COMPOSITIONS AND METHODS FOR DIAGNOSIS AND TREATMENT OF HEPATIC CANCERS

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 61/789,475, filed March 15, 2013, the disclosure of which is incorporated herein by reference as if set forth in its entirety.

SEQUENCE LISTING

The instant application contains a Sequence Listing which has been submitted electronically in ASCII format and is hereby incorporated by reference in its entirety. Said ASCII copy, created on March 13, 2014, is named P5570R1-WO_SL.txt and is 115,666 bytes in size.

FIELD OF THE INVENTION

The present invention relates generally to the field of molecular biology. More specifically, the invention relates to methods of treatment of pathological hepatic conditions, such as cancer.

BACKGROUND

Liver cancer is the fifth most common form of cancer. Each year, approximately 750,000 cases are diagnosed and about 700,000 people die from the disease each year, making it the third most common cause of cancer death in the world (Ferlay et al., Int. J. Cancer 127:2893-2917 (2010)). In the United States, the incidence of primary liver cancer has been rising, and while some progress has been made in detecting and treating localized disease, the five year survival rate for late stage liver cancer is still well below 10% (American-Cancer-Society. 2012. Cancer Facts & Figures 2012. Atlanta: American Cancer Society).

Established treatments for liver cancer include surgical removal of the part of the liver containing the tumor (partial hepatectomy), liver transplantation, transcatheter arterial chemoembolization (TACE), in situ tumor destruction by various methods such as radiofrequency ablation (RFA) or cryosurgery and administration of Sorafenib. Treatment options for late stage liver patients are limited. Thus, effective treatments of liver cancer remains a significant unmet medical need.

The role of Notch signaling in liver cancer is not well understood. Qi et al. report that Notch1 signaling inhibits growth of human hepatocellular carcinoma cells in vitro and in vivo by inducing cell cycle arrest and apoptosis (Qi et al., Cancer Res. 63:8323 (2003)) and Viatour et al. report that expression of Notch1 intracellular domain decreased proliferation and induced apoptosis in murine and human HCC cells (Viatour et al., J. Exp. Med. 208(10):1963 (2011)). Others report that Notch1 small interfering RNA (siRNA) reduced cell invasion and migration but not viability (Zhou et al. Dig. Dis. Sci.). Yet others report that inhibition of individual Notch pathway family members had no effect. Taken together, the Notch pathway's role in liver cancer was not well understood.

SUMMARY

Use of Notch2 signaling inhibitors for the treatment of patients having or at risk of having proliferative disorders of the liver is provided.

In one aspect, there is provided use of an anti-Jagged1 (anti-Jag1) antibody in the manufacture of a medicament for treating a liver cancer in an individual in need thereof, wherein the liver cancer comprises cells that express EpCAM.

Disclosed are methods of treating a liver cancer in an individual in need thereof , comprising the step of administering to the individual an effective amount of a Notch2 signaling inhibitor. In some embodiments, the liver cancer is hepatocellular carcinoma, hepatoma, cholangiocarcinoma, hepatoblastoma, hepatic carcinoma, hepatic angiosarcoma, or metastatic liver cancer. In some embodiments, the hepatocellular carcinoma comprises progenitor-like or cholangiocarcinoma-like liver tumor. In some embodiments, the liver cancer is a refractory cancer.

In some embodiments, the method further comprises administering at least one additional therapeutic agent. Examples of additional therapeutic agents include, but are not limited to chemotherapeutic agent and an antibody.

In some embodiments, the liver cancer comprises cells that express EpCAM, AFP, Notch2, Jag1, Notch2 and Jag1, nuclear Notch2 ICD, Sox9, CK19, Ras, Prom1, Spp1, FoxM1, Plk1, ccnb1, Aurkb, Wnt2, Axin2, or Glul, or any combination thereof. In specific embodiments, the liver cancer comprises cells that are AFP^+ $EpCAM^+$. In some embodiments, the liver cancer comprises cells that are AFP^+ $EpCAM^-$, AFP^+ $EpCAM^+$ $SPP1^+$, AFP^- $EpCAM^+$, AFP^- $EpCAM^+$ $Notch2^+$, AFP^+ $EpCAM^-$ $Notch2^+$, AFP^+ $EpCAM^+$ $Sox9^+$ and AFP^+ $EpCAM^+$ $Sox9^+$ or AFP^- $EpCAM^+$ $SPP1^+$. Liver cancers that comprise cells with alternative combinations of marker expression are specifically contemplated.

In some embodiments, at least one of EpCAM, AFP, Notch2, Jag1, Sox9, CK19, Ras, Prom1, Spp1, FoxM1, Plk1, ccnb1, Aurkb, Wnt2, Axin2, or Glul protein expression was determined in a sample from the individual using immunohistochemistry (IHC). In some

embodiments, expression is nucleic acid expression. In some embodiments, expression is determined by a method selected from the group consisting of RNAseq, microarray analysis, immunohistochemistry, enzyme-linked immunosorbent assay, gene expression profiling, polymerase chain reaction, SAGE, MassARRAY technique, fluorescent in situ hybridization and Western blotting.

In some embodiments, administering the Notch2 signaling inhibitor results in a decrease in the expression in the liver cancer of at least one of EpCAM, AFP, Notch2, Notch2 ICD, Jag1, Prom1, Spp1, FoxM1, Plk1, ccnb1 and Aurkb. In some embodiments, administering the Notch2 signaling inhibitor results in an increase in the expression in the liver cancer of at least one of Wnt2, Axin2 and Glul. In some embodiments, expression is determined by RNAseq, microarray analysis, immunohistochemistry, enzyme-linked immunosorbent assay, and Western blotting.

Any of the antibodies of the above embodiments may be a full-length IgG1 or IgG2a antibody. In some embodiments, the antibody causes cancer cell death, e.g., liver cancer cell death. Any of the antibodies in the above embodiments may be conjugated to a growth inhibitory agent, e.g., a cytotoxic agent. Examples of cytotoxic agent include, but are not limited to, toxins, antibiotics, radioactive isotopes and nucleolytic enzymes. Any of the antibodies in the above embodiments may be produced by known methods in the art, e.g., in bacteria or in CHO cells.

Disclosed are methods for preventing liver cancer in an individual at risk of having liver cancer, comprising the step of administering to the individual an effective amount of a Notch2 signaling inhibitor. In some embodiments, the individual has a liver condition selected from the group consisting of hepatitis B or C, cirrhosis of the liver, non-viral/non-alcoholic steatohepatitis, benign liver tumors, hemangiomas, hepatic adenomas, and focal nodular hyperplasia. In some embodiments, the Notch2 signaling inhibitor is an anti-Jag1 antibody, e.g., an anti-Jag1 antagonist antibody.

Disclosed are methods for inhibiting growth of a cell that expresses secreted phosphoprotein1 (SPP1), comprising contacting the cell with a Notch2 signaling inhibitor, thereby inhibiting growth of the cell. In one embodiment, SPP1 protein comprises the amino acid sequence shown in FIG. 11. In one embodiment, contacting the cell with the Notch2 signaling inhibitor reduces SPP1 expression in the cell. For example, contacting the cell with the Notch2 signaling inhibitor reduces SPP1 expression in the cell by at least about 50%, 60%, 70%, 80%, 90%, or 100%. The expression of SPP1 mRNA or protein can be determined by any method in the art. In some embodiments, the Notch2 signaling inhibitor is

an anti-Notch2 antibody, e.g., an anti-Notch2 negative regulatory region (NRR) antibody, such as any anti-Notch2 NRR antibody disclosed herein. In some embodiments, the antibody is an anti-Jag1 antibody, such as any anti-Jag1 antibody disclosed herein. In some embodiments, the cell is a liver cancer cell. In some embodiments, the liver cancer cell expresses EpCAM, AFP, AFP and EpCAM, Notch2, Jag1, Notch2 and Jag1, nuclear Notch2 ICD, Ras, Prom1, Spp1, FoxM1, Plk1, ccnb1, Aurkb, Wnt2, Axin2, or Glul, or any combination thereof. In some embodiments, contacting the cell with the Notch2 signaling inhibitor results in a decrease in the expression in the cell of at least one of EpCAM, AFP, Notch2, Notch2 ICD, Jag1, Prom1, Spp1, FoxM1, Plk1, ccnb1 and Aurkb. In some embodiments, administering the Notch2 signaling inhibitor results in an increase in the expression in the cell of at least one of Wnt2, Axin2 and Glul. In some embodiments, expression is determined by RNAseq, microarray analysis, immunohistochemistry, enzyme-linked immunosorbent assay, and Western blotting.

Disclosed are methods for inhibiting proliferation of a cell that expresses secreted phosphoprotein1 (SPP1), comprising contacting the cell with a Notch2 signaling inhibitor, thereby inhibiting proliferation of the cell.

Disclosed are methods for treating a mammal having a liver cancer comprising cells that express a Spp1 gene encoding a peptide comprising an amino acid sequence having at least about 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, 100% identity to the polypeptide shown in FIG. 11, comprising administering to the mammal an effective amount of a Notch2 signaling inhibitor, thereby effectively treating the mammal. In some embodiments, the cells express a SPP1 protein comprising an amino acid sequence having at least about 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, 100% identity to the polypeptide shown in FIG. 11.

In some embodiments, the liver cancer is hepatocellular carcinoma, hepatoma, cholangiocarcinoma, hepatoblastoma, hepatic carcinoma, hepatic angiosarcoma, or metastatic liver cancer. In some embodiments, the liver cancer is a refractory cancer. Any of the antibodies herein may be a full-length IgG1 or IgG2a antibody. In some embodiments, the antibody causes cancer cell death, e.g., liver cell death. Any of the herein may be conjugated to a growth inhibitory agent, e.g., a cytotoxic agent. Examples of cytotoxic agent include, but are not limited to, toxins, antibiotics, radioactive isotopes and nucleolytic enzymes. Any of the antibodies herein may be produced by known methods in the art, e.g., in bacteria or in CHO cells.

In some embodiments, the method further comprises administering at least one additional therapeutic agent. Examples of additional therapeutic agents include, but are not limited to chemotherapeutic agent and an antibody.

In some embodiments, the liver cancer comprises cells that express EpCAM, AFP, AFP and EpCAM, Notch2, Jag1, Notch2 and Jag1, nuclear Notch2 ICD, Ras, Prom1, Spp1, FoxM1, Plk1, ccnb1, Aurkb, Wnt2, Axin2, or Glul, or any combination thereof. In some embodiments, administering the Notch2 signaling inhibitor results in a decrease in the expression in the liver cancer of at least one of EpCAM, AFP, Notch2, Notch2 ICD, Jag1, Prom1, Spp1, FoxM1, Plk1, ccnb1 and Aurkb. In some embodiments, administering the Notch2 signaling inhibitor results in an increase in the expression in the liver cancer of at least one of Wnt2, Axin2 and Glul. In some embodiments, expression is determined by RNAseq, microarray analysis, immunohistochemistry, enzyme-linked immunosorbent assay, and Western blotting.

Disclosed are methods for treating a liver cell proliferative disorder associated with increased expression or activity of a protein having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, 100% amino acid sequence identity to the polypeptide shown in FIG. 8C, comprising administering to an individual in need of such treatment an effective amount of an anti-Jag1 antagonist antibody, thereby effectively treating the liver cell proliferative disorder. In some embodiments, the cell proliferative disorder is a cancer, such as liver cancer. In some embodiments the individual has a liver condition selected from the group consisting of hepatitis B or C, cirrhosis of the liver, benign liver tumors, hemangiomas, hepatic adenomas, and focal nodular hyperplasia.

In certain embodiments, the anti-Jag1 antibody is any of the anti-Jag1 antibodies described herein. In certain embodiments, the anti-Jag1 antibody is a human, humanized, or chimeric antibody. In certain embodiments, any of the antibodies of the above embodiments is an antibody fragment.

Disclosed are methods for treating a liver cell proliferative disorder associated with increased expression or activity of a protein having at least 90% amino acid sequence identity to the polypeptide shown in FIG. 11, comprising administering to an individual in need of such treatment an effective amount of an anti-Jag1 antagonist antibody, thereby effectively treating the liver cell proliferative disorder. In some embodiments, the cell proliferative disorder is a cancer, such as liver cancer. In some embodiments the individual has a liver condition selected from the group consisting of hepatitis B or C, cirrhosis of the liver, benign liver tumors, hemangiomas, hepatic adenomas, and focal nodular hyperplasia.

Disclosed are methods for reducing serum SPP1 protein levels in an individual, the method comprising administering to the individual an effective amount of a Notch2 signaling inhibitor thereby reducing serum SPP1 levels in the individual. In one embodiment, the individual has a liver cancer. In one embodiment, the serum SPP1 protein levels prior to administering the Notch2 signaling inhibitor to the individual are at least about 80 ng/ml. In certain embodiments, the serum SPP1 protein levels prior to administering the Notch2 signaling inhibitor to the individual are between about 80 ng/ml and about 500 ng/ml, between about 86 ng/ml and about 250 ng/ml, between about 120 ng/ml and about 170 ng/ml, or about 165 ng/ml. In some embodiments, administering the Notch2 signaling inhibitor to the individual results in serum SPP1 protein levels of less than 80 ng/ml. In specific embodiments, serum SPP1 protein levels prior to administering the Notch2 signaling inhibitor are 24 hours prior to administering the Notch2 signaling inhibitor. Serum SPP1 protein levels prior to or following administration of the Notch2 signaling inhibitor may be determined by any appropriate method, such as enzyme-linked immunosorbent assay. In specific embodiments, serum SPP1 protein levels are reduced about one, two, three, six or 12 month after administering the Notch2 signaling inhibitor. In some embodiments, the liver cancer is hepatocellular carcinoma, hepatoma, cholangiocarcinoma, hepatoblastoma, hepatic carcinoma, hepatic angiosarcoma or metastatic liver cancer. In some embodiments, the Notch2 signaling inhibitor is an siRNA, small-molecule inhibitor or antibody. In some embodiments, the antibody is an antagonist antibody.

In certain embodiments, any of the antibodies of the above embodiments is a monoclonal antibody. In certain embodiments, any of the antibodies of the above embodiments is a human, humanized, or chimeric antibody. In certain embodiments, any of the antibodies of the above embodiments is an antibody fragment.

In some embodiments, the method further comprises administering at least one additional therapeutic agent. Examples of additional therapeutic agents include, but are not limited to chemotherapeutic agent and an antibody. In some embodiments, Sorafenib is an additional therapeutic agent.

In some embodiments, the liver cancer comprises cells that express EpCAM, AFP, AFP and EpCAM, Notch2, Jag1, Notch2 and Jag1, nuclear Notch2 ICD, Ras, Prom1, Spp1, FoxM1, Plk1, ccnb1, Aurkb, Wnt2, Axin2, or Glul, or any combination thereof. In some embodiments, Ras is a mutant Ras. In some embodiments, administering the Notch2 signaling inhibitor results in a decrease in the expression in the liver cancer of at least one of EpCAM, AFP, Notch2, Notch2 ICD, Jag1, Prom1, Spp1, FoxM1, Plk1, ccnb1 and Aurkb. In some

embodiments, administering the Notch2 signaling inhibitor results in an increase in the expression in the liver cancer of at least one of Wnt2, Axin2 and Glul. In some embodiments, expression is determined by RNAseq, microarray analysis, immunohistochemistry, enzyme-linked immunosorbent assay, and Western blotting.

Disclosed are methods for treating a liver tumor in a mammal, wherein the growth of the liver tumor is at least in part dependent upon a growth potentiating effect of Notch2 signaling, comprising contacting the tumor with an antibody that binds to Notch2 or Jag1. In one embodiment, binding of the antibody to the tumor antagonizes the growth-potentiating activity of Notch2. In some embodiments, the mammal is a human.

Disclosed are methods for treating of liver cancer comprising administering to an individual who has elevated serum SPP1 protein levels an effective amount of a Notch2 signaling inhibitor. In one embodiment, the serum SPP1 protein levels of the individual are at least about 80 ng/ml. In certain embodiments, the serum SPP1 protein levels prior to administering the Notch2 signaling inhibitor to the individual are between about 80 ng/ml and about 500 ng/ml, between about 86 ng/ml and about 250 ng/ml, between about 120 ng/ml and about 170 ng/ml, or about 165 ng/ml. In some embodiments, administering the Notch2 signaling inhibitor to the individual results in serum SPP1 protein levels of less than 80 ng/ml. In specific embodiments, serum SPP1 protein levels prior to administering the Notch2 signaling inhibitor are 24 hours prior to administering the Notch2 signaling inhibitor. Serum SPP1 protein levels prior to or following administration of the Notch2 signaling inhibitor may be determined by any appropriate method, such as enzyme-linked immunosorbent assay. In specific embodiments, serum SPP1 protein levels are reduced in the individual about one, two, three, six or 12 month after administering the Notch2 signaling inhibitor. In some embodiments, the liver cancer is hepatocellular carcinoma, hepatoma, cholangiocarcinoma, hepatoblastoma, hepatic carcinoma, hepatic angiosarcoma or metastatic liver cancer. In some embodiments, the Notch2 signaling inhibitor is an siRNA, small-molecule inhibitor or antibody. In some embodiments, the antibody is an antagonist antibody, such as an anti-Notch2 antagonist antibody or an anti-Jag1 antagonist antibody.

Disclosed are methods for treating an individual having a liver cancer, comprising the steps of administering to the individual a Notch2 signaling inhibitor; and determining Notch2 signaling, wherein a decrease in Notch2 signaling following treatment, compared to Notch2 signaling prior to treatment, is indicative of reduction of liver cancer in the individual. In some embodiments, Notch2 signaling is determined by measuring Notch2 ICD nuclear localization, e.g., by immunohistochemical analysis of a liver cancer sample from

the individual. In some embodiments, Notch2 signaling is determined by measuring expression of a gene selected from the group consisting of Notch2, Jag1, Hes and Hey1. Expression can be determined by any method, e.g., RT-PCR, microarray, and RNAseq analysis. In some embodiments, the liver cancer is hepatocellular carcinoma, hepatoma, cholangiocarcinoma, hepatoblastoma, hepatic carcinoma, hepatic angiosarcoma, and metastatic liver cancer. In some embodiments, the Notch2 signaling inhibitor is an siRNA, small-molecule inhibitor or antibody. In some embodiments, the antibody is an antagonist antibody, such as an anti-Notch2 antagonist antibody or an anti-Jag1 antagonist antibody.

Disclosed are methods for inhibiting cellular proliferation comprising treating mammalian liver cancer cells with an antibody to Notch2 or Jag1, whereby proliferation of the liver cancer cell is inhibited. In certain embodiments, the cell is in a patient. In certain embodiments, the cell is in a culture medium. In certain embodiments, the cell is a liver cancer cell. In certain embodiments, the antibody is an anti-Notch2 or anti-Jag1 antagonist antibody is as described herein. In certain embodiments, the antibody is a human, humanized, or chimeric antibody. In certain embodiments, any of the antibodies of the above embodiments is an antibody fragment.

In any of the methods herein, Notch2 signaling inhibitors may be the following inhibitors. In some embodiments, the Notch2 signaling inhibitor is a siRNA, small-molecule inhibitor or antibody. In some embodiments, the antibody is an antagonist antibody. In some embodiments, the antibody is an anti-Notch2 antibody, e.g., an anti-Notch2 negative regulatory region (NRR) antibody. In some embodiments, the antibody does not significantly bind to a Notch family member other than Notch2. In some embodiments, the antibody binds to mouse Notch2 NRR and human Notch2 NRR, e.g., with a Kd of $\leq$ 10 nM. In some embodiments, the antibody comprises:

(a) an HVR-H1 comprising the amino acid sequence of SEQ ID NO:1;
(b) an HVR-H2 comprising the amino acid sequence of SEQ ID NO:3;
(c) an HVR-H3 comprising the amino acid sequence of SEQ ID NO:4;
(d) an HVR-L1 comprising an amino acid sequence that conforms to the consensus sequence of SEQ ID NO:9;
(e) an HVR-L2 comprising an amino acid sequence that conforms to the consensus sequence of SEQ ID NO:14; and
(f) an HVR-L3 comprising an amino acid sequence that conforms to the consensus sequence of SEQ ID NO:19.

