CTG CGC AAA ACA 1200  
 Glu Gln Phe Gln Ala Phe Arg Asn Glu Val Ala Val Leu Arg Lys Thr  
 385 390 395 400  
 CGG CAT GTG AAC ATT CTG CTT TTC ATG GGG TAC ATG ACA AAG GAC AAC 1248  
 Arg His Val Asn Ile Leu Leu Phe Met Gly Tyr Met Thr Lys Asp Asn  
 405 410 415  
 CTG GCA ATT GTG ACC CAG TGG TGC GAG GGC AGC AGC CTC TAC AAA CAC 1296  
 Leu Ala Ile Val Thr Gln Trp Cys Glu Gly Ser Ser Leu Tyr Lys His  
 420 425 430  
 CTG CAT GTC CAG GAG ACC AAG TTT CAG ATG TTC CAG CTA ATT GAC ATT 1344

-38-

Leu His Val Gln Glu Thr Lys Phe Gln Met Phe Gln Leu Ile Asp Ile  
 435 440 445  
 GCC CGG CAG ACG GCT CAG GGA ATG GAC TAT TTG CAT GCA AAG AAC ATC 1392  
 Ala Arg Gln Thr Ala Gln Gly Met Asp Tyr Leu His Ala Lys Asn Ile  
 450 455 460  
 ATC CAT AGA GAC ATG AAA TCC AAC AAT ATA TTT CTC CAT GAA GGC TTA 1440  
 Ile His Arg Asp Met Lys Ser Asn Asn Ile Phe Leu His Glu Gly Leu  
 465 470 475 480  
 ACA GTG AAA ATT GGA GAT TTT GGT TTG GCA ACA GTA AAG TCA CGC TGG 1488  
 Thr Val Lys Ile Gly Asp Phe Gly Leu Ala Thr Val Lys Ser Arg Trp  
 485 490 495  
 AGT GGT TCT CAG CAG GTT GAA CAA CCT ACT GGC TCT GTC CTC TGG ATG 1536  
 Ser Gly Ser Gln Gln Val Glu Gln Pro Thr Gly Ser Val Leu Trp Met  
 500 505 510  
 GCC CCA GAG GTG ATC CGA ATG CAG GAT AAC AAC CCA TTC AGT TTC CAG 1584  
 Ala Pro Glu Val Ile Arg Met Gln Asp Asn Asn Pro Phe Ser Phe Gln  
 515 520 525  
 TCG GAT GTC TAC TCC TAT GGC ATC GTA TTG TAT GAA CTG ATG ACG GGG 1632  
 Ser Asp Val Tyr Ser Tyr Gly Ile Val Leu Tyr Glu Leu Met Thr Gly  
 530 535 540  
 GAG CTT CCT TAT TCT CAC ATC AAC AAC CGA GAT CAG ATC ATC TTC ATG 1680  
 Glu Leu Pro Tyr Ser His Ile Asn Asn Arg Asp Gln Ile Ile Phe Met  
 545 550 555 560  
 GTG GGC CGA GGA TAT GCC TCC CCA GAT CTT AGT AAG CTA TAT AAG AAC 1728  
 Val Gly Arg Gly Tyr Ala Ser Pro Asp Leu Ser Lys Leu Tyr Lys Asn  
 565 570 575  
 TGC CCC AAA GCA ATG AAG AGG CTG GTA GCT GAC TGT GTG AAG AAA GTA 1776  
 Cys Pro Lys Ala Met Lys Arg Leu Val Ala Asp Cys Val Lys Lys Val  
 580 585 590  
 AAG GAA GAG AGG CCT CTT TTT CCC CAG ATC CTG TCT TCC ATT GAG CTG 1824  
 Lys Glu Glu Arg Pro Leu Phe Pro Gln Ile Leu Ser Ser Ile Glu Leu  
 595 600 605  
 CTC CAA CAC TCT CTA CCG AAG ATC AAC CGG AGC GCT TCC GAG CCA TCC 1872  
 Leu Gln His Ser Leu Pro Lys Ile Asn Arg Ser Ala Ser Glu Pro Ser



Ser Thr Lys Val Pro Thr Met Cys Val Asp Trp Ser Asn Ile Arg Gln  
 180 185 190

Leu Leu Leu Phe Pro Asn Ser Thr Ile Gly Asp Ser Gly Val Pro Ala  
 195 200 205

Leu Pro Ser Leu Thr Met Arg Arg Met Arg Glu Ser Val Ser Arg Met  
 210 215 220

Pro Val Ser Ser Gln His Arg Tyr Ser Thr Pro His Ala Phe Thr Phe  
 225 230 235 240

Asn Thr Ser Ser Pro Ser Ser Glu Gly Ser Leu Ser Gln Arg Gln Arg  
 245 250 255

Ser Thr Ser Thr Pro Asn Val His Met Val Ser Thr Thr Leu Pro Val  
 260 265 270

Asp Ser Arg Met Ile Glu Asp Ala Ile Arg Ser His Ser Glu Ser Ala  
 275 280 285

Ser Pro Ser Ala Leu Ser Ser Ser Pro Asn Asn Leu Ser Pro Thr Gly  
 290 295 300

Trp Ser Gln Pro Lys Thr Pro Val Pro Ala Gln Arg Glu Arg Ala Pro  
 305 310 315 320

Val Ser Gly Thr Gln Glu Lys Asn Lys Ile Arg Pro Arg Gly Gln Arg  
 325 330 335

Asp Ser Ser Tyr Tyr Trp Glu Ile Glu Ala Ser Glu Val Met Leu Ser  
 340 345 350

Thr Arg Ile Gly Ser Gly Ser Phe Gly Thr Val Tyr Lys Gly Lys Trp  
 355 360 365

His Gly Asp Val Ala Val Lys Ile Leu Lys Val Val Asp Pro Thr Pro  
 370 375 380

Glu Gln Phe Gln Ala Phe Arg Asn Glu Val Ala Val Leu Arg Lys Thr  
 385 390 395 400

Arg His Val Asn Ile Leu Leu Phe Met Gly Tyr Met Thr Lys Asp Asn  
 405 410 415

Leu Ala Ile Val Thr Gln Trp Cys Glu Gly Ser Ser Leu Tyr Lys His  
 420 425 430

Leu His Val Gln Glu Thr Lys Phe Gln Met Phe Gln Leu Ile Asp Ile  
 435 440 445

Ala Arg Gln Thr Ala Gln Gly Met Asp Tyr Leu His Ala Lys Asn Ile  
 450 455 460

-41-

Ile His Arg Asp Met Lys Ser Asn Asn Ile Phe Leu His Glu Gly Leu  
 465 470 475 480  
 Thr Val Lys Ile Gly Asp Phe Gly Leu Ala Thr Val Lys Ser Arg Trp  
 485 490 495  
 Ser Gly Ser Gln Gln Val Glu Gln Pro Thr Gly Ser Val Leu Trp Met  
 500 505 510  
 Ala Pro Glu Val Ile Arg Met Gln Asp Asn Asn Pro Phe Ser Phe Gln  
 515 520 525  
 Ser Asp Val Tyr Ser Tyr Gly Ile Val Leu Tyr Glu Leu Met Thr Gly  
 530 535 540  
 Glu Leu Pro Tyr Ser His Ile Asn Asn Arg Asp Gln Ile Ile Phe Met  
 545 550 555 560  
 Val Gly Arg Gly Tyr Ala Ser Pro Asp Leu Ser Lys Leu Tyr Lys Asn  
 565 570 575  
 Cys Pro Lys Ala Met Lys Arg Leu Val Ala Asp Cys Val Lys Lys Val  
 580 585 590  
 Lys Glu Glu Arg Pro Leu Phe Pro Gln Ile Leu Ser Ser Ile Glu Leu  
 595 600 605  
 Leu Gln His Ser Leu Pro Lys Ile Asn Arg Ser Ala Ser Glu Pro Ser  
 610 615 620  
 Leu His Arg Ala Ala His Thr Glu Asp Ile Asn Ala Cys Thr Leu Thr  
 625 630 635 640  
 Thr Ser Pro Arg Leu Pro Val Phe  
 645