In further embodiments, the antibody is an anti-Jag1 antibody. In some embodiments, the antibody comprises at least one, two, three, four, five, or six HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO:81; (b) HVR-H2 comprising an amino acid sequence of SEQ ID NO:84; (c) HVR-H3 comprising an amino acid sequence of SEQ ID NO:87; (d) HVR-L1 comprising the amino acid sequence of SEQ ID NO:88; (e) HVR-L2 comprising the amino acid sequence of SEQ ID NO:89; and (f) HVR-L3 comprising an amino acid sequence of SEQ ID NO:92. In one embodiment, the antibody comprises: (a) an HVR-H1 comprising the amino acid sequence of SEQ ID NO:81; (b) an HVR-H2 comprising the amino acid sequence of SEQ ID NO:82; (c) an HVR-H3 comprising the amino acid sequence of SEQ ID NO:85; (d) an HVR-L1 comprising the amino acid sequence of SEQ ID NO:88; (e) an HVR-L2 comprising the amino acid sequence of SEQ ID NO:89; and (f) an HVR-L3 comprising the amino acid sequence of SEQ ID NO:90.

In one embodiment, the antibody comprises: (a) an HVR-H1 comprising the amino acid sequence of SEQ ID NO:81; (b) an HVR-H2 comprising the amino acid sequence of SEQ ID NO:82; (c) an HVR-H3 comprising the amino acid sequence of SEQ ID NO:86; (d) an HVR-L1 comprising the amino acid sequence of SEQ ID NO:88; (e) an HVR-L2 comprising the amino acid sequence of SEQ ID NO:89; and (f) an HVR-L3 comprising the amino acid sequence of SEQ ID NO:91. In one embodiment, the antibody comprises: (a) an HVR-H1 comprising the amino acid sequence of SEQ ID NO:81; (b) an HVR-H2 comprising the amino acid sequence of SEQ ID NO:83; (c) an HVR-H3 comprising the amino acid sequence of SEQ ID NO:85; (d) an HVR-L1 comprising the amino acid sequence of SEQ ID NO:88; (e) an HVR-L2 comprising the amino acid sequence of SEQ ID NO:89; and (f) an HVR-L3 comprising the amino acid sequence of SEQ ID NO:90.

In certain embodiments, any of the antibodies of the embodiments herein is a monoclonal antibody. In certain embodiments, any of the antibodies of the above embodiments is a human, humanized, or chimeric antibody. In certain embodiments, any of the antibodies of the above embodiments is an antibody fragment.

In a further embodiment, any antibody of the embodiments herein further comprises light chain variable domain framework LC-FR1, LC-FR2, LC-FR3, and LC-FR4 comprising, in order, the amino acid sequence of huMAb4D5-8 light chain variable domain framework LC-FR1, LC-FR2, LC-FR3, and LC-FR4 of FIG. 18.

In a further embodiment, any antibody of the embodiments herein further comprises a heavy chain variable domain framework HC-FR1, HC-FR2, HC-FR3, and HC-FR4

comprising, in order, the amino acid sequence of huMAb4D5-8 heavy chain variable domain framework HC-FR1, HC-FR2, HC-FR3, and HC-FR4 of FIG. 18.

In a further embodiment, any antibody of the embodiments herein further comprises a light chain variable domain framework LC-FR1, LC-FR2, LC-FR3, and LC-FR4 comprising, in order, the amino acid sequence of huMAb4D5-8 light chain variable domain framework LC-FR1, LC-FR2, LC-FR3, and LC-FR4 of FIG. 19.

In a further embodiment, any antibody of the embodiments herein further comprises a heavy chain variable domain framework HC-FR1, HC-FR2, HC-FR3, and HC-FR4 comprising, in order, the amino acid sequence of huMAb4D5-8 heavy chain variable domain framework HC-FR1, HC-FR2, HC-FR3, and HC-FR4 of FIG. 19.

In certain embodiments, the antibody is an isolated antibody that binds to Jag1, comprising (a) a VH sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO:94; (b) a VL sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO:97; or (c) a VH sequence as in (a) and a VL sequence as in (b). In some embodiments, the antibody comprises a VH sequence of SEQ ID NO:94. In some embodiments, the antibody comprises a VL sequence of SEQ ID NO:97. In some embodiments, the antibody comprises a VH sequence of SEQ ID NO:94 and a VL sequence of SEQ ID NO:97. In some embodiments, the antibody comprises (a) a VH sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO:95; (b) a VL sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO:98; or (c) a VH sequence as in (a) and a VL sequence as in (b). In some embodiments, the antibody comprises a VH sequence of SEQ ID NO:95. In some embodiments, the antibody comprises a VL sequence of SEQ ID NO:98. In some embodiments, the antibody comprises a VH sequence of SEQ ID NO:95 and a VL sequence of SEQ ID NO:98.

In certain embodiments, the antibody is an isolated antibody that binds to Jag1, comprising (a) a VH sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO:93; (b) a VL sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO:96; or (c) a VH sequence as in (a) and a VL sequence as in (b). In some embodiments, the antibody comprises a VH sequence of SEQ ID NO:93. In some embodiments, the antibody comprises a VL sequence of SEQ ID NO:96. In some embodiments, the antibody comprises a VH sequence of SEQ ID NO:93 and a VL sequence of SEQ ID NO:96.

Disclosed is an article of manufacture comprising (a) a container; (b) a composition of matter contained within the container comprising an anti-Notch2 antibody or an

anti-Jagged1 antibody and a carrier for the treatment of liver cancer; and (c) a label affixed to the container, or a package insert included with the container, referring to the use of the composition of matter for the therapeutic treatment of or the diagnostic detection of a liver cancer.

Disclosed is an anti-Notch2 antibody for use in the treatment of a liver cancer is provided. In certain embodiments, the liver cancer is hepatocellular carcinoma. In certain embodiments, the antibody is an anti-Notch2 NRR antagonist antibody. Disclosed is an anti-Jag1 antibody for use in the treatment of a liver cancer is provided. In certain embodiments, the liver cancer is hepatocellular carcinoma. In certain embodiments, the antibody is an anti-Jag1 antagonist antibody.

Disclosed is use of an anti-Notch2 antibody in the preparation of a medicament treating a liver cancer. Disclosed is use of an anti-Jagged1 antibody in the preparation of a medicament for treating a liver cancer.

Disclosed is use of an article of manufacture described herein in the preparation of a medicament for the therapeutic treatment of a liver cancer. Disclosed is use of an article of manufacture as described herein in the preparation of a medicament for treatment or prevention of a liver cell proliferative disorder.

BRIEF DESCRIPTION OF THE FIGURES

FIGs. 1A-F illustrate characterization of liver cancer marker expression in the AKT/Ras HTV liver cancer model. FIGs. 1A-C depict immunohistochemical staining of tumors that are $AFP^{+}EpCAM^{-}$(FIG. 1A), $AFP^{+}EpCAM^{+}$(FIG. 1B) and $AFP^{-}EpCAM^{+}$(FIG. 1C). FIG. 1D depicts the prevalence of marker expression, expressed in percentage of total cells. FIG. 1F depicts immunohistochemical staining of activation of Notch2 signaling indicated by localization of the Notch2 protein in the nucleus. FIG. 1E depicts the percent cells with nuclear Notch2 staining.

FIGs. 2A-D illustrate reduced tumor burden in Ras/AKT HTV mice treated with anti-Notch2 or anti-Jag1 antagonist antibodies. FIG. 2A depicts isolated livers from HTV mice treated with an isotype control antibody (upper left), an anti-Notch2 antibody (upper right) or an anti-Jag1 antibody (lower left) beginning on the day of the HTV. FIG. 2B depicts Ras/AKT HTV mice liver weight following antibody treatment administered at the time of HTV injection, expressed in percent body weight. FIG. 2C depicts Ras/AKT HTV mice liver weight

following antibody treatment administered two weeks after HTV injection, expressed in percent body weight ($p<0.05$, $n>8$). FIG. 2D depicts Ras/AKT HTV mice liver weight following antibody treatment ($p<0.02$, $n>6$).

FIGs. 3A-H illustrate treatment of AKT/Ras HTV tumor-bearing mice with Notch inhibitory antibodies impedes the development of a broad range of tumor types. FIG. 3A depicts immunofluorescence analysis of AFP and EpCAM expression in livers of AKT/Ras HTV mice treated with anti-Notch2, anti-Jag1 or isotype control antibody. FIGs. 3B and C depict a decrease in $EpCAM^+$ (FIG. 3B; $p<0.007$, $n\geq7$) and AFP^+ (FIG. 3C; $p<0.03$, $n\geq7$) area following anti-Notch2 and anti-Jag1 treatment. FIG. 3D depicts immunofluorescence analysis of AFP and EpCAM expression in livers of AKT/Ras HTV mice treated with anti-Notch1 antibody. FIG. 3E depicts the percentage of $EpCAM^+$ cells following AKT/Ras HTV mice treatment with an anti-Notch1, anti-Notch2, anti-Notch3, anti-Jag1 or isotype control antibody. FIG. 3F depicts relative expression of Cytokeratin 19 (CK19) following AKT/Ras HTV mice treatment with an anti-Notch1, anti-Notch2, anti-Notch3, anti-Jag1 or isotype control antibody. FIG. 3G depicts RNA and FIG. 3H depicts protein levels of Sox9 following AKT/Ras HTV mice treatment with an anti-Notch1, anti-Notch2, anti-Notch3, anti-Jag1 or isotype control antibody.

FIGs. 4A-E illustrate that treatment of AKT/Ras HTV mice with Notch inhibitory antibodies reduces Notch pathway activation in tumor-bearing livers. FIG. 4A depicts Notch2 nuclear immunohistochemical staining expressed in number of cells. FIG. 4B depicts relative expression of Notch2, determined by QRTPCR. FIG. 4C depicts immunohistochemical staining for Hes1 in AKT/Ras HTV tumor-bearing livers. FIG.4D depicts the fraction of $Hes1^+$ cells, determined by immunohistochemistry. FIG. 4E depicts relative expression of HeyL, determined by QRTPCR.

FIGs. 5A-I illustrate the effect of Notch inhibitory antibodies on expression of Notch signaling pathway components in the AKT/Ras model of liver cancer. Mice subjected to AKT/Ras HTV were treated with antagonistic antibodies to Notch1, Notch2, Notch3, or Jag1, or an anti-Ragweed negative control antibody and quantitative real-time PCR was performed on the isolated RNA from livers after 5 weeks for Notch1 (FIG.5A), Notch2 (FIG.5B), Notch3 (FIG.5C), Notch4 (FIG.5D), Jag1 (FIG.5E), Jag2 (FIG.5F), DLL1 (FIG. 5G), DLL3 (FIG.5H), DLL4 (FIG.5I).

FIGs. 6A-I illustrate results from RNAseq analysis of livers from AKT/Ras HTV mice treated with isotype control, anti-Notch2 or anti-Jag1 antibody. Depicted are normalized counts for Prom1 (FIG. 6A), Spp1 (FIG. 6B), FoxM1 (FIG. 6C), Plk1 (FIG. 6D), ccnb1 (FIG.

6E), Aurkb (FIG. 6F), Wnt2 (FIG. 6G), Axin2 (FIG. 6H) and glutamine synthetase (Glul, FIG. 6I).

FIGs. 7A-B illustrate expression of Notch2 in human HCC. FIG. 7A depicts Notch1, Notch2 and Notch3 expression, determined by RT-PCR, in cultured human HCC cell lines. FIG. 7B depicts immunohistochemical staining of human HCC tumors for Notch2, Jag1 and Hes1.

FIGs. 8A-D show exemplary amino acid sequences of human (C) and murine (D) Notch2 protein and human (A) and murine (B) Notch2 negative regulatory region (NRR).

FIG. 9 shows exemplary amino acid sequences of human and murine Jagged 1 protein.

FIGs. 10A-B show the amino acid sequences of peptides used for phage antibody library screening and selection. All proteins were expressed as a secreted protein in BEVS cells and their sequences are listed in the N-terminal to C-terminal direction. FIG. 10A shows the amino acid sequence of expressed protein murine Jagged 1-DSL-EGF1-4 (Q34-D377). The bold font at the N-terminus represents a short linker sequence (ADLGS (SEQ ID NO: 2)). The bold font at the C-terminus represents a short linker sequence (EFG), a thrombin cleavage site (LVPRGS (SEQ ID NO: 26)), a G spacer and the 6-His tag (SEQ ID NO: 27). FIG. 10B shows the amino acid sequence of expressed protein human Jag1-DSL-EGF1-4. Only the Jag1 sequence is shown although the antigen also contained a TEV protease cleavage site and 6-His tag (SEQ ID NO: 27) at the C-terminus.

FIG. 11 shows an exemplary amino acid sequences of human secreted phosphoprotein1 (SPP1).

FIG. 12 shows the H1, H2, and H3 heavy chain hypervariable region (HVR) sequences of anti-Notch2 NRR antagonist antibodies. Amino acid positions are numbered according to the Kabat numbering system as described below.

FIG. 13 shows the L1, L2, and L3 light chain HVR sequences of anti-Notch2 NRR antagonist antibodies. Amino acid positions are numbered according to the Kabat numbering system as described below.

FIGs. 14A-B show an alignment of the amino acid sequences for the heavy chain variable domains of anti-Notch2 antibodies. Amino acid positions of the complementarity determining regions (CDRs) are indicated.

FIGs. 15A-B show an alignment of the amino acid sequences for the light chain variable domains of anti-Notch2 antibodies. Amino acid positions of the complementarity determining regions (CDRs) are indicated.

FIGs. 16A-B show exemplary acceptor human variable heavy (VH) consensus framework sequences for use in practicing the instant invention. Sequence identifiers are as follows:

- human VH subgroup I consensus framework "A" minus Kabat CDRs (SEQ ID NOs:32, 33, 34, 35).
- human VH subgroup I consensus frameworks "B," "C," and "D" minus extended hypervariable regions (SEQ ID NOs:36, 37, 34, 35; SEQ ID NOs:36, 37, 38, 35; and SEQ ID NOs:36, 37, 39, 35).
- human VH subgroup II consensus framework "A" minus Kabat CDRs (SEQ ID NOs:40, 41, 42, 35).
- human VH subgroup II consensus frameworks "B," "C," and "D" minus extended hypervariable regions (SEQ ID NOs:43, 44, 42, 35; SEQ ID NOs:43, 44, 45, 35; and SEQ ID NOs:43, 44, 46, and 35).
- human VH subgroup III consensus framework "A" minus Kabat CDRs (SEQ ID NOs:47, 48, 49, 35).
- human VH subgroup III consensus frameworks "B," "C," and "D" minus extended hypervariable regions (SEQ ID NOs:50, 51, 49, 35; SEQ ID NOs:50, 51, 52, 35; and SEQ ID NOs:50, 51, 53, 35).
- human VH acceptor framework "A" minus Kabat CDRs (SEQ ID NOs:54, 48, 55, 35).
- human VH acceptor frameworks "B" and "C" minus extended hypervariable regions (SEQ ID NOs:50, 51, 55, 35; and SEQ ID NOs:50, 51, 56, 35).
- human VH acceptor 2 framework "A" minus Kabat CDRs (SEQ ID NOs:54, 48, 57, 35).
- human VH acceptor 2 framework "B," "C," and "D" minus extended hypervariable regions (SEQ ID NOs:50, 51, 57, 35; SEQ ID NOs:50, 51, 58, 35; and SEQ ID NOs:50, 51, 59, 35).

FIG. 17 shows exemplary acceptor human variable light (VL) consensus framework sequences for use in practicing the instant invention. Sequence identifiers are as follows:

- human VL kappa subgroup I consensus framework (κv1): SEQ ID NOs:60, 61, 62, 63
- human VL kappa subgroup II consensus framework (κv2): SEQ ID NOs:64, 65, 66, 63

- human VL kappa subgroup III consensus framework (κv3): SEQ ID NOs:67, 68, 69, 63
- human VL kappa subgroup IV consensus framework (κv4): SEQ ID NOs:70, 71, 72, 63.

FIG. 18 depicts framework region sequences of huMAb4D5-8 light and heavy chains (SEQ ID NOS 60, 61, 30, 63, 50, 51, 59 and 35, respectively, in order of appearance). Numbers in superscript indicate amino acid positions according to Kabat.

FIG. 19 depicts modified/variant framework region sequences of huMAb4D5-8 light and heavy chains (SEQ ID NOS 60, 61, 62, 31, 50, 51, 53 and 35, respectively, in order of appearance). Numbers in superscript indicate amino acid positions according to Kabat.

FIG. 20 shows the H1, H2, and H3 heavy chain hypervariable region (HVR) sequences of anti- Jagged antibodies, as described in the Example s. Amino acid positions are numbered according to the Kabat numbering system as described below.

FIG. 21 shows the L1, L2, and L3 light chain HVR sequences of anti-Jagged antibodies, as described in the Examples. Amino acid positions are numbered according to the Kabat numbering system as described below.

FIG. 22 shows light and heavy chain variable domain framework sequences of anti-Jagged antibodies (SEQ ID NOS 60, 61, 62, 77, 50, 99, 57 and 35, respectively, in order of appearance). Numbers in superscript indicate amino acid positions according to Kabat.

FIGs. 23A-B show an alignment of the amino acid sequences for the heavy chain variable domains of antibodies to Notch2 (SEQ ID NO: 100) (B?), Notch1 (SEQ ID NO: 101) (Y), Notch3 (SEQ ID NO: 102) (W) and Jag1 (SEQ ID NO: 103) (A-2) described in the Examples.

FIGs. 24A-B show an alignment of the amino acid sequences for the light chain variable domains of antibodies to Notch2 (SEQ ID NO: 104), Notch1 (SEQ ID NO: 105), Notch3 (SEQ ID NO: 106) and Jag1 (SEQ ID NO: 107) used in the Examples.

FIGs. 25A-B show an alignment of the amino acid sequences for the heavy (FIG. 25A) and light (FIG. 25B) chain variable domains of anti-Jag1 antibodies. Amino acid positions of the complementarity determining regions (CDRs) are indicated.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

I. DEFINITIONS

An "acceptor human framework" for the purposes herein is a framework comprising the amino acid sequence of a light chain variable domain (VL) framework or a heavy chain

variable domain (VH) framework derived from a human immunoglobulin framework or a human consensus framework, as defined below. An acceptor human framework "derived from" a human immunoglobulin framework or a human consensus framework may comprise the same amino acid sequence thereof, or it may contain amino acid sequence changes. In some embodiments, the number of amino acid changes are 10 or less, 9 or less, 8 or less, 7 or less, 6 or less, 5 or less, 4 or less, 3 or less, or 2 or less. In some embodiments, the VL acceptor human framework is identical in sequence to the VL human immunoglobulin framework sequence or human consensus framework sequence.

"Affinity" refers to the strength of the sum total of noncovalent interactions between a single binding site of a molecule (e.g., an antibody) and its binding partner (e.g., an antigen). Unless indicated otherwise, as used herein, "binding affinity" refers to intrinsic binding affinity which reflects a 1:1 interaction between members of a binding pair (e.g., antibody and antigen). The affinity of a molecule X for its partner Y can generally be represented by the dissociation constant (Kd). Affinity can be measured by common methods known in the art, including those described herein. Specific illustrative and exemplary embodiments for measuring binding affinity are described in the following.