-42-

WHAT IS CLAIMED IS:

1. A method of identifying an individual at an increased risk for developing cancer, comprising:  
amplifying a region of the c-raf-1 gene of said individual;  
analyzing products of said amplification for evidence of mutation; and  
classifying an individual having one or more mutations in said region as having an increased risk for developing cancer.
2. The method according to claim 1, wherein said region encodes at least amino acids 514 to 535 of SEQ ID NO:12.
3. The method according to claim 2, wherein said region encodes at least amino acids 500 to 550 of SEQ ID NO:12.
4. The method according to claim 3, wherein said region encodes at least amino acids 450 to 630 of SEQ ID NO:12.
5. The method according to claim 1, wherein said products are analyzed by DNA sequencing.
6. The method according to claim 1, wherein said amplification is effected using a polymerase chain reaction (PCR).
7. The method according to claim 6, wherein said PCR employs a primer comprising SEQ ID NO:7 and a primer comprising SEQ ID NO:8.
8. A method for determining a prognosis in patients afflicted with cancer, comprising:

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amplifying a region of the c-raf-1 gene of said individual;

analyzing products of said amplification for evidence of mutation; and

classifying a patient having no mutation in said region as being less likely to suffer disease relapse or having an increased chance of survival than a patient having one or more mutations in said region.

9. The method according to claim 8, wherein said region encodes at least amino acids 514 to 535 of SEQ ID NO:12.

10. The method according to claim 9, wherein said region encodes at least amino acids 500 to 550 of SEQ ID NO:12.

11. The method according to claim 10, wherein said region encodes at least amino acids 450 to 630 of SEQ ID NO:12.

12. The method according to claim 9, wherein said products are analyzed by DNA sequencing.

13. The method according to claim 9, wherein said amplification is effected using polymerase chain reaction (PCR).

14. The method according to claim 13, wherein said PCR employs a primer comprising SEQ ID NO:7 and a primer comprising SEQ ID NO:8.

15. A method for determining the proper course of treatment for a patient afflicted with cancer, comprising:

amplifying a region of the c-raf-1 gene of said patient;

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analyzing products of said amplification for evidence of mutation;

identifying a patient having at least one mutation in said region, which patient may require treatment proper for a patient having a lesser chance of survival or decreased time to relapse; and

identifying a patient lacking mutations in said region, which patient may require treatment proper for a patient having a greater chance of survival or being less likely to suffer disease relapse.