An "affinity matured" antibody refers to an antibody with one or more alterations in one or more hypervariable regions (HVRs), compared to a parent antibody which does not possess such alterations, such alterations resulting in an improvement in the affinity of the antibody for antigen.

The terms "anti-Jag1 antibody" and "an antibody that binds to Jag1" refer to an antibody that is capable of binding Jag1 with sufficient affinity such that the antibody is useful as a diagnostic and/or therapeutic agent in targeting Jag1. In one embodiment, the extent of binding of an anti Jag1 antibody to an unrelated, non-Jag1 protein is less than about 10% of the binding of the antibody to Jag1 as measured, e.g., by a radioimmunoassay (RIA). In certain embodiments, an antibody that binds to Jag1 has a dissociation constant (Kd) of $\leq 1\mu M$, ≤ 100 nM, ≤ 10 nM, ≤ 1 nM, ≤ 0.1 nM, ≤ 0.01 nM, or ≤ 0.001 nM (e.g. 10^{-8} M or less, e.g. from 10^{-8} M to 10^{-13} M, e.g., from 10^{-9} M to 10^{-13} M). In certain embodiments, an anti- Jag1 antibody binds to an epitope of Jag1 that is conserved among Jag1 from different species.

An "anti-Jag1 antagonist antibody" is an anti-Jag1antibody that effects decreased Jag1-mediated signaling, e.g., Jag1-mediated Notch2 signaling.

The terms "anti-Notch2 antibody" and "an antibody that binds to Notch2" refer to an antibody that is capable of binding Notch2 with sufficient affinity such that the antibody is useful as a diagnostic and/or therapeutic agent in targeting Notch2. In one embodiment, the

extent of binding of an anti-Notch2 antibody to an unrelated, non- Notch2 protein is less than about 10% of the binding of the antibody to Notch2 as measured, e.g., by a radioimmunoassay (RIA). In certain embodiments, an antibody that binds to Notch2 has a dissociation constant (Kd) of $\leq 1\mu M$, ≤ 100 nM, ≤ 10 nM, ≤ 1 nM, ≤ 0.1 nM, ≤ 0.01 nM, or ≤ 0.001 nM (e.g. 10^{-8} M or less, e.g. from 10^{-8} M to 10^{-13} M, e.g., from 10^{-9} M to 10^{-13} M). In certain embodiments, an anti-Notch2 antibody binds to an epitope of Notch2 that is conserved among Notch2 from different species.

An "anti-Notch2 antagonist antibody" is an anti-Notch2 antibody (including an anti-Notch2 NRR antibody) that effects decreased Notch2 signaling, as defined below.

The term "antibody" herein is used in the broadest sense and encompasses various antibody structures, including but not limited to monoclonal antibodies, polyclonal antibodies, multispecific antibodies (e.g., bispecific antibodies), and antibody fragments so long as they exhibit the desired antigen-binding activity.

An "antibody fragment" refers to a molecule other than an intact antibody that comprises a portion of an intact antibody that binds the antigen to which the intact antibody binds. Examples of antibody fragments include but are not limited to Fv, Fab, Fab', Fab'-SH, $F(ab')_2$; diabodies; linear antibodies; single-chain antibody molecules (e.g. scFv); and multispecific antibodies formed from antibody fragments.

An "antibody that binds to the same epitope" as a reference antibody refers to an antibody that blocks binding of the reference antibody to its antigen in a competition assay by 50% or more, and conversely, the reference antibody blocks binding of the antibody to its antigen in a competition assay by 50% or more. An exemplary competition assay is provided herein.

A "blocking" antibody or an "antagonist" antibody is one which significantly inhibits (either partially or completely) a biological activity of the antigen it binds.

The term "chimeric" antibody refers to an antibody in which a portion of the heavy and/or light chain is derived from a particular source or species, while the remainder of the heavy and/or light chain is derived from a different source or species.

The terms "cancer" and "cancerous" refer to or describe the physiological condition in mammals that is typically characterized by unregulated cell growth/proliferation. Examples of liver cancer include, but are not limited to, hepatocellular carcinoma, hepatoma, hepatoblastoma, cholangiocarcinoma, hepatoblastoma, hepatic carcinoma, sarcoma, lymphoma and hepatic angiosarcoma. Liver cancer also includes cancer that originated in the liver and has metastasized to another part of the body.

The terms "cell proliferative disorder" and "proliferative disorder" refer to disorders that are associated with some degree of abnormal cell proliferation. In one embodiment, the cell proliferative disorder is cancer.

A "chemotherapeutic agent" refers to a chemical compound useful in the treatment of cancer. Examples of chemotherapeutic agents include alkylating agents such as thiotepa and cyclosphosphamide (CYTOXAN®); alkyl sulfonates such as busulfan, improsulfan and piposulfan; aziridines such as benzodopa, carboquone, meturedopa, and uredopa; ethylenimines and methylamelamines including altretamine, triethylenemelamine, triethylenephosphoramide, triethylenethiophosphoramide and trimethylomelamine; acetogenins (especially bullatacin and bullatacinone); delta-9-tetrahydrocannabinol (dronabinol, MARINOL®); beta-lapachone; lapachol; colchicines; betulinic acid; a camptothecin (including the synthetic analogue topotecan (HYCAMTIN®), CPT-11 (irinotecan, CAMPTOSAR®), acetylcamptothecin, scopolectin, and 9-aminocamptothecin); bryostatin; callystatin; CC-1065 (including its adozelesin, carzelesin and bizelesin synthetic analogues); podophyllotoxin; podophyllinic acid; teniposide; cryptophycins (particularly cryptophycin 1 and cryptophycin 8); dolastatin; duocarmycin (including the synthetic analogues, KW-2189 and CB1-TM1); eleutherobin; pancratistatin; a sarcodictyin; spongistatin; nitrogen mustards such as chlorambucil, chlornaphazine, chlorophosphamide, estramustine, ifosfamide, mechlorethamine, mechlorethamine oxide hydrochloride, melphalan, novembichin, phenesterine, prednimustine, trofosfamide, uracil mustard; nitrosoureas such as carmustine, chlorozotocin, fotemustine, lomustine, nimustine, and ranimnustine; antibiotics such as the enediyne antibiotics (e. g., calicheamicin, especially calicheamicin gamma1I and calicheamicin omegaI1 (see, e.g., Nicolaou *et al.*, *Angew. Chem Intl. Ed. Engl.*, 33: 183-186 (1994)); CDP323, an oral alpha-4 integrin inhibitor; dynemicin, including dynemicin A; an esperamicin; as well as neocarzinostatin chromophore and related chromoprotein enediyne antibiotic chromophores), aclacinomysins, actinomycin, authramycin, azaserine, bleomycins, cactinomycin, carabicin, carminomycin, carzinophilin, chromomycins, dactinomycin, daunorubicin, detorubicin, 6-diazo-5-oxo-L-norleucine, doxorubicin (including ADRIAMYCIN®, morpholino-doxorubicin, cyanomorpholino-doxorubicin, 2-pyrrolino-doxorubicin, doxorubicin HCl liposome injection (DOXIL®), liposomal doxorubicin TLC D-99 (MYOCET®), peglylated liposomal doxorubicin (CAELYX®), and deoxydoxorubicin), epirubicin, esorubicin, idarubicin, marcellomycin, mitomycins such as mitomycin C, mycophenolic acid, nogalamycin, olivomycins, peplomycin, porfiromycin, puromycin, quelamycin, rodorubicin, streptonigrin, streptozocin, tubercidin, ubenimex, zinostatin,

zorubicin; anti-metabolites such as methotrexate, gemcitabine (GEMZAR®), tegafur (UFTORAL®), capecitabine (XELODA®), an epothilone, and 5-fluorouracil (5-FU); folic acid analogues such as denopterin, methotrexate, pteropterin, trimetrexate; purine analogs such as fludarabine, 6-mercaptopurine, thiamiprine, thioguanine; pyrimidine analogs such as ancitabine, azacitidine, 6-azauridine, carmofur, cytarabine, dideoxyuridine, doxifluridine, enocitabine, floxuridine; androgens such as calusterone, dromostanolone propionate, epitiostanol, mepitiostane, testolactone; anti-adrenals such as aminoglutethimide, mitotane, trilostane; folic acid replenisher such as frolinic acid; aceglatone; aldophosphamide glycoside; aminolevulinic acid; eniluracil; amsacrine; bestrabucil; bisantrene; edatraxate; defofamine; demecolcine; diaziquone; elfornithine; elliptinium acetate; an epothilone; etoglucid; gallium nitrate; hydroxyurea; lentinan; lonidainine; maytansinoids such as maytansine and ansamitocins; mitoguazone; mitoxantrone; mopidanmol; nitraerine; pentostatin; phenamet; pirarubicin; losoxantrone; 2-ethylhydrazide; procarbazine; PSK® polysaccharide complex (JHS Natural Products, Eugene, OR); razoxane; rhizoxin; sizofiran; spirogermanium; tenuazonic acid; triaziquone; 2,2',2'-trichlorotriethylamine; trichothecenes (especially T-2 toxin, verracurin A, roridin A and anguidine); urethan; vindesine (ELDISINE®, FILDESIN®); dacarbazine; mannomustine; mitobronitol; mitolactol; pipobroman; gacytosine; arabinoside ("Ara-C"); thiotepa; taxoid, *e.g.*, paclitaxel (TAXOL®), albumin-engineered nanoparticle formulation of paclitaxel (ABRAXANE™), and docetaxel (TAXOTERE®); chloranbucil; 6-thioguanine; mercaptopurine; methotrexate; platinum agents such as cisplatin, oxaliplatin (e.g., ELOXATIN®), and carboplatin; vincas, which prevent tubulin polymerization from forming microtubules, including vinblastine (VELBAN®), vincristine (ONCOVIN®), vindesine (ELDISINE®, FILDESIN®), and vinorelbine (NAVELBINE®); etoposide (VP-16); ifosfamide; mitoxantrone; leucovorin; novantrone; edatrexate; daunomycin; aminopterin; ibandronate; topoisomerase inhibitor RFS 2000; difluoromethylornithine (DMFO); retinoids such as retinoic acid, including bexarotene (TARGRETIN®); bisphosphonates such as clodronate (for example, BONEFOS® or OSTAC®), etidronate (DIDROCAL®), NE-58095, zoledronic acid/zoledronate (ZOMETA®), alendronate (FOSAMAX®), pamidronate (AREDIA®), tiludronate (SKELID®), or risedronate (ACTONEL®); troxacitabine (a 1,3-dioxolane nucleoside cytosine analog); antisense oligonucleotides, particularly those that inhibit expression of genes in signaling pathways implicated in aberrant cell proliferation, such as, for example, PKC-alpha, Raf, H-Ras, and epidermal growth factor receptor (EGF-R); vaccines such as THERATOPE® vaccine and gene therapy vaccines, for example, ALLOVECTIN® vaccine, LEUVECTIN® vaccine, and VAXID® vaccine; topoisomerase 1

inhibitor (*e.g.*, LURTOTECAN®); rmRH (*e.g.*, ABARELIX®); BAY439006 (Sorafenib; Bayer); SU-11248 (sunitinib, SUTENT®, Pfizer); perifosine, COX-2 inhibitor (*e.g.* celecoxib or etoricoxib), proteosome inhibitor (*e.g.* PS341); bortezomib (VELCADE®); CCI-779; tipifarnib (R11577); orafenib, ABT510; Bcl-2 inhibitor such as oblimersen sodium (GENASENSE®); pixantrone; EGFR inhibitors (see definition below); tyrosine kinase inhibitors (see definition below); serine-threonine kinase inhibitors such as rapamycin (sirolimus, RAPAMUNE®); farnesyltransferase inhibitors such as lonafarnib (SCH 6636, SARASAR™); and pharmaceutically acceptable salts, acids or derivatives of any of the above; as well as combinations of two or more of the above such as CHOP, an abbreviation for a combined therapy of cyclophosphamide, doxorubicin, vincristine, and prednisolone; and FOLFOX, an abbreviation for a treatment regimen with oxaliplatin (ELOXATIN™) combined with 5-FU and leucovorin.

Chemotherapeutic agents as defined herein include "anti-hormonal agents" or "endocrine therapeutics" which act to regulate, reduce, block, or inhibit the effects of hormones that can promote the growth of cancer. They may be hormones themselves, including, but not limited to: anti-estrogens with mixed agonist/antagonist profile, including, tamoxifen (NOLVADEX®), 4-hydroxytamoxifen, toremifene (FARESTON®), idoxifene, droloxifene, raloxifene (EVISTA®), trioxifene, keoxifene, and selective estrogen receptor modulators (SERMs) such as SERM3; pure anti-estrogens without agonist properties, such as fulvestrant (FASLODEX®), and EM800 (such agents may block estrogen receptor (ER) dimerization, inhibit DNA binding, increase ER turnover, and/or suppress ER levels); aromatase inhibitors, including steroidal aromatase inhibitors such as formestane and exemestane (AROMASIN®), and nonsteroidal aromatase inhibitors such as anastrazole (ARIMIDEX®), letrozole (FEMARA®) and aminoglutethimide, and other aromatase inhibitors include vorozole (RIVISOR®), megestrol acetate (MEGASE®), fadrozole, and 4(5)-imidazoles; lutenizing hormone-releaseing hormone agonists, including leuprolide (LUPRON® and ELIGARD®), goserelin, buserelin, and tripterelin; sex steroids, including progestines such as megestrol acetate and medroxyprogesterone acetate, estrogens such as diethylstilbestrol and premarin, and androgens/retinoids such as fluoxymesterone, all transretionic acid and fenretinide; onapristone; anti-progesterones; estrogen receptor down-regulators (ERDs); anti-androgens such as flutamide, nilutamide and bicalutamide; and pharmaceutically acceptable salts, acids or derivatives of any of the above; as well as combinations of two or more of the above.

The "class" of an antibody refers to the type of constant domain or constant region possessed by its heavy chain. There are five major classes of antibodies: IgA, IgD, IgE, IgG,

and IgM, and several of these may be further divided into subclasses (isotypes), e.g., IgG_1, IgG_2, IgG_3, IgG_4, IgA_1, and IgA_2. The heavy chain constant domains that correspond to the different classes of immunoglobulins are called α, δ, ε, γ, and μ, respectively.

"Complement dependent cytotoxicity" or "CDC" refers to the lysis of a target cell in the presence of complement. Activation of the classical complement pathway is initiated by the binding of the first component of the complement system (C1q) to antibodies (of the appropriate subclass), which are bound to their cognate antigen. To assess complement activation, a CDC assay, *e.g.*, as described in Gazzano-Santoro *et al.*, *J. Immunol. Methods* 202:163 (1996), may be performed. Polypeptide variants with altered Fc region amino acid sequences (polypeptides with a variant Fc region) and increased or decreased C1q binding capability are described, *e.g.*, in US Patent No. 6,194,551 B1 and WO 1999/51642. See also, *e.g.*, Idusogie *et al. J. Immunol.* 164: 4178-4184 (2000).

The term "cytotoxic agent" as used herein refers to a substance that inhibits or prevents a cellular function and/or causes cell death or destruction. Cytotoxic agents include, but are not limited to, radioactive isotopes (e.g., At^{211}, I^{131}, I^{125}, Y^{90}, Re^{186}, Re^{188}, Sm^{153}, Bi^{212}, P^{32}, Pb^{212} and radioactive isotopes of Lu); chemotherapeutic agents or drugs (e.g., methotrexate, adriamicin, vinca alkaloids (vincristine, vinblastine, etoposide), doxorubicin, melphalan, mitomycin C, chlorambucil, daunorubicin or other intercalating agents); growth inhibitory agents; enzymes and fragments thereof such as nucleolytic enzymes; antibiotics; toxins such as small molecule toxins or enzymatically active toxins of bacterial, fungal, plant or animal origin, including fragments and/or variants thereof; and the various antitumor or anticancer agents disclosed below.

The term "cytostatic agent" refers to a compound or composition which arrests growth of a cell either in vitro or in vivo. Thus, a cytostatic agent may be one which significantly reduces the percentage of cells in S phase. Further examples of cytostatic agents include agents that block cell cycle progression by inducing G0/G1 arrest or M-phase arrest. The humanized anti-Her2 antibody trastuzumab (HERCEPTIN®) is an example of a cytostatic agent that induces G0/G1 arrest. Classical M-phase blockers include the vincas (vincristine and vinblastine), taxanes, and topoisomerase II inhibitors such as doxorubicin, epirubicin, daunorubicin, etoposide, and bleomycin. Certain agents that arrest G1 also spill over into S-phase arrest, for example, DNA alkylating agents such as tamoxifen, prednisone, dacarbazine, mechlorethamine, cisplatin, methotrexate, 5-fluorouracil, and ara-C. Further information can be found in Mendelsohn and Israel, eds., *The Molecular Basis of Cancer*, Chapter 1, entitled

"Cell cycle regulation, oncogenes, and antineoplastic drugs" by Murakami et al. (W.B. Saunders, Philadelphia, 1995), *e.g.*, p. 13. The taxanes (paclitaxel and docetaxel) are anticancer drugs both derived from the yew tree. Docetaxel (TAXOTERE®, Rhone-Poulenc Rorer), derived from the European yew, is a semisynthetic analogue of paclitaxel (TAXOL®, Bristol-Myers Squibb). Paclitaxel and docetaxel promote the assembly of microtubules from tubulin dimers and stabilize microtubules by preventing depolymerization, which results in the inhibition of mitosis in cells.

"Effector functions" refer to those biological activities attributable to the Fc region of an antibody, which vary with the antibody isotype. Examples of antibody effector functions include: C1q binding and complement dependent cytotoxicity (CDC); Fc receptor binding; antibody-dependent cell-mediated cytotoxicity (ADCC); phagocytosis; down regulation of cell surface receptors (e.g. B cell receptor); and B cell activation.

An "effective amount" of an agent, e.g., a pharmaceutical formulation, refers to an amount effective, at dosages and for periods of time necessary, to achieve the desired therapeutic or prophylactic result.

The term "expression" refers to conversion of the information encoded in a gene into messenger RNA (mRNA), and then to the protein.

Herein, a sample or cell that "expresses" a protein of interest is one in which mRNA encoding the protein, or the protein, including fragments thereof, is determined to be present in the sample or cell.

The term "Fc region" herein is used to define a C-terminal region of an immunoglobulin heavy chain that contains at least a portion of the constant region. The term includes native sequence Fc regions and variant Fc regions. In one embodiment, a human IgG heavy chain Fc region extends from Cys226, or from Pro230, to the carboxyl-terminus of the heavy chain. However, the C-terminal lysine (Lys447) of the Fc region may or may not be present. Unless otherwise specified herein, numbering of amino acid residues in the Fc region or constant region is according to the EU numbering system, also called the EU index, as described in Kabat et al., *Sequences of Proteins of Immunological Interest*, 5th Ed. Public Health Service, National Institutes of Health, Bethesda, MD, 1991.

"Framework" or "FR" refers to variable domain residues other than hypervariable region (HVR) residues. The FR of a variable domain generally consists of four FR domains: FR1, FR2, FR3, and FR4. Accordingly, the HVR and FR sequences generally appear in the following sequence in VH (or VL): FR1-H1(L1)-FR2-H2(L2)-FR3-H3(L3)-FR4.

The terms "full length antibody," "intact antibody," and "whole antibody" are used herein interchangeably to refer to an antibody having a structure substantially similar to a native antibody structure or having heavy chains that contain an Fc region as defined herein.

The terms "host cell," "host cell line," and "host cell culture" are used interchangeably and refer to cells into which exogenous nucleic acid has been introduced, including the progeny of such cells. Host cells include "transformants" and "transformed cells," which include the primary transformed cell and progeny derived therefrom without regard to the number of passages. Progeny may not be completely identical in nucleic acid content to a parent cell, but may contain mutations. Mutant progeny that have the same function or biological activity as screened or selected for in the originally transformed cell are included herein.

A "human antibody" is one which possesses an amino acid sequence which corresponds to that of an antibody produced by a human or a human cell or derived from a non-human source that utilizes human antibody repertoires or other human antibody-encoding sequences. This definition of a human antibody specifically excludes a humanized antibody comprising non-human antigen-binding residues.

A "human consensus framework" is a framework which represents the most commonly occurring amino acid residues in a selection of human immunoglobulin VL or VH framework sequences. Generally, the selection of human immunoglobulin VL or VH sequences is from a subgroup of variable domain sequences. Generally, the subgroup of sequences is a subgroup as in Kabat et al., *Sequences of Proteins of Immunological Interest*, Fifth Edition, NIH Publication 91-3242, Bethesda MD (1991), vols. 1-3. In one embodiment, for the VL, the subgroup is subgroup kappa I as in Kabat et al., *supra.* In one embodiment, for the VH, the subgroup is subgroup III as in Kabat et al., *supra*.

A "humanized" antibody refers to a chimeric antibody comprising amino acid residues from non-human HVRs and amino acid residues from human FRs. In certain embodiments, a humanized antibody will comprise substantially all of at least one, and typically two, variable domains, in which all or substantially all of the HVRs (e.g., CDRs) correspond to those of a non-human antibody, and all or substantially all of the FRs correspond to those of a human antibody. A humanized antibody optionally may comprise at least a portion of an antibody constant region derived from a human antibody. A "humanized form" of an antibody, e.g., a non-human antibody, refers to an antibody that has undergone humanization.

The term "hypervariable region" or "HVR" as used herein refers to each of the regions of an antibody variable domain which are hypervariable in sequence ("complementarity determining regions" or "CDRs") and/or form structurally defined loops ("hypervariable

loops") and/or contain the antigen-contacting residues ("antigen contacts"). Generally, antibodies comprise six HVRs: three in the VH (H1, H2, H3), and three in the VL (L1, L2, L3). Exemplary HVRs herein include:

(a) hypervariable loops occurring at amino acid residues 26-32 (L1), 50-52 (L2), 91-96 (L3), 26-32 (H1), 53-55 (H2), and 96-101 (H3) (Chothia and Lesk, *J. Mol. Biol.* 196:901-917 (1987));

(b) CDRs occurring at amino acid residues 24-34 (L1), 50-56 (L2), 89-97 (L3), 31-35b (H1), 50-65 (H2), and 95-102 (H3) (Kabat et al., *Sequences of Proteins of Immunological Interest*, 5th Ed. Public Health Service, National Institutes of Health, Bethesda, MD (1991));

(c) antigen contacts occurring at amino acid residues 27c-36 (L1), 46-55 (L2), 89-96 (L3), 30-35b (H1), 47-58 (H2), and 93-101 (H3) (MacCallum et al. *J. Mol. Biol.* 262: 732-745 (1996)); and

(d) combinations of (a), (b), and/or (c), including HVR amino acid residues 46-56 (L2), 47-56 (L2), 48-56 (L2), 49-56 (L2), 26-35 (H1), 26-35b (H1), 49-65 (H2), 93-102 (H3), and 94-102 (H3).

In one embodiment, HVR residues comprise those identified in Figures 12, 13, 20 and 21.

Unless otherwise indicated, HVR residues and other residues in the variable domain (e.g., FR residues) are numbered herein according to Kabat et al., *supra*.

An "immunoconjugate" is an antibody conjugated to one or more heterologous molecule(s), including but not limited to a cytotoxic agent.

An "individual" or "subject" is a mammal. Mammals include, but are not limited to, domesticated animals (e.g., cows, sheep, cats, dogs, and horses), primates (e.g., humans and non-human primates such as monkeys), rabbits, and rodents (e.g., mice and rats). In certain embodiments, the individual or subject is a human.

An "individual at risk of having liver cancer" refers to an individual having a higher than average propensity of acquiring liver cancer. Examples of individuals at risk of having liver cancer include, without limitation, individuals having hepatitis, e.g., hepatitis B or C, cirrhosis of the liver, benign liver tumors, hemangiomas, hepatic adenomas, and focal nodular hyperplasias.

The term "inhibit" means to decrease or reduce an activityu, function, and/or amount as compared to a reference.

"Inhibiting cell growth or proliferation" means decreasing a cell's growth or proliferation by at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 95%, or 100%, and includes inducing cell death.

An "isolated" antibody is one which has been separated from a component of its natural environment. In some embodiments, an antibody is purified to greater than 95% or 99% purity as determined by, for example, electrophoretic (e.g., SDS-PAGE, isoelectric focusing (IEF), capillary electrophoresis) or chromatographic (e.g., ion exchange or reverse phase HPLC). For review of methods for assessment of antibody purity, see, e.g., Flatman et al., *J. Chromatogr. B* 848:79-87 (2007).

An "isolated" nucleic acid refers to a nucleic acid molecule that has been separated from a component of its natural environment. An isolated nucleic acid includes a nucleic acid molecule contained in cells that ordinarily contain the nucleic acid molecule, but the nucleic acid molecule is present extrachromosomally or at a chromosomal location that is different from its natural chromosomal location.

"Isolated nucleic acid encoding an anti-Jag1 antibody" or "isolated nucleic acid encoding an anti-Notch2 antibody" refers to one or more nucleic acid molecules encoding antibody heavy and light chains (or fragments thereof), including such nucleic acid molecule(s) in a single vector or separate vectors, and such nucleic acid molecule(s) present at one or more locations in a host cell.

The term "Jagged" or "Jag," as used herein, refers to any native Jagged from any vertebrate source, including mammals such as primates (e.g. humans) and rodents (e.g., mice and rats), unless otherwise indicated. The term encompasses "full-length," unprocessed Jag as well as any form of Jagged that results from processing in the cell. The term also encompasses naturally occurring variants of Jagged, e.g., splice variants or allelic variants.

The term "Jagged1" or "Jag1," as used herein, refers to any native Jag1 from any vertebrate source, including mammals such as primates (e.g. humans) and rodents (e.g., mice and rats), unless otherwise indicated. The term encompasses "full-length," unprocessed Jag1 as well as any form of Jag1 that results from processing in the cell. The term also encompasses naturally occurring variants of Jag1, e.g., splice variants or allelic variants. The amino acid sequence of an exemplary human and murine Jag1 is shown in FIG. 9.

The term "level of expression" or "expression level" as used herein, refers to the amount of a polynucleotide, mRNA, or an amino acid product or protein in a biological sample.

The term "monoclonal antibody" as used herein refers to an antibody obtained from a population of substantially homogeneous antibodies, i.e., the individual antibodies comprising the population are identical and/or bind the same epitope, except for possible variant antibodies, e.g., containing naturally occurring mutations or arising during production of a monoclonal antibody preparation, such variants generally being present in minor amounts. In contrast to polyclonal antibody preparations, which typically include different antibodies directed against different determinants (epitopes), each monoclonal antibody of a monoclonal antibody preparation is directed against a single determinant on an antigen. Thus, the modifier "monoclonal" indicates the character of the antibody as being obtained from a substantially homogeneous population of antibodies, and is not to be construed as requiring production of the antibody by any particular method. For example, the monoclonal antibodies to be used in accordance with the present invention may be made by a variety of techniques, including but not limited to the hybridoma method, recombinant DNA methods, phage-display methods, and methods utilizing transgenic animals containing all or part of the human immunoglobulin loci, such methods and other exemplary methods for making monoclonal antibodies being described herein.

A "naked antibody" refers to an antibody that is not conjugated to a heterologous moiety (e.g., a cytotoxic moiety) or radiolabel. The naked antibody may be present in a pharmaceutical formulation.

"Native antibodies" refer to naturally occurring immunoglobulin molecules with varying structures. For example, native IgG antibodies are heterotetrameric glycoproteins of about 150,000 daltons, composed of two identical light chains and two identical heavy chains that are disulfide-bonded. From N- to C-terminus, each heavy chain has a variable region (VH), also called a variable heavy domain or a heavy chain variable domain, followed by three constant domains (CH1, CH2, and CH3). Similarly, from N- to C-terminus, each light chain has a variable region (VL), also called a variable light domain or a light chain variable domain, followed by a constant light (CL) domain. The light chain of an antibody may be assigned to one of two types, called kappa (κ) and lambda (λ), based on the amino acid sequence of its constant domain.

The term "Notch," as used herein, refers to any native Notch from any vertebrate source, including mammals such as primates (e.g. humans) and rodents (e.g., mice and rats), unless otherwise indicated. The term encompasses "full-length," unprocessed Notch as well as any form of Notch that results from processing in the cell. The term also encompasses naturally occurring variants of Notch, e.g., splice variants or allelic variants.

The term "Notch2," as used herein, refers to any native Notch2 from any vertebrate source, including mammals such as primates (e.g. humans) and rodents (e.g., mice and rats), unless otherwise indicated. The term encompasses "full-length," unprocessed Notch2 as well as any form of Notch2 that results from processing in the cell. The term also encompasses naturally occurring variants of Notch2, e.g., splice variants or allelic variants. The amino acid sequence of an exemplary human Notch2 is shown in FIG.8.

The term "Notch2 signaling inhibitor" refers to an agent that effects decreased Notch2 signaling, as defined above. Notch2 signaling inhibitors include Notch2-specific antagonists and Jag1-specific antagonists. A Notch2-specific antagonist decreases Notch2 signaling and does not significantly affect signaling by another Notch receptor (Notch1, 3, or 4 in mammals). Examples of Notch2-specific antagonist include agents that block Notch2 binding to a Notch2 ligand. A Jag1-specific antagonist decreases Jag1-mediated signaling. Examples of Jag1-specific antagonists include agents that bind Notch2. Pan-Notch inhibitors, such as gamma secretase inhibitors, are explicitly excluded from Notch2 signaling inhibitors defined herein.

The term "package insert" is used to refer to instructions customarily included in commercial packages of therapeutic products, that contain information about the indications, usage, dosage, administration, combination therapy, contraindications and/or warnings concerning the use of such therapeutic products.

"Percent (%) amino acid sequence identity" with respect to a reference polypeptide sequence is defined as the percentage of amino acid residues in a candidate sequence that are identical with the amino acid residues in the reference polypeptide sequence, after aligning the sequences and introducing gaps, if necessary, to achieve the maximum percent sequence identity, and not considering any conservative substitutions as part of the sequence identity. Alignment for purposes of determining percent amino acid sequence identity can be achieved in various ways that are within the skill in the art, for instance, using publicly available computer software such as BLAST, BLAST-2, ALIGN or Megalign (DNASTAR) software. Those skilled in the art can determine appropriate parameters for aligning sequences, including any algorithms needed to achieve maximal alignment over the full length of the sequences being compared. For purposes herein, however, % amino acid sequence identity values are generated using the sequence comparison computer program ALIGN-2. The ALIGN-2 sequence comparison computer program was authored by Genentech, Inc., and the source code has been filed with user documentation in the U.S. Copyright Office, Washington D.C., 20559, where it is registered under U.S. Copyright Registration No. TXU510087. The ALIGN-2 program is publicly available from Genentech, Inc., South San Francisco, California, or may be

compiled from the source code. The ALIGN-2 program should be compiled for use on a UNIX operating system, including digital UNIX V4.0D. All sequence comparison parameters are set by the ALIGN-2 program and do not vary.

In situations where ALIGN-2 is employed for amino acid sequence comparisons, the % amino acid sequence identity of a given amino acid sequence A to, with, or against a given amino acid sequence B (which can alternatively be phrased as a given amino acid sequence A that has or comprises a certain % amino acid sequence identity to, with, or against a given amino acid sequence B) is calculated as follows:

100 times the fraction X/Y

where X is the number of amino acid residues scored as identical matches by the sequence alignment program ALIGN-2 in that program's alignment of A and B, and where Y is the total number of amino acid residues in B. It will be appreciated that where the length of amino acid sequence A is not equal to the length of amino acid sequence B, the % amino acid sequence identity of A to B will not equal the % amino acid sequence identity of B to A. Unless specifically stated otherwise, all % amino acid sequence identity values used herein are obtained as described in the immediately preceding paragraph using the ALIGN-2 computer program.

The term "pharmaceutical formulation" refers to a preparation which is in such form as to permit the biological activity of an active ingredient contained therein to be effective, and which contains no additional components which are unacceptably toxic to a subject to which the formulation would be administered.

A "pharmaceutically acceptable carrier" refers to an ingredient in a pharmaceutical formulation, other than an active ingredient, which is nontoxic to a subject., A pharmaceutically acceptable carrier includes, but is not limited to, a buffer, excipient, stabilizer, or preservative.

"Relapsed" refers to the regression of the patient's illness back to its former diseased state, especially the return of symptoms following an apparent recovery or partial recovery. Unless otherwise indicted, relapsed state refers to the process of returning to or the return to illness before the previous treatment including, but not limited to, chemotherapies and stem cell transplantation treatments.

"Refractory" refers to the resistance or non-responsiveness of a disease or condition to a treatment (e.g., the number of neoplastic plasma cells increases even though treatment if given). Unless otherwise indicated, the term "refractory" refers a resistance or non-

responsiveness to any previous treatment including, but not limited to, chemotherapies and stem cell transplantation treatments.

The term "secreted phosphoprotein1" or "SPP1" or "osteopontin," as used herein, refers to any native SPP1 from any vertebrate source, including mammals such as primates (e.g. humans) and rodents (e.g., mice and rats), unless otherwise indicated. The term encompasses "full-length," unprocessed SPP1 as well as any form of SPP1 that results from processing in the cell. The term also encompasses naturally occurring variants of SPP1, e.g., splice variants or allelic variants. The amino acid sequence of an exemplary human SPP1 is shown in FIG.11.

The phrase "substantially reduced" or "substantially different," as used herein, refers to a sufficiently high degree of difference between two numeric values (generally one associated with a molecule and the other associated with a reference/comparator molecule) such that one of skill in the art would consider the difference between the two values to be of statistical significance within the context of the biological characteristic measured by said values (e.g., Kd values).

The term "substantially similar" or "substantially the same," as used herein, refers to a sufficiently high degree of similarity between two numeric values (for example, one associated with an antibody of the invention and the other associated with a reference/comparator antibody), such that one of skill in the art would consider the difference between the two values to be of little or no biological and/or statistical significance within the context of the biological characteristic measured by said values (*e.g.*, Kd values).

The term "tumor" refers to all neoplastic cell growth and proliferation, whether malignant or benign, and all pre-cancerous and cancerous cells and tissues. The terms "cancer," "cancerous," "cell proliferative disorder," "proliferative disorder" and "tumor" are not mutually exclusive as referred to herein.

As used herein, "treatment" (and grammatical variations thereof such as "treat" or "treating") refers to clinical intervention in an attempt to alter the natural course of the individual being treated, and can be performed either for prophylaxis or during the course of clinical pathology. Desirable effects of treatment include, but are not limited to, preventing occurrence or recurrence of disease, alleviation of symptoms, diminishment of any direct or indirect pathological consequences of the disease, preventing metastasis, decreasing the rate of disease progression, amelioration or palliation of the disease state, and remission or improved prognosis. In some embodiments, antibodies of the invention are used to delay development of a disease or to slow the progression of a disease.

The term "variable region" or "variable domain" refers to the domain of an antibody heavy or light chain that is involved in binding the antibody to antigen. The variable domains of the heavy chain and light chain (VH and VL, respectively) of a native antibody generally have similar structures, with each domain comprising four conserved framework regions (FRs) and three hypervariable regions (HVRs). (See, e.g., Kindt et al. *Kuby Immunology*, 6th ed., W.H. Freeman and Co., page 91 (2007).) A single VH or VL domain may be sufficient to confer antigen-binding specificity. Furthermore, antibodies that bind a particular antigen may be isolated using a VH or VL domain from an antibody that binds the antigen to screen a library of complementary VL or VH domains, respectively. See, e.g., Portolano et al., *J. Immunol.* 150:880-887 (1993); Clarkson et al., *Nature* 352:624-628 (1991).

The term "vector," as used herein, refers to a nucleic acid molecule capable of propagating another nucleic acid to which it is linked. The term includes the vector as a self-replicating nucleic acid structure as well as the vector incorporated into the genome of a host cell into which it has been introduced. Certain vectors are capable of directing the expression of nucleic acids to which they are operatively linked. Such vectors are referred to herein as "expression vectors."

II. COMPOSITIONS AND METHODS

In one aspect, the invention is based, in part, on inhibition of Notch pathway components for the treatment of liver cancer.

In one aspect, methods of treating a liver cancer in an individual in need thereof are provided, comprising the step of administering to the individual an effective amount of a Notch2 signaling inhibitor. In some embodiments, the liver cancer is hepatocellular carcinoma, hepatoma, cholangiocarcinoma, hepatoblastoma, hepatic carcinoma, hepatic angiosarcoma, or metastatic liver cancer. In some embodiments, the liver cancer is a refractory cancer.

Examples of Notch2 signaling inhibitors are known in the art and some are exemplified herein, including, but not limited to, soluble Notch receptors, soluble Notch ligand variants, *e.g.,* dominant negative ligand variants, aptamers or oligopeptides that bind Notch2 or Jag1, organic or inorganic molecules that interfere specifically with Notch2 signaling, anti-Notch2 antagonist antibodies and anti-Jag1 antagonist antibodies. Examples of Notch2-specfic antagonists include those described in U.S. Patent Application Publication No. US 2010/0111958 and Sjölund et al., J. Clin. Invest. 118(1):217–228 (2008).

In certain embodiments, the Notch2 signaling inhibitor is an anti-Notch2 antagonist antibody. In one such embodiment, the anti-Notch2 antagonist antibody is an antibody that

binds to the extracellular domain of Notch2 and effects decreased Notch2 signaling. In one such embodiment, the anti-Notch2 antagonist antibody is an anti-Notch2 NRR antibody. Anti-Notch2 NRR antibodies include, but are not limited to, any anti-Notch2 NRR antibodies disclosed in International Application Publication No. WO2010039832, which is expressly incorporated by reference herein in its entirety. Such antibodies include, but are not limited to anti-Notch2 NRR antibodies that bind to the LNR-A and HD-C domains of Notch2 NRR. Exemplary anti-Notch2 NRR antibodies are monoclonal antibodies designated herein as Antibody B, Antibody B-1, Antibody B-2, and Antibody B-3. Antibody B that binds to Notch2 NRR was isolated from a phage library. That antibody was affinity matured to generate Antibody B-1, Antibody B-2, and Antibody B-3. The sequences of the heavy chain and light chain hypervariable regions (HVRs) of Antibody B, Antibody B-1, Antibody B-2, and Antibody B-3 are shown in FIGs. 12 and 13, respectively. The sequences of the heavy and light chain variable domains of Antibody B, Antibody B-1, Antibody B-2, and Antibody B-3 are shown in FIGs. 14 and 15. Further embodiments of anti-Notch2 NRR antibodies are provided as follows.