16. The method according to claim 15, wherein said region encodes at least amino acids 514 to 535 of SEQ ID NO:12.

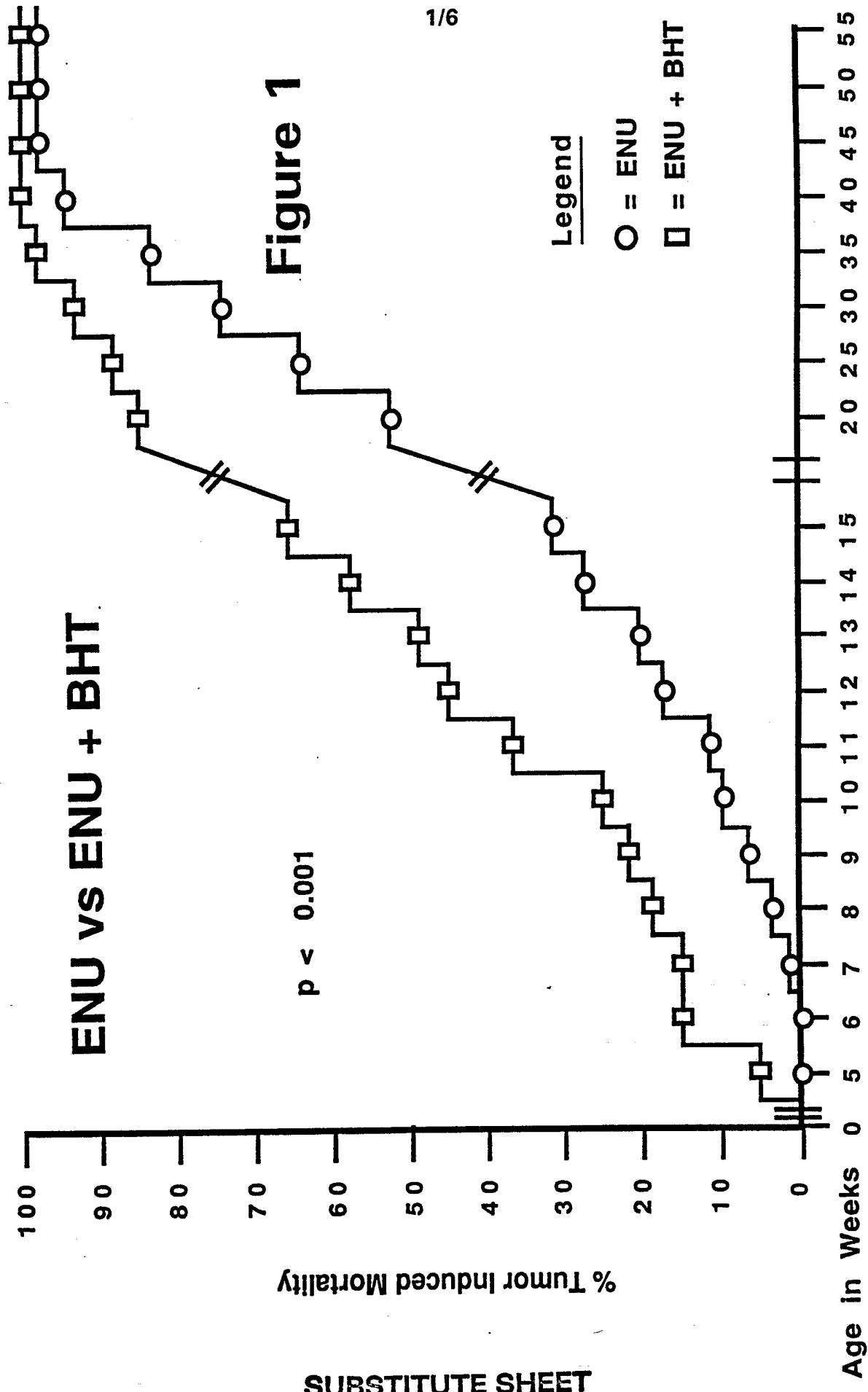
17. The method according to claim 16, wherein said region encodes at least amino acids 500 to 550 of SEQ ID NO:12.

18. The method according to claim 17, wherein said region encodes at least amino acids 450 to 630 of SEQ ID NO:12.

19. The method according to claim 16, wherein said products are analyzed by DNA sequencing.

20. The method according to claim 16, wherein said amplification is effected using a polymerase chain reaction (PCR).

21. The method according to claim 20, wherein said PCR employs a primer comprising SEQ ID NO:7 and a primer comprising SEQ ID NO:8.