In one aspect, an antagonist antibody that specifically binds to Notch2 NRR is provided, wherein the antibody comprises at least one, two, three, four, five, or six HVRs selected from:

(a) an HVR-H1 comprising the amino acid sequence of SEQ ID NO:1;

(b) an HVR-H2 comprising the amino acid sequence of SEQ ID NO:3;

(c) an HVR-H3 comprising the amino acid sequence of SEQ ID NO:4;

(d) an HVR-L1 comprising an amino acid sequence that conforms to the consensus sequence of SEQ ID NO:9;

(e) an HVR-L2 comprising an amino acid sequence that conforms to the consensus sequence of SEQ ID NO:14; and

(f) an HVR-L3 comprising an amino acid sequence that conforms to the consensus sequence of SEQ ID NO:19.

In a further aspect, the antibody comprises an HVR-H3 comprising the amino acid sequence of SEQ ID NO:4 and at least one, two, three, four, or five HVRs selected from (a), (b), (d), (e), and (f) above. In a further aspect, the antibody comprises (a), (b), (c), (d), (e), and (f) above. With respect to (a), (d), (e), and (f), any one or more of the following embodiments are contemplated: HVR-H1 comprises an amino acid sequence of SEQ ID NO:1; HVR-L1 comprises an amino acid sequence selected from SEQ ID NOs:5-8; HVR-L2 comprises an

amino acid sequence selected from SEQ ID NOs:10-13; and HVR-L3 comprises an amino acid sequence selected from SEQ ID NOs:15-18.

In another aspect, an antibody that specifically binds to Notch2 NRR is provided, wherein the antibody comprises an HVR-H1 comprising the amino acid sequence of SEQ ID NO:1, an HVR-H2 comprising the amino acid sequence of SEQ ID NO:3, and an HVR-H3 comprising the amino acid sequence of SEQ ID NO:4.

In another aspect, an antibody that specifically binds to Notch2 NRR is provided, wherein the antibody comprises an HVR-L1 comprising an amino acid sequence that conforms to the consensus sequence of SEQ ID NO:9, an HVR-L2 comprising an amino acid sequence that conforms to the consensus sequence of SEQ ID NO:14, and an HVR-L3 comprising an amino acid sequence that conforms to the consensus sequence of SEQ ID NO:19. The following embodiments are contemplated in any combination: HVR-L1 comprises an amino acid sequence selected from SEQ ID NOs:5-8; HVR-L2 comprises an amino acid sequence selected from SEQ ID NOs:10-13; and HVR-L3 comprises an amino acid sequence selected from SEQ ID NOs:15-18. In one embodiment, an antibody that binds to Notch2 NRR comprises an HVR-L1 comprising the amino acid sequence of SEQ ID NO:5; an HVR-L2 comprising the amino acid sequence of SEQ ID NO:10; and an HVR-L3 comprising the amino acid sequence of SEQ ID NO:15. In another embodiment, an antibody that binds to Notch2 NRR comprises an HVR-L1 comprising the amino acid sequence of SEQ ID NO:6; an HVR-L2 comprising the amino acid sequence of SEQ ID NO:11; and an HVR-L3 comprising the amino acid sequence of SEQ ID NO:16. In another embodiment, an antibody that binds to Notch2 NRR comprises an HVR-L1 comprising the amino acid sequence of SEQ ID NO:7; an HVR-L2 comprising the amino acid sequence of SEQ ID NO:12; and an HVR-L3 comprising the amino acid sequence of SEQ ID NO:17. In another embodiment, an antibody that binds to Notch2 NRR comprises an HVR-L1 comprising the amino acid sequence of SEQ ID NO:8; an HVR-L2 comprising the amino acid sequence of SEQ ID NO:13; and an HVR-L3 comprising the amino acid sequence of SEQ ID NO:18.

In one embodiment, an antibody that specifically binds to Notch2 NRR is provided, wherein the antibody comprises:

(a) an HVR-H1 comprising the amino acid sequence of SEQ ID NO:1;

(b) an HVR-H2 comprising the amino acid sequence of SEQ ID NO:3;

(c) an HVR-H3 comprising the amino acid sequence of SEQ ID NO:4;

(d) an HVR-L1 comprising the amino acid sequence of SEQ ID NO:5;

(e) an HVR-L2 comprising the amino acid sequence of SEQ ID NO:10; and

(f) an HVR-L3 comprising the amino acid sequence of SEQ ID NO:15.

In another embodiment, an antibody that specifically binds to Notch2 NRR is provided, wherein the antibody comprises:

(a) an HVR-H1 comprising the amino acid sequence of SEQ ID NO:1;

(b) an HVR-H2 comprising the amino acid sequence of SEQ ID NO:3;

(c) an HVR-H3 comprising the amino acid sequence of SEQ ID NO:4;

(d) an HVR-L1 comprising the amino acid sequence of SEQ ID NO:6;

(e) an HVR-L2 comprising the amino acid sequence of SEQ ID NO:11; and

(f) an HVR-L3 comprising the amino acid sequence of SEQ ID NO:16.

In another embodiment, an antibody that specifically binds to Notch2 NRR is provided, wherein the antibody comprises:

(a) an HVR-H1 comprising the amino acid sequence of SEQ ID NO:1;

(b) an HVR-H2 comprising the amino acid sequence of SEQ ID NO:3;

(c) an HVR-H3 comprising the amino acid sequence of SEQ ID NO:4;

(d) an HVR-L1 comprising the amino acid sequence of SEQ ID NO:7;

(e) an HVR-L2 comprising the amino acid sequence of SEQ ID NO:12; and

(f) an HVR-L3 comprising the amino acid sequence of SEQ ID NO:17.

In another embodiment, an antibody that specifically binds to Notch2 NRR is provided, wherein the antibody comprises:

(a) an HVR-H1 comprising the amino acid sequence of SEQ ID NO:1;

(b) an HVR-H2 comprising the amino acid sequence of SEQ ID NO:3;

(c) an HVR-H3 comprising the amino acid sequence of SEQ ID NO:4;

(d) an HVR-L1 comprising the amino acid sequence of SEQ ID NO:8;

(e) an HVR-L2 comprising the amino acid sequence of SEQ ID NO:13; and

(f) an HVR-L3 comprising the amino acid sequence of SEQ ID NO:18.

In certain embodiments, any of the above antibodies further comprises at least one framework selected from a VH subgroup III consensus framework and a VL subgroup I consensus framework.

In certain embodiments, an anti-Notch2 NRR antibody is affinity matured. For example, any one or more of the following substitutions in the indicated HVR positions (Kabat numbered) may be made in any combination:

- in HVR-L1 (SEQ ID NO:5): S28N; I29N or V; S30R or K; S31R; Y32F
- in HVR-L2 (SEQ ID NO:10): G50R; S53I or T; A55E
- in HVR-L3 (SEQ ID NO:15): S93I or R; L96S or H

The specific antibodies disclosed herein, Antibody B as well as affinity matured forms of Antibody B (B-1, B-2, and B-3), may undergo further affinity maturation. Accordingly, affinity matured forms of any of the antibodies described herein are provided.

In certain embodiments, the Notch2 signaling inhibitor is an anti-Jag1 antagonist antibody. In one such embodiment, the anti-Jag1 antagonist antibody is an antibody that binds to the extracellular domain of Jag1 and effects decreased Notch2 signaling. In one such embodiment, the anti-Jag1 antagonist antibody is an anti-Jag1 EGF1-4 antibody. Anti-Jag1 antibodies include, but are not limited to, any anti-Jag1 antibodies disclosed herein.

In further embodiments, the antibody is an anti-Jag1 antibody. In some embodiments, the antibody comprises at least one, two, three, four, five, or six HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO:81; (b) HVR-H2 comprising an amino acid sequence of SEQ ID NO:84; (c) HVR-H3 comprising an amino acid sequence of SEQ ID NO:87; (d) HVR-L1 comprising the amino acid sequence of SEQ ID NO:88; (e) HVR-L2 comprising the amino acid sequence of SEQ ID NO:89; and (f) HVR-L3 comprising an amino acid sequence of SEQ ID NO:92. In one embodiment, the antibody comprises: (a) an HVR-H1 comprising the amino acid sequence of SEQ ID NO:81; (b) an HVR-H2 comprising the amino acid sequence of SEQ ID NO:82; (c) an HVR-H3 comprising the amino acid sequence of SEQ ID NO:85; (d) an HVR-L1 comprising the amino acid sequence of SEQ ID NO:88; (e) an HVR-L2 comprising the amino acid sequence of SEQ ID NO:89; and (f) an HVR-L3 comprising the amino acid sequence of SEQ ID NO:90.

In one embodiment, the antibody comprises: (a) an HVR-H1 comprising the amino acid sequence of SEQ ID NO:81; (b) an HVR-H2 comprising the amino acid sequence of SEQ ID NO:82; (c) an HVR-H3 comprising the amino acid sequence of SEQ ID NO:86; (d) an HVR-L1 comprising the amino acid sequence of SEQ ID NO:88; (e) an HVR-L2 comprising the amino acid sequence of SEQ ID NO:89; and (f) an HVR-L3 comprising the amino acid sequence of SEQ ID NO:91. In one embodiment, the antibody comprises: (a) an HVR-H1 comprising the amino acid sequence of SEQ ID NO:81; (b) an HVR-H2 comprising the amino acid sequence of SEQ ID NO:83; (c) an HVR-H3 comprising the amino acid sequence of SEQ ID NO:85; (d) an HVR-L1 comprising the amino acid sequence of SEQ ID NO:88; (e) an HVR-L2 comprising the amino acid sequence of SEQ ID NO:89; and (f) an HVR-L3 comprising the amino acid sequence of SEQ ID NO:90.

In certain embodiments, an anti-Notch2 NRR antibody or anti-Jag1 antibody having any of the above HVR sequences can further comprise any suitable framework variable domain sequence, provided binding activity to Notch2 NRR and Jag1, respectively, is substantially

retained. In certain embodiments, an anti-Notch2 NRR antibody or anti-Jag1 antibody comprises a human variable heavy (VH) consensus framework sequence, as in any of the VH consensus framework sequences shown in FIGs. 16A and 16B. In one embodiment, the VH consensus framework sequence comprises a human subgroup III heavy chain framework consensus sequence, e.g., as shown in FIGs. 16A and 16B. In another embodiment, the VH consensus framework sequence comprises an "Acceptor 2" framework sequence, e.g., as shown in FIGs. 16A and 16B. In a particular embodiment, the VH framework consensus sequence comprises FR1-FR4 of Acceptor 2B or Acceptor 2D, wherein the FR4 comprises SEQ ID NO:35 (FIGs. 16A and 16B), with the last residue of SEQ ID NO:35 (S11) optionally being substituted with alanine. In a further particular embodiment, the VH framework consensus sequence comprises the sequences of SEQ ID NOs:50; 51; 57 or 59; and 35, wherein S11 of SEQ ID NO:35 is optionally substituted with alanine.

In certain embodiments, an anti-Notch2 NRR antibody or anti-Jag1 antibody having any of the above HVR sequences can further comprise a human variable light (VL) consensus framework sequence as shown in FIGs. 17. In one embodiment, the VL consensus framework sequence comprises a human VL kappa subgroup I consensus framework (κv1) sequence, e.g., as shown in FIGs. 17. In another embodiment, the VL framework consensus sequence comprises FR1-FR4 of huMAb4D5-8 as shown in FIGs. 18 or 19. In a particular embodiment, the VL framework consensus sequence comprises the sequences of SEQ ID NOs:60, 61, 62, and 63.

In another aspect, an anti-Notch2 NRR antibody comprises a heavy chain variable domain (VH) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NOs:20. In certain embodiments, a VH sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity contains substitutions (e.g., conservative substitutions), insertions, or deletions relative to the reference sequence, but an anti-Notch2 NRR antibody comprising that sequence retains the ability to bind to Notch2 NRR. In certain embodiments, a total of 1 to 10 amino acids have been substituted, inserted and/or deleted in the amino acid sequence of SEQ ID NOs:20. In certain embodiments, substitutions, insertions, or deletions occur in regions outside the HVRs (i.e., in the FRs). In a particular embodiment, the VH comprises one, two or three HVRs selected from: (a) an HVR-H1 comprising the amino acid sequence of SEQ ID NO:1, (b) an HVR-H2 comprising the amino acid sequence of SEQ ID NO:3, and (c) an HVR-H3 comprising the amino acid sequence of SEQ ID NO:4.

In another aspect, an antibody that specifically binds to Notch2 NRR is provided, wherein the antibody comprises a light chain variable domain (VL) having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to an amino acid sequence selected from SEQ ID NOs:22-25. In certain embodiments, a VL sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity contains substitutions (e.g., conservative substitutions), insertions, or deletions relative to the reference sequence, but an anti-Notch2 NRR antibody comprising that sequence retains the ability to bind to Notch2 NRR. In certain embodiments, a total of 1 to 10 amino acids have been substituted, inserted and/or deleted in an amino acid sequence selected from SEQ ID NOs:22-25. In certain embodiments, the substitutions, insertions, or deletions occur in regions outside the HVRs (i.e., in the FRs). In a particular embodiment, the VL comprises one, two or three HVRs selected from (a) an HVR-L1 comprising an amino acid sequence that conforms to the consensus sequence of SEQ ID NO:9; (b) an HVR-L2 comprising an amino acid sequence that conforms to the consensus sequence of SEQ ID NO:14; and (c) an HVR-L3 comprising an amino acid sequence that conforms to the consensus sequence of SEQ ID NO:19. In one such embodiment, the VL comprises one, two or three HVRs selected from (a) an HVR-L1 comprising an amino acid sequence selected from SEQ ID NOs:5-8; (b) an HVR-L2 comprising an amino acid sequence selected from SEQ ID NOs:10-13; and (c) an HVR-L3 comprising an amino acid sequence selected from SEQ ID NOs:15-18. In one such embodiment, the VL comprises one, two or three HVRs selected from (a) an HVR-L1 comprising the amino acid sequence of SEQ ID NO:5; (b) an HVR-L2 comprising the amino acid sequence of SEQ ID NO:10; and (c) an HVR-L3 comprising the amino acid sequence of SEQ ID NO:15. In another such embodiment, the VL comprises one, two or three HVRs selected from (a) an HVR-L1 comprising the amino acid sequence of SEQ ID NO:6; (b) an HVR-L2 comprising the amino acid sequence of SEQ ID NO:11; and (c) an HVR-L3 comprising the amino acid sequence of SEQ ID NO:16. In another such embodiment, the VL comprises one, two or three HVRs selected from (a) an HVR-L1 comprising the amino acid sequence of SEQ ID NO:7; (b) an HVR-L2 comprising the amino acid sequence of SEQ ID NO:12; and (c) an HVR-L3 comprising the amino acid sequence of SEQ ID NO:17. In another such embodiment, the VL comprises one, two or three HVRs selected from (a) an HVR-L1 comprising the amino acid sequence of SEQ ID NO:8; (b) an HVR-L2 comprising the amino acid sequence of SEQ ID NO:13; and (c) an HVR-L3 comprising the amino acid sequence of SEQ ID NO:18.

In certain embodiments of the variant VH and VL sequences provided above, substitutions, insertions, or deletions may occur within the HVRs. In such embodiments, substitutions, insertions, or deletions may occur within one or more HVRs so long as such alterations do not substantially reduce the ability of the antibody to bind antigen. For example, conservative alterations that do not substantially reduce binding affinity may be made in HVRs. In certain instances, alterations in HVRs may actually improve antibody affinity. Such alterations may be made in HVR "hotspots" (i.e., residues encoded by codons that undergo mutation at high frequency during the somatic maturation process) in order to increase antibody affinity. (See, e.g., Chowdhury, *Methods Mol. Biol.* 207:179-196, 2008.) In certain embodiments of the variant VH and VL sequences provided above, each HVR either is conserved (unaltered), or contains no more than a single amino acid substitution, insertion or deletion.

In another aspect, an antibody that specifically binds Notch2 NRR is provided, wherein the antibody comprises a VH as in any of the embodiments provided above, and a VL as in any of the embodiments provided above. In one embodiment, the antibody comprises a VH having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO:20, and a VL having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO:22. In one such embodiment, the VH comprises one, two or three HVRs selected from: (a) an HVR-H1 comprising the amino acid sequence of SEQ ID NO:1, (b) an HVR-H2 comprising the amino acid sequence of SEQ ID NO:3, and (c) an HVR-H3 comprising the amino acid sequence of SEQ ID NO:4, and the VL comprises one, two or three HVRs selected from (a) an HVR-L1 comprising the amino acid sequence of SEQ ID NO:5; (b) an HVR-L2 comprising the amino acid sequence of SEQ ID NO:10; and (c) an HVR-L3 comprising the amino acid sequence of SEQ ID NO:15. In a particular embodiment, the antibody comprises a VH comprising the amino acid sequence of SEQ ID NO:20, and a VL comprising the amino acid sequence of SEQ ID NO:22.

In another embodiment, an anti-Notch2 NRR antibody that specifically binds Notch2 NRR comprises a VH having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO:20, and a VL having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to an amino acid sequence selected from SEQ ID NOs:23-25. In one such embodiment, the VH comprises one, two or three HVRs selected from: (a) an HVR-H1 comprising the amino acid sequence of SEQ ID NO:1, (b) an HVR-H2 comprising the amino acid sequence of SEQ ID

NO:3, and (c) an HVR-H3 comprising the amino acid sequence of SEQ ID NO:4, and the VL comprises one, two or three HVRs selected from (a) an HVR-L1 comprising an amino acid sequence selected from SEQ ID NOs:6-8; (b) an HVR-L2 comprising an amino acid sequence selected from SEQ ID NOs:11-13; and (c) an HVR-L3 comprising an amino acid sequence selected from SEQ ID NOs:16-18. In particular embodiments, the antibody comprises a VH comprising the amino acid sequence of SEQ ID NO:20 and a VL comprising an amino acid sequence selected from SEQ ID NOs:23-25.

In another aspect, an antibody that specifically binds Jag1 is provided, wherein the antibody comprises a VH as in any of the embodiments provided above, and a VL as in any of the embodiments provided above. In one embodiment, the antibody comprises a VH having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to an amino acid sequence selected from SEQ ID NOs:93-95, and a VL having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to an amino acid sequence selected from SEQ ID NOs:96-98. In one such embodiment, the VH comprises one, two or three HVRs selected from: (a) an HVR-H1 comprising the amino acid sequence of SEQ ID NO:81, (b) an HVR-H2 comprising the amino acid sequence of SEQ ID NO:82, and (c) an HVR-H3 comprising the amino acid sequence of SEQ ID NO:85, and the VL comprises one, two or three HVRs selected from (a) an HVR-L1 comprising the amino acid sequence of SEQ ID NO:88; (b) an HVR-L2 comprising the amino acid sequence of SEQ ID NO:89; and (c) an HVR-L3 comprising the amino acid sequence of SEQ ID NO:90. In a particular embodiment, the antibody comprises a VH comprising the amino acid sequence of SEQ ID NO:93, and a VL comprising the amino acid sequence of SEQ ID NO:96.

In another embodiment, an anti-Jag1 antibody that specifically binds Jag1 comprises a VH having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO:94, and a VL having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO:97. In one such embodiment, the VH comprises one, two or three HVRs selected from: (a) an HVR-H1 comprising the amino acid sequence of SEQ ID NO:81, (b) an HVR-H2 comprising the amino acid sequence of SEQ ID NO:82, and (c) an HVR-H3 comprising the amino acid sequence of SEQ ID NO:86, and the VL comprises one, two or three HVRs selected from (a) an HVR-L1 comprising the amino acid sequence of SEQ ID NO:88; (b) an HVR-L2 comprising the amino acid sequence of SEQ ID NO:89; and (c) an HVR-L3 comprising the amino acid sequence of SEQ ID NO:91. In particular embodiments,

the antibody comprises a VH comprising the amino acid sequence of SEQ ID NO:94 and a VL comprising the amino acid sequence of SEQ ID NO:97.