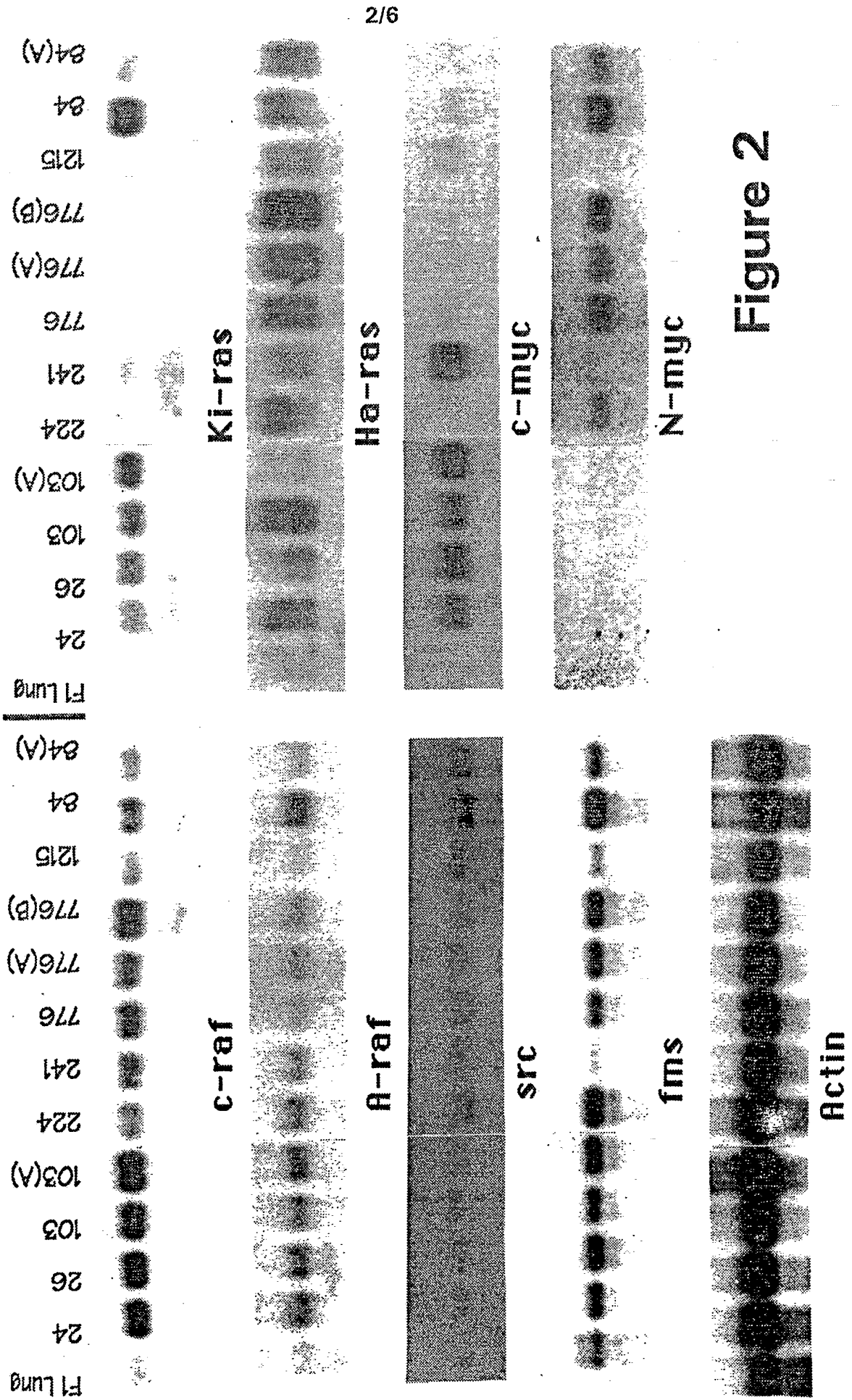
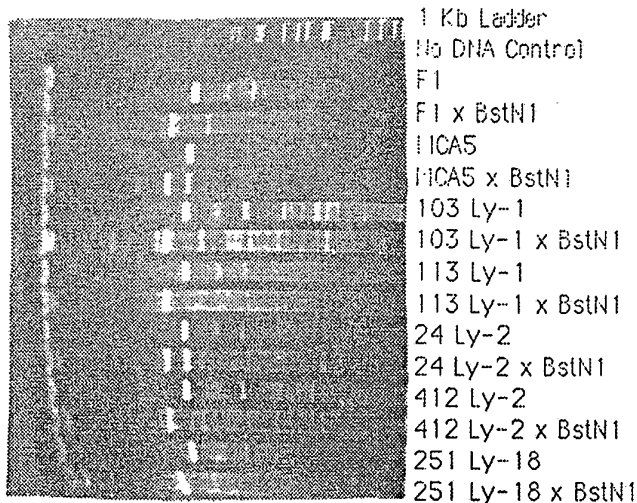
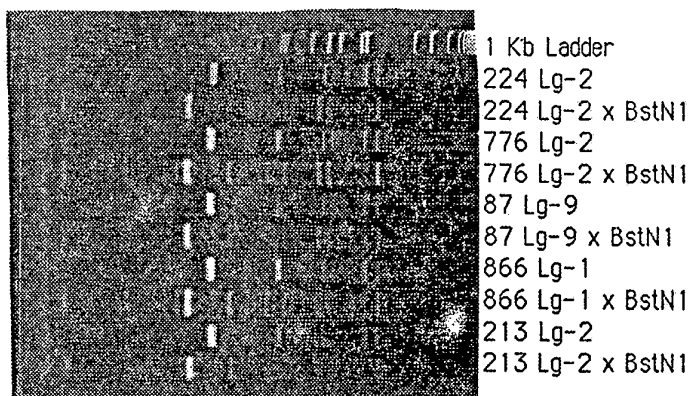


Figure 2

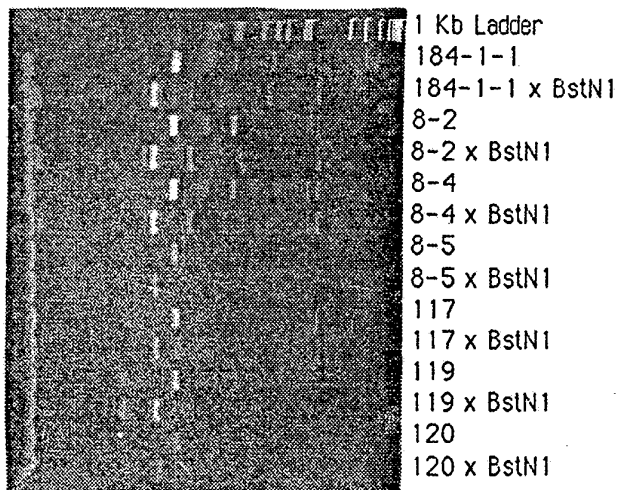
# Figure 3



## Lymphomas

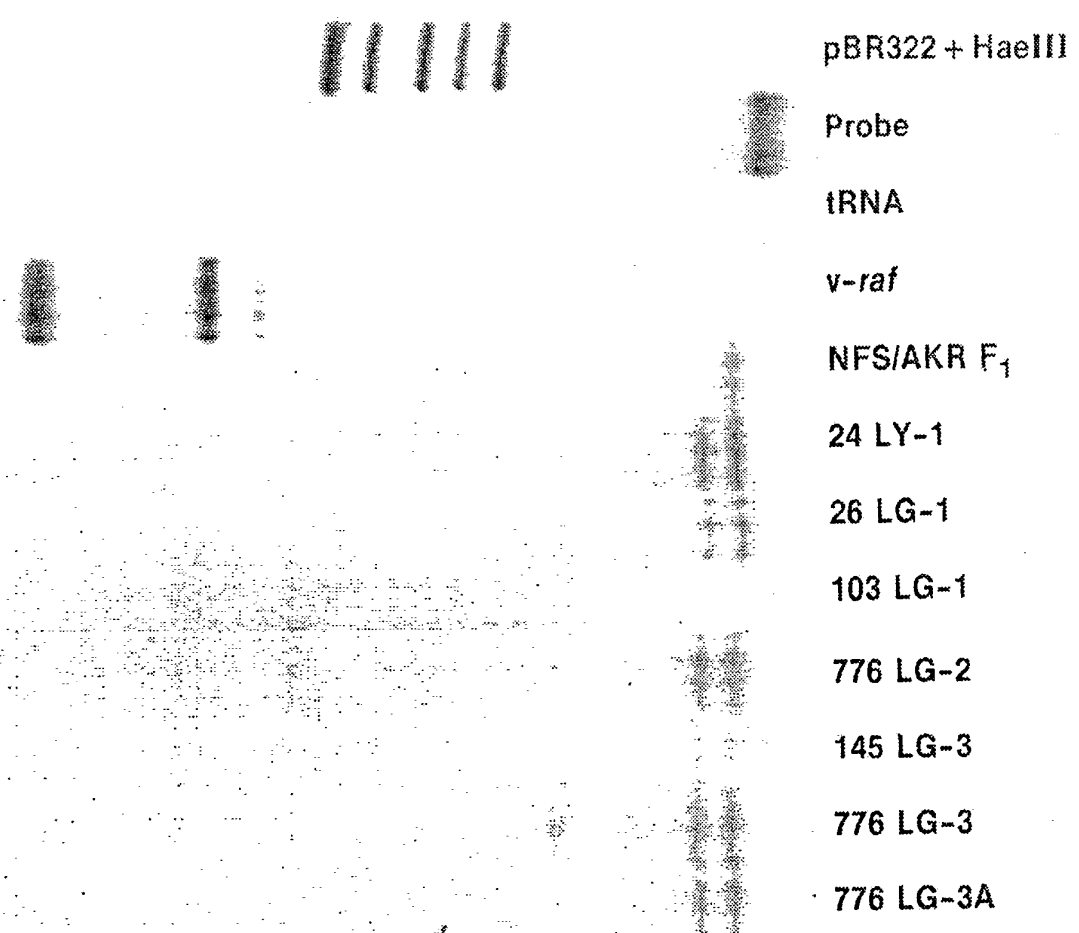


## Lung Tumors

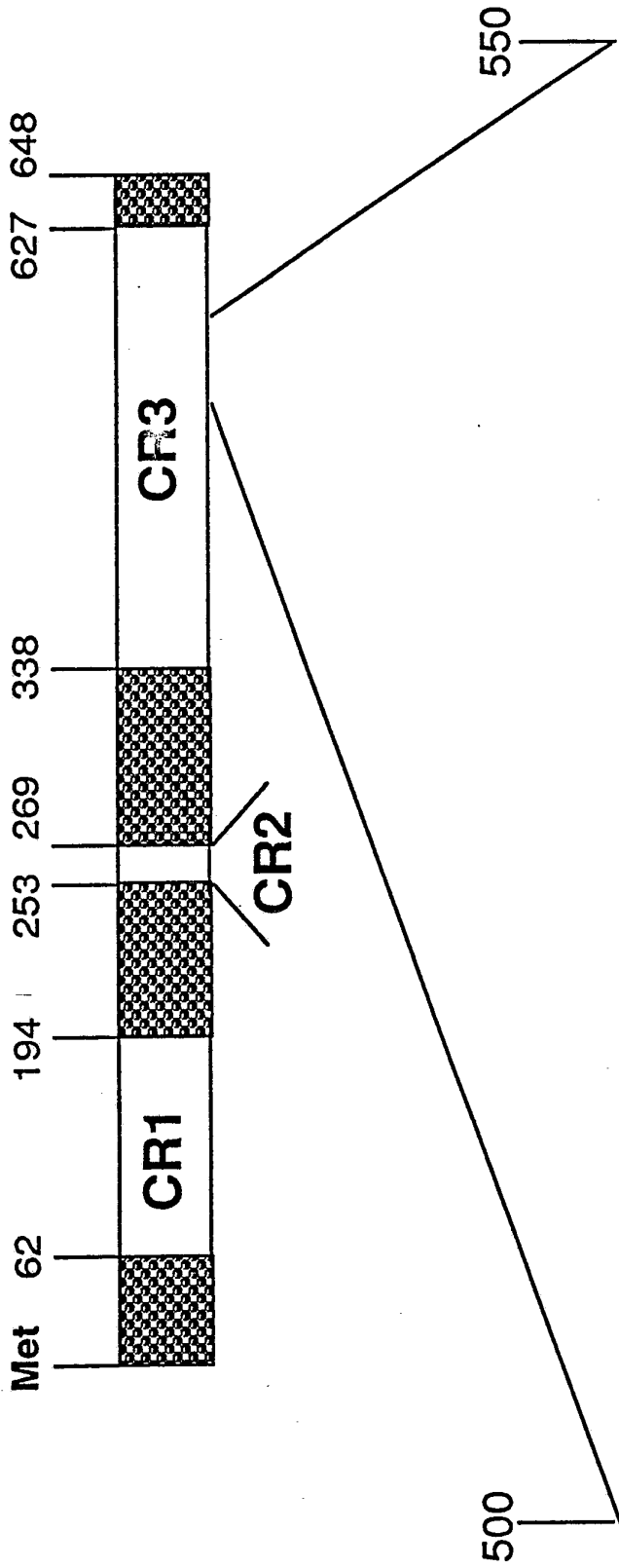


## Cell Lines

# Figure 4



# Mouse Raf-1



500 550

**QVEQPTGSVLWMAPEVIRMQDDNPFQSDVYSYGIVLYELMAGELPYAH**

Isoleucine to Valine

Aspartic Acid to Asparagine

Phenylalanine to Serine

TCTF

## Figure 5



# INTERNATIONAL SEARCH REPORT

International Application No. PCT/US 92/07817

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) <sup>5</sup>				
According to International Patent Classification (IPC) or to both National Classification and IPC				
IPC5: C 12 Q 1/68				
<b>II. FIELDS SEARCHED</b>				
Minimum Documentation Searched <sup>7</sup>				
Classification System	Classification Symbols			
IPC5	C 12 Q			
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched <sup>8</sup>				
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup></b>				
Category *	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>		
A	WO, A1, 9112343 (CETUS CORPORATION) 22 August 1991, see the whole document  --	1-21		
A	WO, A1, 9105064 (USA, REPR. BY THE SECR., D. OF HEALTH/HUMAN S.) 18 April 1991, see the whole document  --	1-21		
A	WO, A1, 9009456 (VIKTOR BALAZS) 23 August 1990, see the whole document  --	1-21		