In another embodiment, an anti-Jag1 antibody that specifically binds Jag1 comprises a VH having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO:95, and a VL having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO:98. In one such embodiment, the VH comprises one, two or three HVRs selected from: (a) an HVR-H1 comprising the amino acid sequence of SEQ ID NO:81, (b) an HVR-H2 comprising the amino acid sequence of SEQ ID NO:83, and (c) an HVR-H3 comprising the amino acid sequence of SEQ ID NO:85, and the VL comprises one, two or three HVRs selected from (a) an HVR-L1 comprising the amino acid sequence of SEQ ID NO:88; (b) an HVR-L2 comprising the amino acid sequence of SEQ ID NO:89; and (c) an HVR-L3 comprising the amino acid sequence of SEQ ID NO:90. In particular embodiments, the antibody comprises a VH comprising the amino acid sequence of SEQ ID NO:95 and a VL comprising the amino acid sequence of SEQ ID NO:98.

In certain embodiments, an affinity-matured form of any of the above antibodies is provided. In further embodiments, a recombinant protein that specifically binds Notch2 NRR or Jag1 is provided, wherein the recombinant protein comprises an antigen binding site(s) of any of the above antibodies. In one such embodiment, a recombinant protein comprises any one or more of the HVRs provided above.

In certain embodiments, a polynucleotide encoding any of the above antibodies is provided. In one embodiment, a vector comprising the polynucleotide is provided. In one embodiment, a host cell comprising the vector is provided. In one embodiment, the host cell is eukaryotic. In one embodiment, the host cell is a CHO cell. In one embodiment, a method of making an anti-Notch2 NRR antibody is provided, wherein the method comprises culturing the host cell under conditions suitable for expression of the polynucleotide encoding the antibody, and isolating the antibody.

In another embodiment, an isolated antibody is provided that binds to the same epitope as an antibody provided herein. In one embodiment, an isolated anti-Notch2 NRR antibody is provided that binds to the same epitope as an antibody selected from Antibody B, Antibody B-1, Antibody B-2, and Antibody B-3. In another embodiment, the invention provides an anti-Notch2 NRR antibody that competes for binding with an antibody selected from Antibody B, Antibody B-1, Antibody B-2, and Antibody B-3. In another embodiment, an isolated antibody is provided that binds to at least one domain selected from the LNR-A domain and the HD-C

domain of Notch2. In one such embodiment, the antibody binds to both the LNR-A domain and the HD-C domain. In another such embodiment, the antibody further binds to the LNR-B and/or HD-N domains.

In one embodiment, an isolated anti-Jag1 antibody is provided that binds to the same epitope as an antibody selected from Antibody A, Antibody A-1, and Antibody A-2. In another embodiment, the invention provides an anti-Jag1 antibody that competes for binding with an antibody selected from Antibody A, Antibody A-1, and Antibody A-2. In another embodiment, an isolated antibody is provided that binds to at least one domain selected from the DSL domain and the EGF domain of Jag1. In one such embodiment, the antibody binds to EGF1-4 of Jag1.

Any of the Notch2 signaling inhibitors provided herein may be used in the methods described herein.

The invention also provides methods for selecting a therapeutic treatment for a patient having a liver cancer, the method comprising determining expression of one or more of Notch2, Jag1 and SPP1 in a sample obtained from the patient. In some embodiments, the patient is selected for treatment with a Notch2 signaling inhibitor if expression of one or more of Notch2, Jag1 and SPP1 is detected in the patient sample. In some embodiments, elevated expression of one or more of Notch2, Jag1 and Spp1 in the sample obtained from the patient, relative to a control, identifies the patient as suitable for receiving treatment with a Notch2 signaling inhibitor, as described herein. In some embodiments, additional parameters, such as, *e.g.*, examination by a physician, histologic evaluation of a biopsy, determination of serum levels characterizing the liver cancer, are employed to identify the patient for receiving the Notch2 signaling inhibitor treatment.

In some embodiments, a sample or biopsy from the patient is analyzed for mRNA expression of one or more of Notch2, Jag1 and Spp1 using methods well known in the art, such as, *e.g.*, quantitative PCR analysis, and compared to expression of the same gene or genes in a biopsy obtained from a control individual or compared to a reference value. In some embodiments, expression is determined using enzyme linked immunosorbent assay (ELISA). In some embodiments, a sample or biopsy from the patient is analyzed for Notch2 activation, for example by detection of the activated form of Notch2 as described herein.

In one aspect, methods are provided for preventing liver cancer in an individual at risk of having liver cancer, comprising the step of administering to the individual an effective amount of a Notch2 signaling inhibitor. In some embodiments, the individual has a liver condition selected from the group consisting of hepatitis B or C, cirrhosis of the liver, benign

liver tumors, hemangiomas, hepatic adenomas, and focal nodular hyperplasia. In some embodiments, the method further comprises administering at least one additional therapeutic agent. Examples of additional therapeutic agents include growth inhibitory agents, such as cytotoxic agents, peptides, small-molecules and antibodies.

In another aspect, methods are provided for inhibiting the growth of a cell that expresses secreted phosphoprotein1 (SPP1), comprising contacting the cell with a Notch2 signaling inhibitor, thereby inhibiting growth of the cell. In one embodiment, SPP1 protein comprises the amino acid sequence shown in FIG. 11. In one embodiment, contacting the cell with the Notch2 signaling inhibitor reduces SPP1 expression in the cell. For example, contacting the cell with the Notch2 signaling inhibitor reduces SPP1 expression in the cell by at least about 50%, 60%, 70%, 80%, 90%, or 90%. The expression of SPP1 mRNA or protein can be determined by any method in the art. In some embodiments, the cell is a liver cancer cell. In some embodiments, the liver cancer cell expresses EpCAM, AFP, AFP and EpCAM, Notch2, Jag1, Notch2 and Jag1, nuclear Notch2 ICD, Ras, Prom1, Spp1, FoxM1, Plk1, ccnb1, Aurkb, Wnt2, Axin2, or Glul, or any combination thereof. In some embodiments, contacting the cell with the Notch2 signaling inhibitor results in a decrease in the expression in the cell of at least one of EpCAM, AFP, Notch2, Notch2 ICD, Jag1, Prom1, Spp1, FoxM1, Plk1, ccnb1 and Aurkb. In some embodiments, administering the Notch2 signaling inhibitor results in an increase in the expression in the cell of at least one of Wnt2, Axin2 and Glul. In some embodiments, expression is determined by RNAseq, microarray analysis, immunohistochemistry, enzyme-linked immunosorbent assay, and Western blotting.

In another aspect, methods are provided for therapeutically treating a mammal having a liver cancer comprising cells that express an Spp1 gene encoding a peptide comprising an amino acid sequence having at least 90% identity to the polypeptide shown in FIG. 11, comprising administering to the mammal a therapeutically effective amount of a Notch2 signaling inhibitor, thereby effectively treating the mammal.

In another aspect, methods are provided for treating or preventing a liver cell proliferative disorder associated with increased expression or activity of a protein having at least 90% amino acid sequence identity to the polypeptide shown in FIG. 8C, comprising administering to an individual in need of such treatment an effective amount of an anti-Jag1 antagonist antibody, thereby effectively treating or preventing the liver cell proliferative disorder. In some embodiments, the cell proliferative disorder is a cancer, such as liver cancer. In some embodiments the individual has a liver condition selected from the group consisting of

hepatitis B or C, cirrhosis of the liver, benign liver tumors, hemangiomas, hepatic adenomas, and focal nodular hyperplasia.

In one aspect, methods are provided for reducing serum SPP1 protein levels in an individual, the method comprising administering to the individual an effective amount of a Notch2 signaling inhibitor thereby reducing serum SPP1 levels in the individual. In some embodiments, reducing is relative to serum SPP1 levels in the individual prior to administering the Notch2 signaling inhibitor. In some embodiments, reducing is relative to a reference level. In one embodiment, the individual has a liver cancer. In one embodiment, the serum SPP1 protein levels prior to administering the Notch2 signaling inhibitor to the individual are at least about 80 ng/ml. In certain embodiments, the serum SPP1 protein levels prior to administering the Notch2 signaling inhibitor to the individual are between about 80 ng/ml and about 500 ng/ml, between about 86 ng/ml and about 250 ng/ml, between about 120 ng/ml and about 170 ng/ml, or about 165 ng/ml. In some embodiments, administering the Notch2 signaling inhibitor to the individual results in serum SPP1 protein levels of less than 80 ng/ml. In specific embodiments, serum SPP1 protein levels prior to administering the Notch2 signaling inhibitor are 24 hours prior to administering the Notch2 signaling inhibitor. Serum SPP1 protein levels prior to or following administration of the Notch2 signaling inhibitor may be determined by any appropriate method, such as enzyme-linked immunosorbent assay. In specific embodiments, serum SPP1 protein levels are reduced about one, two, three, six or 12 month after administering the Notch2 signaling inhibitor.

In one aspect, methods are provided for therapeutically treating a liver tumor in a mammal, wherein the growth of the liver tumor is at least in part dependent upon a growth potentiating effect of Notch2 signaling, comprising contacting the tumor with an antibody that binds to Notch2 or Jag1, thereby effectively treating the tumor. In one embodiment, binding of the antibody to the tumor antagonizes the growth-potentiating activity of Notch2.

In one aspect, methods are provided for preventing recurrence of liver cancer comprising administering to an individual who has been treated for liver cancer and who has elevated serum SPP1 protein levels an effective amount of a Notch2 signaling inhibitor. In one embodiment, the serum SPP1 protein levels of the individual are at least about 80 ng/ml. In certain embodiments, the serum SPP1 protein levels prior to administering the Notch2 signaling inhibitor to the individual are between about 80 ng/ml and about 500 ng/ml, between about 86 ng/ml and about 250 ng/ml, between about 120 ng/ml and about 170 ng/ml, or about 165 ng/ml. In some embodiments, administering the Notch2 signaling inhibitor to the individual results in serum SPP1 protein levels of less than 80 ng/ml.

In some aspects, methods are provided for treating an individual having a liver cancer, comprises the steps of administering to the individual a Notch2 signaling inhibitor; and determining Notch2 signaling, wherein a decrease in Notch2 signaling following treatment, compared to Notch2 signaling prior to treatment, is indicative of reduction of liver cancer in the individual. In some embodiments, Notch2 signaling is determined by measuring Notch2 ICD nuclear localization, e.g., by immunohistochemical analysis. In some embodiments, Notch2 signaling is determined by measuring expression of a gene selected from the group consisting of Notch2, Jag1, Hes and Hey1. In some embodiments, the liver cancer is hepatocellular carcinoma, hepatoma, cholangiocarcinoma, hepatoblastoma, hepatic carcinoma, hepatic angiosarcoma, and metastatic liver cancer. In some embodiments, the Notch2 signaling inhibitor is an siRNA, small-molecule inhibitor or antibody. In some embodiments, the antibody is an antagonist antibody, such as an anti-Notch2 antagonist antibody or an anti-Jag1 antagonist antibody.

In some aspects, methods for inhibiting cellular proliferation comprising treating mammalian liver cancer cells with an antibody to Notch2 or Jag1, whereby proliferation of the liver cancer cell is inhibited. In certain embodiments, the antibody is an anti-Notch2 or anti-Jag1 antagonist antibody is as described herein. In certain embodiments, the antibody is a human, humanized, or chimeric antibody. In certain embodiments, any of the antibodies of the above embodiments is an antibody fragment. In certain embodiments, the cells are in a patient. In certain embodiments, the cells are in a culture medium.

Notch2 signaling inhibitors of the invention, such as anti-Notch2 and anti-Jag1 antibodies, can be used either alone or in combination with other agents in a therapy. For instance, an antibody of the invention may be co-administered with at least one additional therapeutic agent.

Such combination therapies noted above encompass combined administration (where two or more therapeutic agents are included in the same or separate formulations), and separate administration, in which case, administration of the antagonist of the invention can occur prior to, simultaneously, and/or following, administration of the additional therapeutic agent and/or adjuvant. Notch2 signaling inhibitors of the invention can also be used in combination with radiation therapy.

The antagonist can be administered to a human patient by any known method, such as intravenous administration, *e.g.*, as a bolus or by continuous infusion over a period of time, by intramuscular, intraperitoneal, intracerobrospinal, subcutaneous, intra-articular, intrasynovial, intrathecal, oral, topical, or inhalation routes. The Notch2 signaling inhibitor might be

administered as a protein or as a nucleic acid encoding a protein (see, for example, International Application Publication No. WO96/07321). Other therapeutic regimens may be combined with the administration of the Notch2 signaling inhibitor. The combined administration includes co-administration, using separate formulations or a single pharmaceutical formulation, and consecutive administration in either order, wherein preferably there is a time period while both (or all) active agents simultaneously exert their biological activities. In some embodiments, such combined therapy results in a synergistic therapeutic effect.

The dosage and mode of administration will be chosen by the physician according to known criteria. The appropriate dosage of antibody, or other Notch2 signaling inhibitor, will depend on the type of disease to be treated, the severity and course of the disease, whether the antibody, oligopeptide or organic molecule is administered for preventive or therapeutic purposes, previous therapy, the patient's clinical history and response to the Notch2 signaling inhibitor, and the discretion of the attending physician. The Notch2 signaling inhibitor can be administered to the patient at one time or over a series of treatments.

Success of treatment of liver cancer can be monitored by assessing parameters of liver function and recovery. Such parameters include, but are not limited to, improved liver function tests, (*e.g.,* assessing serum albumin, bilirubin, bile acids, total protein, clotting times), liver enzymes (*e.g.,* alanine transaminase, aspartate transaminase, alkaline phosphatase, gamma glutamyl transpeptidase), histologic appearance (*e.g.,* needle biopsy showing improved hepatic architecture), and imaging modalities (*e.g.,* ultrasound, magnetic resonance imaging for fibrosis and liver size). Success of treatment can also be monitored by measuring serum levels of SPP1 protein, wherein a decrease in serum levels in a treated patient, compared to pre-treatment levels, indicate successful treatment.

In a further aspect, a Notch2 signaling inhibitor is an antibody used in any of the above embodiments that incorporates any of the features, singly or in combination, as described in Sections 1-7 below.

1. Antibody Affinity

In certain embodiments, an antibody provided herein has a dissociation constant (Kd) of $\leq 1\mu M$, ≤ 100 nM, ≤ 10 nM, ≤ 1 nM, ≤ 0.1 nM, ≤ 0.01 nM, or ≤ 0.001 nM (e.g. 10^{-8} M or less, e.g. from 10^{-8} M to 10^{-13} M, e.g., from 10^{-9} M to 10^{-13} M).

In one embodiment, Kd is measured by a radiolabeled antigen binding assay (RIA). In one embodiment, an RIA is performed with the Fab version of an antibody of interest and its

antigen. For example, solution binding affinity of Fabs for antigen is measured by equilibrating Fab with a minimal concentration of (^{125}I)-labeled antigen in the presence of a titration series of unlabeled antigen, then capturing bound antigen with an anti-Fab antibody-coated plate (see, e.g., Chen et al., *J. Mol. Biol.* 293:865-881(1999)). To establish conditions for the assay, MICROTITER® multi-well plates (Thermo Scientific) are coated overnight with 5 μg/ml of a capturing anti-Fab antibody (Cappel Labs) in 50 mM sodium carbonate (pH 9.6), and subsequently blocked with 2% (w/v) bovine serum albumin in PBS for two to five hours at room temperature (approximately 23°C). In a non-adsorbent plate (Nunc #269620), 100 pM or 26 pM [^{125}I]-antigen are mixed with serial dilutions of a Fab of interest (e.g., consistent with assessment of the anti-VEGF antibody, Fab-12, in Presta et al., *Cancer Res.* 57:4593-4599 (1997)). The Fab of interest is then incubated overnight; however, the incubation may continue for a longer period (e.g., about 65 hours) to ensure that equilibrium is reached. Thereafter, the mixtures are transferred to the capture plate for incubation at room temperature (e.g., for one hour). The solution is then removed and the plate washed eight times with 0.1% polysorbate 20 (TWEEN-20®) in PBS. When the plates have dried, 150 μl/well of scintillant (MICROSCINT-20 ™; Packard) is added, and the plates are counted on a TOPCOUNT ™ gamma counter (Packard) for ten minutes. Concentrations of each Fab that give less than or equal to 20% of maximal binding are chosen for use in competitive binding assays.

According to another embodiment, Kd is measured using a BIACORE® surface plasmon resonance assay. For example, an assay using a BIACORE®-2000 or a BIACORE ®-3000 (BIAcore, Inc., Piscataway, NJ) is performed at 25°C with immobilized antigen CM5 chips at ~10 response units (RU). In one embodiment, carboxymethylated dextran biosensor chips (CM5, BIACORE, Inc.) are activated with *N*-ethyl-*N'*- (3-dimethylaminopropyl)-carbodiimide hydrochloride (EDC) and *N*-hydroxysuccinimide (NHS) according to the supplier's instructions. Antigen is diluted with 10 mM sodium acetate, pH 4.8, to 5 μg/ml (~0.2 μM) before injection at a flow rate of 5 μl/minute to achieve approximately 10 response units (RU) of coupled protein. Following the injection of antigen, 1 M ethanolamine is injected to block unreacted groups. For kinetics measurements, two-fold serial dilutions of Fab (0.78 nM to 500 nM) are injected in PBS with 0.05% polysorbate 20 (TWEEN-20™) surfactant (PBST) at 25°C at a flow rate of approximately 25 μl/min. Association rates (k_{on}) and dissociation rates (k_{off}) are calculated using a simple one-to-one Langmuir binding model (BIACORE ® Evaluation Software version 3.2) by simultaneously fitting the association and dissociation sensorgrams. The equilibrium dissociation constant (Kd) is calculated as the ratio k_{off}/k_{on}. See, e.g., Chen et al., *J. Mol. Biol.* 293:865-881 (1999). If the on-rate exceeds 10^6

M^{-1} s^{-1} by the surface plasmon resonance assay above, then the on-rate can be determined by using a fluorescent quenching technique that measures the increase or decrease in fluorescence emission intensity (excitation = 295 nm; emission = 340 nm, 16 nm band-pass) at 25°C of a 20 nM anti-antigen antibody (Fab form) in PBS, pH 7.2, in the presence of increasing concentrations of antigen as measured in a spectrometer, such as a stop-flow equipped spectrophometer (Aviv Instruments) or a 8000-series SLM-AMINCO™ spectrophotometer (ThermoSpectronic) with a stirred cuvette.

2. Antibody Fragments

In certain embodiments, an antibody provided herein is an antibody fragment. Antibody fragments include, but are not limited to, Fab, Fab', Fab'-SH, $F(ab')_2$, Fv, and scFv fragments, and other fragments described below. For a review of certain antibody fragments, see Hudson et al. *Nat. Med.* 9:129-134 (2003). For a review of scFv fragments, see, e.g., Pluckthün, in *The Pharmacology of Monoclonal Antibodies*, vol. 113, Rosenburg and Moore eds., (Springer-Verlag, New York), pp. 269-315 (1994); see also WO 93/16185; and U.S. Patent Nos. 5,571,894 and 5,587,458. For discussion of Fab and $F(ab')_2$ fragments comprising salvage receptor binding epitope residues and having increased in vivo half-life, see U.S. Patent No. 5,869,046.

Diabodies are antibody fragments with two antigen-binding sites that may be bivalent or bispecific. See, for example, EP 404,097; WO 1993/01161; Hudson et al., *Nat. Med.* 9:129-134 (2003); and Hollinger et al., *Proc. Natl. Acad. Sci. USA* 90: 6444-6448 (1993). Triabodies and tetrabodies are also described in Hudson et al., *Nat. Med.* 9:129-134 (2003).

Single-domain antibodies are antibody fragments comprising all or a portion of the heavy chain variable domain or all or a portion of the light chain variable domain of an antibody. In certain embodiments, a single-domain antibody is a human single-domain antibody (Domantis, Inc., Waltham, MA; *see,* e.g., U.S. Patent No. 6,248,516 B1).

Antibody fragments can be made by various techniques, including but not limited to proteolytic digestion of an intact antibody as well as production by recombinant host cells (e.g. *E. coli* or phage), as described herein.

3. Chimeric and Humanized Antibodies

In certain embodiments, an antibody provided herein is a chimeric antibody. Certain chimeric antibodies are described, e.g., in U.S. Patent No. 4,816,567; and Morrison et al., *Proc. Natl. Acad. Sci. USA*, 81:6851-6855 (1984)). In one example, a chimeric antibody comprises a non-human variable region (e.g., a variable region derived from a mouse, rat, hamster, rabbit,

or non-human primate, such as a monkey) and a human constant region. In a further example, a chimeric antibody is a "class switched" antibody in which the class or subclass has been changed from that of the parent antibody. Chimeric antibodies include antigen-binding fragments thereof.

In certain embodiments, a chimeric antibody is a humanized antibody. Typically, a non-human antibody is humanized to reduce immunogenicity to humans, while retaining the specificity and affinity of the parental non-human antibody. Generally, a humanized antibody comprises one or more variable domains in which HVRs, e.g., CDRs, (or portions thereof) are derived from a non-human antibody, and FRs (or portions thereof) are derived from human antibody sequences. A humanized antibody optionally will also comprise at least a portion of a human constant region. In some embodiments, some FR residues in a humanized antibody are substituted with corresponding residues from a non-human antibody (e.g., the antibody from which the HVR residues are derived), e.g., to restore or improve antibody specificity or affinity.

Humanized antibodies and methods of making them are reviewed, e.g., in Almagro and Fransson, *Front. Biosci.* 13:1619-1633 (2008), and are further described, e.g., in Riechmann et al., *Nature* 332:323-329 (1988); Queen et al., *Proc. Nat'l Acad. Sci. USA* 86:10029-10033 (1989); US Patent Nos. 5, 821,337, 7,527,791, 6,982,321, and 7,087,409; Kashmiri *et al.*, *Methods* 36:25-34 (2005) (describing specificity determining region (SDR) grafting); Padlan, *Mol. Immunol.* 28:489-498 (1991) (describing "resurfacing"); Dall'Acqua et al., *Methods* 36:43-60 (2005) (describing "FR shuffling"); and Osbourn et al., *Methods* 36:61-68 (2005) and Klimka et al., *Br. J. Cancer*, 83:252-260 (2000) (describing the "guided selection" approach to FR shuffling).

Human framework regions that may be used for humanization include but are not limited to: framework regions selected using the "best-fit" method (see, e.g., Sims et al. *J. Immunol.* 151:2296 (1993)); framework regions derived from the consensus sequence of human antibodies of a particular subgroup of light or heavy chain variable regions (see, e.g., Carter et al. *Proc. Natl. Acad. Sci. USA*, 89:4285 (1992); and Presta et al. *J. Immunol.*, 151:2623 (1993)); human mature (somatically mutated) framework regions or human germline framework regions (see, e.g., Almagro and Fransson, *Front. Biosci.* 13:1619-1633 (2008)); and framework regions derived from screening FR libraries (see, e.g., Baca et al., *J. Biol. Chem.* 272:10678-10684 (1997) and Rosok et al., *J. Biol. Chem.* 271:22611-22618 (1996)).

4. Human Antibodies

In certain embodiments, an antibody provided herein is a human antibody. Human antibodies can be produced using various techniques known in the art. Human antibodies are described generally in van Dijk and van de Winkel, *Curr. Opin. Pharmacol.* 5: 368-74 (2001) and Lonberg, *Curr. Opin. Immunol.* 20:450-459 (2008).

Human antibodies may be prepared by administering an immunogen to a transgenic animal that has been modified to produce intact human antibodies or intact antibodies with human variable regions in response to antigenic challenge. Such animals typically contain all or a portion of the human immunoglobulin loci, which replace the endogenous immunoglobulin loci, or which are present extrachromosomally or integrated randomly into the animal's chromosomes. In such transgenic mice, the endogenous immunoglobulin loci have generally been inactivated. For review of methods for obtaining human antibodies from transgenic animals, see Lonberg, *Nat. Biotech.* 23:1117-1125 (2005). See also, e.g., U.S. Patent Nos. 6,075,181 and 6,150,584 describing XENOMOUSE™ technology; U.S. Patent No. 5,770,429 describing HUMAB® technology; U.S. Patent No. 7,041,870 describing K-M MOUSE® technology, and U.S. Patent Application Publication No. US 2007/0061900, describing VELOCIMOUSE® technology). Human variable regions from intact antibodies generated by such animals may be further modified, e.g., by combining with a different human constant region.

Human antibodies can also be made by hybridoma-based methods. Human myeloma and mouse-human heteromyeloma cell lines for the production of human monoclonal antibodies have been described. (See, e.g., Kozbor *J. Immunol.*, 133: 3001 (1984); Brodeur et al., *Monoclonal Antibody Production Techniques and Applications*, pp. 51-63 (Marcel Dekker, Inc., New York, 1987); and Boerner et al., *J. Immunol.*, 147: 86 (1991).) Human antibodies generated via human B-cell hybridoma technology are also described in Li et al., *Proc. Natl. Acad. Sci. USA*, 103:3557-3562 (2006). Additional methods include those described, for example, in U.S. Patent No. 7,189,826 (describing production of monoclonal human IgM antibodies from hybridoma cell lines) and Ni, *Xiandai Mianyixue*, 26(4):265-268 (2006) (describing human-human hybridomas). Human hybridoma technology (Trioma technology) is also described in Vollmers and Brandlein, *Histology and Histopathology*, 20(3):927-937 (2005) and Vollmers and Brandlein, *Methods and Findings in Experimental and Clinical Pharmacology*, 27(3):185-91 (2005).

Human antibodies may also be generated by isolating Fv clone variable domain sequences selected from human-derived phage display libraries. Such variable domain sequences may then be combined with a desired human constant domain. Techniques for selecting human antibodies from antibody libraries are described below.

5. Library-Derived Antibodies

Antibodies of the invention may be isolated by screening combinatorial libraries for antibodies with the desired activity or activities. For example, a variety of methods are known in the art for generating phage display libraries and screening such libraries for antibodies possessing the desired binding characteristics. Such methods are reviewed, e.g., in Hoogenboom et al. in *Methods in Molecular Biology* 178:1-37 (O'Brien et al., ed., Human Press, Totowa, NJ, 2001) and further described, e.g., in the McCafferty et al., *Nature* 348:552-554; Clackson et al., *Nature* 352: 624-628 (1991); Marks et al., *J. Mol. Biol.* 222: 581-597 (1992); Marks and Bradbury, in *Methods in Molecular Biology* 248:161-175 (Lo, ed., Human Press, Totowa, NJ, 2003); Sidhu et al., *J. Mol. Biol.* 338(2): 299-310 (2004); Lee et al., *J. Mol. Biol.* 340(5): 1073-1093 (2004); Fellouse, *Proc. Natl. Acad. Sci. USA* 101(34): 12467-12472 (2004); and Lee et al., *J. Immunol. Methods* 284(1-2): 119-132(2004).

In certain phage display methods, repertoires of VH and VL genes are separately cloned by polymerase chain reaction (PCR) and recombined randomly in phage libraries, which can then be screened for antigen-binding phage as described in Winter et al., *Ann. Rev. Immunol.*, 12: 433-455 (1994). Phage typically display antibody fragments, either as single-chain Fv (scFv) fragments or as Fab fragments. Libraries from immunized sources provide high-affinity antibodies to the immunogen without the requirement of constructing hybridomas. Alternatively, the naive repertoire can be cloned (e.g., from human) to provide a single source of antibodies to a wide range of non-self and also self antigens without any immunization as described by Griffiths et al., *EMBO J,* 12: 725-734 (1993). Finally, naive libraries can also be made synthetically by cloning unrearranged V-gene segments from stem cells, and using PCR primers containing random sequence to encode the highly variable CDR3 regions and to accomplish rearrangement *in vitro*, as described by Hoogenboom and Winter, *J. Mol. Biol.*, 227: 381-388 (1992). Patent publications describing human antibody phage libraries include, for example: US Patent No. 5,750,373, and US Patent Publication Nos. 2005/0079574, 2005/0119455, 2005/0266000, 2007/0117126, 2007/0160598, 2007/0237764, 2007/0292936, and 2009/0002360.

Antibodies or antibody fragments isolated from human antibody libraries are considered human antibodies or human antibody fragments herein.

6. Multispecific Antibodies

In certain embodiments, an antibody provided herein is a multispecific antibody, e.g. a bispecific antibody. Multispecific antibodies are monoclonal antibodies that have binding specificities for at least two different sites. In certain embodiments, one of the binding specificities is for Jag1 and the other is for any other antigen. In certain embodiments, one of the binding specificities is for Notch2 and the other is for any other antigen. In certain embodiments, bispecific antibodies may bind to two different epitopes of Jag1. In certain embodiments, bispecific antibodies may bind to two different epitopes of Notch2. Bispecific antibodies may also be used to localize cytotoxic agents to cells which express Jag1 and/or Notch2. Bispecific antibodies can be prepared as full length antibodies or antibody fragments.

Techniques for making multispecific antibodies include, but are not limited to, recombinant co-expression of two immunoglobulin heavy chain-light chain pairs having different specificities (see Milstein and Cuello, *Nature* 305: 537 (1983)), WO 93/08829, and Traunecker et al., *EMBO J.* 10: 3655 (1991)), and "knob-in-hole" engineering (see, e.g., U.S. Patent No. 5,731,168). Multi-specific antibodies may also be made by engineering electrostatic steering effects for making antibody Fc-heterodimeric molecules (WO 2009/089004A1); cross-linking two or more antibodies or fragments (see, e.g., US Patent No. 4,676,980, and Brennan et al., *Science*, 229: 81 (1985)); using leucine zippers to produce bi-specific antibodies (see, e.g., Kostelny et al., *J. Immunol.*, 148(5):1547-1553 (1992)); using "diabody" technology for making bispecific antibody fragments (see, e.g., Hollinger et al., *Proc. Natl. Acad. Sci. USA*, 90:6444-6448 (1993)); and using single-chain Fv (sFv) dimers (see, e.g. Gruber et al., *J. Immunol.*, 152:5368 (1994)); and preparing trispecific antibodies as described, e.g., in Tutt et al. *J. Immunol.* 147: 60 (1991).

Engineered antibodies with three or more functional antigen binding sites, including "Octopus antibodies," are also included herein (see, e.g. US 2006/0025576A1).

The antibody or fragment herein also includes a "Dual Acting FAb" or "DAF" comprising an antigen binding site that binds to Jag1 or Notch2, as well as another, different antigen (see, US 2008/0069820, for example).

7. Antibody Variants

In certain embodiments, amino acid sequence variants of the antibodies provided herein are contemplated. For example, it may be desirable to improve the binding affinity and/or

other biological properties of the antibody. Amino acid sequence variants of an antibody may be prepared by introducing appropriate modifications into the nucleotide sequence encoding the antibody, or by peptide synthesis. Such modifications include, for example, deletions from, and/or insertions into and/or substitutions of residues within the amino acid sequences of the antibody. Any combination of deletion, insertion, and substitution can be made to arrive at the final construct, provided that the final construct possesses the desired characteristics, e.g., antigen-binding.

a) Substitution, Insertion, and Deletion Variants

In certain embodiments, antibody variants having one or more amino acid substitutions are provided. Sites of interest for substitutional mutagenesis include the HVRs and FRs. Conservative substitutions are shown in Table 1 under the heading of "preferred substitutions." More substantial changes are provided in Table 1 under the heading of "exemplary substitutions," and as further described below in reference to amino acid side chain classes. Amino acid substitutions may be introduced into an antibody of interest and the products screened for a desired activity, e.g., retained/improved antigen binding, decreased immunogenicity, or improved ADCC or CDC.

TABLE 1

Original Residue	Exemplary Substitutions	Preferred Substitutions
Ala (A)	Val; Leu; Ile	Val
Arg (R)	Lys; Gln; Asn	Lys
Asn (N)	Gln; His; Asp, Lys; Arg	Gln
Asp (D)	Glu; Asn	Glu
Cys (C)	Ser; Ala	Ser
Gln (Q)	Asn; Glu	Asn
Glu (E)	Asp; Gln	Asp
Gly (G)	Ala	Ala
His (H)	Asn; Gln; Lys; Arg	Arg
Ile (I)	Leu; Val; Met; Ala; Phe; Norleucine	Leu
Leu (L)	Norleucine; Ile; Val; Met; Ala; Phe	Ile
Lys (K)	Arg; Gln; Asn	Arg
Met (M)	Leu; Phe; Ile	Leu
Phe (F)	Trp; Leu; Val; Ile; Ala; Tyr	Tyr
Pro (P)	Ala	Ala

Original Residue	Exemplary Substitutions	Preferred Substitutions
Ser (S)	Thr	Thr
Thr (T)	Val; Ser	Ser
Trp (W)	Tyr; Phe	Tyr
Tyr (Y)	Trp; Phe; Thr; Ser	Phe
Val (V)	Ile; Leu; Met; Phe; Ala; Norleucine	Leu

Amino acids may be grouped according to common side-chain properties:

(1) hydrophobic: Norleucine, Met, Ala, Val, Leu, Ile;

(2) neutral hydrophilic: Cys, Ser, Thr, Asn, Gln;

(3) acidic: Asp, Glu;

(4) basic: His, Lys, Arg;

(5) residues that influence chain orientation: Gly, Pro;

(6) aromatic: Trp, Tyr, Phe.

Non-conservative substitutions will entail exchanging a member of one of these classes for another class.

One type of substitutional variant involves substituting one or more hypervariable region residues of a parent antibody (*e.g.* a humanized or human antibody). Generally, the resulting variant(s) selected for further study will have modifications (e.g., improvements) in certain biological properties (e.g., increased affinity, reduced immunogenicity) relative to the parent antibody and/or will have substantially retained certain biological properties of the parent antibody. An exemplary substitutional variant is an affinity matured antibody, which may be conveniently generated, e.g., using phage display-based affinity maturation techniques such as those described herein. Briefly, one or more HVR residues are mutated and the variant antibodies displayed on phage and screened for a particular biological activity (e.g. binding affinity).

Alterations (e.g., substitutions) may be made in HVRs, e.g., to improve antibody affinity. Such alterations may be made in HVR "hotspots," i.e., residues encoded by codons that undergo mutation at high frequency during the somatic maturation process (see, e.g., Chowdhury, *Methods Mol. Biol.* 207:179-196 (2008)), and/or residues that contact antigen, with the resulting variant VH or VL being tested for binding affinity. Affinity maturation by constructing and reselecting from secondary libraries has been described, e.g., in Hoogenboom et al. in *Methods in Molecular Biology* 178:1-37 (O'Brien et al., ed., Human Press, Totowa, NJ, (2001).) In some embodiments of affinity maturation, diversity is introduced into the

variable genes chosen for maturation by any of a variety of methods (e.g., error-prone PCR, chain shuffling, or oligonucleotide-directed mutagenesis). A secondary library is then created. The library is then screened to identify any antibody variants with the desired affinity. Another method to introduce diversity involves HVR-directed approaches, in which several HVR residues (e.g., 4-6 residues at a time) are randomized. HVR residues involved in antigen binding may be specifically identified, e.g., using alanine scanning mutagenesis or modeling. CDR-H3 and CDR-L3 in particular are often targeted.

In certain embodiments, substitutions, insertions, or deletions may occur within one or more HVRs so long as such alterations do not substantially reduce the ability of the antibody to bind antigen. For example, conservative alterations (e.g., conservative substitutions as provided herein) that do not substantially reduce binding affinity may be made in HVRs. Such alterations may, for example, be outside of antigen contacting residues in the HVRs. In certain embodiments of the variant VH and VL sequences provided above, each HVR either is unaltered, or contains no more than one, two or three amino acid substitutions.

A useful method for identification of residues or regions of an antibody that may be targeted for mutagenesis is called "alanine scanning mutagenesis" as described by Cunningham and Wells (1989) *Science*, 244:1081-1085. In this method, a residue or group of target residues (e.g., charged residues such as arg, asp, his, lys, and glu) are identified and replaced by a neutral or negatively charged amino acid (e.g., alanine or polyalanine) to determine whether the interaction of the antibody with antigen is affected. Further substitutions may be introduced at the amino acid locations demonstrating functional sensitivity to the initial substitutions. Alternatively, or additionally, a crystal structure of an antigen-antibody complex to identify contact points between the antibody and antigen. Such contact residues and neighboring residues may be targeted or eliminated as candidates for substitution. Variants may be screened to determine whether they contain the desired properties.

Amino acid sequence insertions include amino- and/or carboxyl-terminal fusions ranging in length from one residue to polypeptides containing a hundred or more residues, as well as intrasequence insertions of single or multiple amino acid residues. Examples of terminal insertions include an antibody with an N-terminal methionyl residue. Other insertional variants of the antibody molecule include the fusion to the N- or C-terminus of the antibody to an enzyme (e.g. for ADEPT) or a polypeptide which increases the serum half-life of the antibody.

b) Glycosylation variants

In certain embodiments, an antibody provided herein is altered to increase or decrease the extent to which the antibody is glycosylated. Addition or deletion of glycosylation sites to an antibody may be conveniently accomplished by altering the amino acid sequence such that one or more glycosylation sites is created or removed.

Where the antibody comprises an Fc region, the carbohydrate attached thereto may be altered. Native antibodies produced by mammalian cells typically comprise a branched, biantennary oligosaccharide that is generally attached by an N-linkage to Asn297 of the CH2 domain of the Fc region. See, e.g., Wright et al. *TIBTECH* 15:26-32 (1997). The oligosaccharide may include various carbohydrates, e.g., mannose, N-acetyl glucosamine (GlcNAc), galactose, and sialic acid, as well as a fucose attached to a GlcNAc in the "stem" of the biantennary oligosaccharide structure. In some embodiments, modifications of the oligosaccharide in an antibody of the invention may be made in order to create antibody variants with certain improved properties.

In one embodiment, antibody variants are provided having a carbohydrate structure that lacks fucose attached (directly or indirectly) to an Fc region. For example, the amount of fucose in such antibody may be from 1% to 80%, from 1% to 65%, from 5% to 65% or from 20% to 40%. The amount of fucose is determined by calculating the average amount of fucose within the sugar chain at Asn297, relative to the sum of all glycostructures attached to Asn 297 (e. g. complex, hybrid and high mannose structures) as measured by MALDI-TOF mass spectrometry, as described in WO 2008/077546, for example. Asn297 refers to the asparagine residue located at about position 297 in the Fc region (Eu numbering of Fc region residues); however, Asn297 may also be located about ± 3 amino acids upstream or downstream of position 297, i.e., between positions 294 and 300, due to minor sequence variations in antibodies. Such fucosylation variants may have improved ADCC function. See, e.g., US Patent Publication Nos. US 2003/0157108 (Presta, L.); US 2004/0093621 (Kyowa Hakko Kogyo Co., Ltd). Examples of publications related to "defucosylated" or "fucose-deficient" antibody variants include: US 2003/0157108; WO 2000/61739; WO 2001/29246; US 2003/0115614; US 2002/0164328; US 2004/0093621; US 2004/0132140; US 2004/0110704; US 2004/0110282; US 2004/0109865; WO 2003/085119; WO 2003/084570; WO 2005/035586; WO 2005/035778; WO2005/053742; WO2002/031140; Okazaki et al. *J. Mol. Biol.* 336:1239-1249 (2004); Yamane-Ohnuki et al. *Biotech. Bioeng.* 87: 614 (2004). Examples of cell lines capable of producing defucosylated antibodies include Lec13 CHO cells deficient in protein fucosylation (Ripka et al. *Arch. Biochem. Biophys.* 249:533-545 (1986); US

Pat Appl No US 2003/0157108 A1, Presta, L; and WO 2004/056312 A1, Adams *et al.*, especially at Example 11), and knockout cell lines, such as alpha-1,6-fucosyltransferase gene, *FUT8,* knockout CHO cells (see, e.g., Yamane-Ohnuki et al. *Biotech. Bioeng.* 87: 614 (2004); Kanda, Y. et al., *Biotechnol. Bioeng.*, 94(4):680-688 (2006); and WO2003/085107).