A	Chemical Abstracts, volume 104, no. 19, 12 May 1986, (Columbus, Ohio, US), Bonner Tom I. et al.: "The complete coding sequence of the human raf oncogene and the corresponding structure of the c-raf-1 gene", see page 141, abstract 162785c, & Nucleic Acids Res. 1986, 14( 2), 1009-1015	1-21		
<p>* Special categories of cited documents:<sup>10</sup></p> <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none;"> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </td> <td style="width: 50%; border: none;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&amp;" document member of the same patent family</p> </td> </tr> </table>			<p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p>	<p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&amp;" document member of the same patent family</p>
<p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p>	<p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&amp;" document member of the same patent family</p>			
<b>IV. CERTIFICATION</b>				
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report			
14th December 1992	12.01.93			
International Searching Authority	Signature of Authorized Officer			
EUROPEAN PATENT OFFICE	Mikael G:son Bergstrand			

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/US92/07817

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:  
Remark: Claims 1-21  
Diagnostic methods, c.f. PCT Rule 39(iv). Nevertheless, a search has been made concerning the subject matter of the application (the analytical method).
2.  Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3.  Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1.  As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2.  As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3.  As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4.  No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- The additional search fees were accompanied by the applicant's protest.
- No protest accompanied the payment of additional search fees.

**ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO.PCT/US 92/07817**

SA 64903

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.  
The members are as contained in the European Patent Office EDP file on 02/12/92  
The European Patent office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO-A1- 9112343	22/08/91	AU-D- 7758991	03/09/91
		EP-A- 0514501	25/11/92
WO-A1- 9105064	18/04/91	AU-D- 6606190	28/04/91
		CA-A- 2067114	03/04/91
		EP-A- 0494968	22/07/92
WO-A1- 9009456	23/08/90	EP-A- 0458831	04/12/91

For more details about this annex : see Official Journal of the European patent Office, No. 12/82