Antibodies variants are further provided with bisected oligosaccharides, e.g., in which a biantennary oligosaccharide attached to the Fc region of the antibody is bisected by GlcNAc. Such antibody variants may have reduced fucosylation and/or improved ADCC function. Examples of such antibody variants are described, e.g., in WO 2003/011878 (Jean-Mairet et al.); US Patent No. 6,602,684 (Umana et al.); and US 2005/0123546 (Umana *et al.*). Antibody variants with at least one galactose residue in the oligosaccharide attached to the Fc region are also provided. Such antibody variants may have improved CDC function. Such antibody variants are described, e.g., in WO 1997/30087 (Patel et al.); WO 1998/58964 (Raju, S.); and WO 1999/22764 (Raju, S.).

c) Fc region variants

In certain embodiments, one or more amino acid modifications may be introduced into the Fc region of an antibody provided herein, thereby generating an Fc region variant. The Fc region variant may comprise a human Fc region sequence (*e.g.*, a human IgG1, IgG2, IgG3 or IgG4 Fc region) comprising an amino acid modification (*e.g.* a substitution) at one or more amino acid positions.

In certain embodiments, the invention contemplates an antibody variant that possesses some but not all effector functions, which make it a desirable candidate for applications in which the half life of the antibody *in vivo* is important yet certain effector functions (such as complement and ADCC) are unnecessary or deleterious. *In vitro* and/or *in vivo* cytotoxicity assays can be conducted to confirm the reduction/depletion of CDC and/or ADCC activities. For example, Fc receptor (FcR) binding assays can be conducted to ensure that the antibody lacks FcγR binding (hence likely lacking ADCC activity), but retains FcRn binding ability. The primary cells for mediating ADCC, NK cells, express FcγRIII only, whereas monocytes express FcγRI, FcγRII and FcγRIII. FcR expression on hematopoietic cells is summarized in Table 3 on page 464 of Ravetch and Kinet, *Annu. Rev. Immunol.* 9:457-492 (1991). Non-limiting examples of *in vitro* assays to assess ADCC activity of a molecule of interest is described in U.S. Patent No. 5,500,362 (see, e.g. Hellstrom, I. et al. *Proc. Nat'l Acad. Sci. USA* 83:7059-7063 (1986)) and Hellstrom, I et al., *Proc. Nat'l Acad. Sci. USA* 82:1499-1502 (1985); 5,821,337 (see Bruggemann, M. et al., *J. Exp. Med.* 166:1351-1361 (1987)). Alternatively,

non-radioactive assays methods may be employed (see, for example, ACTI™ non-radioactive cytotoxicity assay for flow cytometry (CellTechnology, Inc. Mountain View, CA; and CytoTox 96® non-radioactive cytotoxicity assay (Promega, Madison, WI). Useful effector cells for such assays include peripheral blood mononuclear cells (PBMC) and Natural Killer (NK) cells. Alternatively, or additionally, ADCC activity of the molecule of interest may be assessed *in vivo*, *e.g.*, in a animal model such as that disclosed in Clynes et al. *Proc. Nat'l Acad. Sci. USA* 95:652-656 (1998). C1q binding assays may also be carried out to confirm that the antibody is unable to bind C1q and hence lacks CDC activity. See, e.g., C1q and C3c binding ELISA in WO 2006/029879 and WO 2005/100402. To assess complement activation, a CDC assay may be performed (see, for example, Gazzano-Santoro *et al.*, *J. Immunol. Methods* 202:163 (1996); Cragg, M.S. et al., *Blood* 101:1045-1052 (2003); and Cragg, M.S. and M.J. Glennie, *Blood* 103:2738-2743 (2004)). FcRn binding and *in vivo* clearance/half life determinations can also be performed using methods known in the art (see, e.g., Petkova, S.B. et al., *Int'l. Immunol.* 18(12):1759-1769 (2006)).

Antibodies with reduced effector function include those with substitution of one or more of Fc region residues 238, 265, 269, 270, 297, 327 and 329 (U.S. Patent No. 6,737,056). Such Fc mutants include Fc mutants with substitutions at two or more of amino acid positions 265, 269, 270, 297 and 327, including the so-called "DANA" Fc mutant with substitution of residues 265 and 297 to alanine (US Patent No. 7,332,581).

Certain antibody variants with improved or diminished binding to FcRs are described. (See, e.g., U.S. Patent No. 6,737,056; WO 2004/056312, and Shields et al., *J. Biol. Chem.* 9(2): 6591-6604 (2001).)

In certain embodiments, an antibody variant comprises an Fc region with one or more amino acid substitutions which improve ADCC, e.g., substitutions at positions 298, 333, and/or 334 of the Fc region (EU numbering of residues).

In some embodiments, alterations are made in the Fc region that result in altered (*i.e.*, either improved or diminished) C1q binding and/or Complement Dependent Cytotoxicity (CDC), e.g., as described in US Patent No. 6,194,551, WO 99/51642, and Idusogie et al. *J. Immunol.* 164: 4178-4184 (2000).

Antibodies with increased half lives and improved binding to the neonatal Fc receptor (FcRn), which is responsible for the transfer of maternal IgGs to the fetus (Guyer et al., *J. Immunol.* 117:587 (1976) and Kim et al., *J. Immunol.* 24:249 (1994)), are described in US2005/0014934A1 (Hinton et al.). Those antibodies comprise an Fc region with one or more substitutions therein which improve binding of the Fc region to FcRn. Such Fc variants

include those with substitutions at one or more of Fc region residues: 238, 256, 265, 272, 286, 303, 305, 307, 311, 312, 317, 340, 356, 360, 362, 376, 378, 380, 382, 413, 424 or 434, e.g., substitution of Fc region residue 434 (US Patent No. 7,371,826).

See also Duncan & Winter, *Nature* 322:738-40 (1988); U.S. Patent No. 5,648,260; U.S. Patent No. 5,624,821; and WO 94/29351 concerning other examples of Fc region variants.

d) Cysteine engineered antibody variants

In certain embodiments, it may be desirable to create cysteine engineered antibodies, e.g., "thioMAbs," in which one or more residues of an antibody are substituted with cysteine residues. In particular embodiments, the substituted residues occur at accessible sites of the antibody. By substituting those residues with cysteine, reactive thiol groups are thereby positioned at accessible sites of the antibody and may be used to conjugate the antibody to other moieties, such as drug moieties or linker-drug moieties, to create an immunoconjugate, as described further herein. In certain embodiments, any one or more of the following residues may be substituted with cysteine: V205 (Kabat numbering) of the light chain; A118 (EU numbering) of the heavy chain; and S400 (EU numbering) of the heavy chain Fc region. Cysteine engineered antibodies may be generated as described, e.g., in U.S. Patent No. 7,521,541.

e) Antibody Derivatives

In certain embodiments, an antibody provided herein may be further modified to contain additional nonproteinaceous moieties that are known in the art and readily available. The moieties suitable for derivatization of the antibody include but are not limited to water soluble polymers. Non-limiting examples of water soluble polymers include, but are not limited to, polyethylene glycol (PEG), copolymers of ethylene glycol/propylene glycol, carboxymethylcellulose, dextran, polyvinyl alcohol, polyvinyl pyrrolidone, poly-1, 3-dioxolane, poly-1,3,6-trioxane, ethylene/maleic anhydride copolymer, polyaminoacids (either homopolymers or random copolymers), and dextran or poly(n-vinyl pyrrolidone)polyethylene glycol, propropylene glycol homopolymers, prolypropylene oxide/ethylene oxide co-polymers, polyoxyethylated polyols (e.g., glycerol), polyvinyl alcohol, and mixtures thereof. Polyethylene glycol propionaldehyde may have advantages in manufacturing due to its stability in water. The polymer may be of any molecular weight, and may be branched or unbranched. The number of polymers attached to the antibody may vary, and if more than one polymer are attached, they can be the same or different molecules. In general, the number and/or type of polymers used for derivatization can be determined based on considerations including, but not

limited to, the particular properties or functions of the antibody to be improved, whether the antibody derivative will be used in a therapy under defined conditions, etc.

In another embodiment, conjugates of an antibody and nonproteinaceous moiety that may be selectively heated by exposure to radiation are provided. In one embodiment, the nonproteinaceous moiety is a carbon nanotube (Kam et al., *Proc. Natl. Acad. Sci. USA* 102: 11600-11605 (2005)). The radiation may be of any wavelength, and includes, but is not limited to, wavelengths that do not harm ordinary cells, but which heat the nonproteinaceous moiety to a temperature at which cells proximal to the antibody-nonproteinaceous moiety are killed.

B. Recombinant Methods and Compositions

Antibodies may be produced using recombinant methods and compositions, e.g., as described in U.S. Patent No. 4,816,567. In one embodiment, isolated nucleic acid encoding an anti-Jag1 antibody described herein is provided. In one embodiment, isolated nucleic acid encoding an anti-Notch2 antibody described herein is provided. Such nucleic acid may encode an amino acid sequence comprising the VL and/or an amino acid sequence comprising the VH of the antibody (e.g., the light and/or heavy chains of the antibody). In a further embodiment, one or more vectors (e.g., expression vectors) comprising such nucleic acid are provided. In a further embodiment, a host cell comprising such nucleic acid is provided. In one such embodiment, a host cell comprises (e.g., has been transformed with): (1) a vector comprising a nucleic acid that encodes an amino acid sequence comprising the VL of the antibody and an amino acid sequence comprising the VH of the antibody, or (2) a first vector comprising a nucleic acid that encodes an amino acid sequence comprising the VL of the antibody and a second vector comprising a nucleic acid that encodes an amino acid sequence comprising the VH of the antibody. In one embodiment, the host cell is eukaryotic, e.g. a Chinese Hamster Ovary (CHO) cell or lymphoid cell (e.g., Y0, NS0, Sp20 cell). In one embodiment, a method of making an anti-Jag1 antibody is provided, wherein the method comprises culturing a host cell comprising a nucleic acid encoding the antibody, as provided above, under conditions suitable for expression of the antibody, and optionally recovering the antibody from the host cell (or host cell culture medium). In one embodiment, a method of making an anti-Notch2 antibody is provided, wherein the method comprises culturing a host cell comprising a nucleic acid encoding the antibody, as provided above, under conditions suitable for expression of the antibody, and optionally recovering the antibody from the host cell (or host cell culture medium).

For recombinant production of an anti-Jag1 antibody or an anti-Notch2 antibody, nucleic acid encoding an antibody, e.g., as described above, is isolated and inserted into one or more vectors for further cloning and/or expression in a host cell. Such nucleic acid may be readily isolated and sequenced using conventional procedures (e.g., by using oligonucleotide probes that are capable of binding specifically to genes encoding the heavy and light chains of the antibody).

Suitable host cells for cloning or expression of antibody-encoding vectors include prokaryotic or eukaryotic cells described herein. For example, antibodies may be produced in bacteria, in particular when glycosylation and Fc effector function are not needed. For expression of antibody fragments and polypeptides in bacteria, see, e.g., U.S. Patent Nos. 5,648,237, 5,789,199, and 5,840,523. (See also Charlton, *Methods in Molecular Biology, Vol. 248* (B.K.C. Lo, ed., Humana Press, Totowa, NJ, 2003), pp. 245-254, describing expression of antibody fragments in *E. coli*.) After expression, the antibody may be isolated from the bacterial cell paste in a soluble fraction and can be further purified.

In addition to prokaryotes, eukaryotic microbes such as filamentous fungi or yeast are suitable cloning or expression hosts for antibody-encoding vectors, including fungi and yeast strains whose glycosylation pathways have been "humanized," resulting in the production of an antibody with a partially or fully human glycosylation pattern. See Gerngross, *Nat. Biotech.* 22:1409-1414 (2004), and Li et al., *Nat. Biotech.* 24:210-215 (2006).

Suitable host cells for the expression of glycosylated antibody are also derived from multicellular organisms (invertebrates and vertebrates). Examples of invertebrate cells include plant and insect cells. Numerous baculoviral strains have been identified which may be used in conjunction with insect cells, particularly for transfection of *Spodoptera frugiperda* cells.

Plant cell cultures can also be utilized as hosts. *See,* e.g., US Patent Nos. 5,959,177, 6,040,498, 6,420,548, 7,125,978, and 6,417,429 (describing PLANTIBODIES™ technology for producing antibodies in transgenic plants).

Vertebrate cells may also be used as hosts. For example, mammalian cell lines that are adapted to grow in suspension may be useful. Other examples of useful mammalian host cell lines are monkey kidney CV1 line transformed by SV40 (COS-7); human embryonic kidney line (293 or 293 cells as described, e.g., in Graham et al., *J. Gen Virol.* 36:59 (1977)); baby hamster kidney cells (BHK); mouse sertoli cells (TM4 cells as described, e.g., in Mather, *Biol. Reprod.* 23:243-251 (1980)); monkey kidney cells (CV1); African green monkey kidney cells (VERO-76); human cervical carcinoma cells (HELA); canine kidney cells (MDCK; buffalo rat liver cells (BRL 3A); human lung cells (W138); human liver cells (Hep G2); mouse mammary

tumor (MMT 060562); TRI cells, as described, e.g., in Mather et al., *Annals N.Y. Acad. Sci.* 383:44-68 (1982); MRC 5 cells; and FS4 cells. Other useful mammalian host cell lines include Chinese hamster ovary (CHO) cells, including $DHFR^-$ CHO cells (Urlaub et al., *Proc. Natl. Acad. Sci. USA* 77:4216 (1980)); and myeloma cell lines such as Y0, NS0 and Sp2/0. For a review of certain mammalian host cell lines suitable for antibody production, see, e.g., Yazaki and Wu, *Methods in Molecular Biology, Vol. 248* (B.K.C. Lo, ed., Humana Press, Totowa, NJ), pp. 255-268 (2003).

C. Assays

The antibodies provided herein may be identified, screened for, or characterized for their physical/chemical properties and/or biological activities by various assays known in the art.

1. Binding assays and other assays

In one aspect, an antibody of the invention is tested for its antigen binding activity, e.g., by known methods such as ELISA, Western blot, etc.

In another aspect, competition assays may be used to identify an antibody that competes with Antibody A, A-1 or A-2 for binding to Jag1. In certain embodiments, such a competing antibody binds to the same epitope (e.g., a linear or a conformational epitope) that is bound by Antibody A, A-1 or A-2. In another aspect, competition assays may be used to identify an antibody that competes with Antibody B, B-1, B-2 or B-3 for binding to Notch2. In certain embodiments, such a competing antibody binds to the same epitope (e.g., a linear or a conformational epitope) that is bound by Antibody B, B-1, B-2 or B-3. Detailed exemplary methods for mapping an epitope to which an antibody binds are provided in Morris (1996) "Epitope Mapping Protocols," in *Methods in Molecular Biology* vol. 66 (Humana Press, Totowa, NJ).

In an exemplary competition assay, immobilized Jag1 is incubated in a solution comprising a first labeled antibody that binds to Jag1 (e.g., Antibody A, A-1 or A-2) and a second unlabeled antibody that is being tested for its ability to compete with the first antibody for binding to Jag1. The second antibody may be present in a hybridoma supernatant. As a control, immobilized Jag1 is incubated in a solution comprising the first labeled antibody but not the second unlabeled antibody. After incubation under conditions permissive for binding of the first antibody to Jag1, excess unbound antibody is removed, and the amount of label associated with immobilized Jag1is measured. If the amount of label associated with

immobilized Jag1 is substantially reduced in the test sample relative to the control sample, then that indicates that the second antibody is competing with the first antibody for binding to Jag1. See Harlow and Lane (1988) *Antibodies: A Laboratory Manual* ch.14 (Cold Spring Harbor Laboratory, Cold Spring Harbor, NY). In another exemplary competition assay, immobilized Notch2 is incubated in a solution comprising a first labeled antibody that binds to Notch2 (e.g., Antibody B, B-1, B-2 or B3) and a second unlabeled antibody that is being tested for its ability to compete with the first antibody for binding to Notch2. The second antibody may be present in a hybridoma supernatant. As a control, immobilized Notch2 is incubated in a solution comprising the first labeled antibody but not the second unlabeled antibody. After incubation under conditions permissive for binding of the first antibody to Notch2, excess unbound antibody is removed, and the amount of label associated with immobilized Notch2 is measured. If the amount of label associated with immobilized Jag1 is substantially reduced in the test sample relative to the control sample, then that indicates that the second antibody is competing with the first antibody for binding to Notch2.

2. Activity assays

In one aspect, assays are provided for identifying Notch2 signaling inhibitor antibodies, such as anti-Jag1 antibodies and anti-Notch2 antibodies, having biological activity. Biological activity may include, e.g., inhibition or reduction of Notch2 activity, e.g., Notch2 signaling, inhibition or reduction of Jag1-mediated Notch signaling, e.g., Jag1-mediated Notch2 signaling. Antibodies having such biological activity in vivo and/or in vitro are also provided.

In certain embodiments, an antibody of the invention is tested for such biological activity. In certain embodiments, an antibody of the invention is tested for its ability to inhibit reduce Spp1 expression. An exemplary assay is provided in the Examples. In certain other embodiments, an antibody of the invention is tested for its ability to inhibit expression of a reporter gene that is responsive to Notch2 signaling. In certain other embodiments, an antibody of the invention is tested for its ability to inhibit expression of a reporter gene that is responsive to Jag1-mediated signaling, e.g., Jag1-mediated Notch2 signaling. In one exemplary assay, NIH-3T3 cells stably transfected with Notch 2 or transiently transfected with plasmids containing other Notch receptors are co-transfected with a Notch-responsive TP-I (12X CSL) Firefly luciferase reporter and a constitutively active Renilla Luciferase reporter (pRL-CMV, Promega) to control for transfection efficiency. Cells are allowed to recover from the transfection from 6 hours to overnight. Treatments of antibodies and NIH-3T3 cells stably transfected with ligand are used to stimulate the receptor cells. After 20 hours, firefly and

Renilla luciferase are measured with Dual GIo Luciferase Assay system (Promega). Replicates are analyzed for each condition by dividing the Firefly signal by the Renilla signal to control for transfection efficiency. The mean and standard deviation are calculated and values are normalized to calculated values for co-culture stimulated with NIH-3T3 cells without ligand transfected.

In certain embodiments, an antibody of the invention is tested for its ability to inhibit cell growth or proliferation in vitro. Assays for inhibition of cell growth or proliferation are well known in the art. Certain assays for cell proliferation, exemplified by the "cell killing" assays described herein, measure cell viability. One such assay is the CellTiter-Glo™ Luminescent Cell Viability Assay, which is commercially available from Promega (Madison, WI). That assay determines the number of viable cells in culture based on quantitation of ATP present, which is an indication of metabolically active cells. *See* Crouch et al (1993) *J. Immunol. Meth.* 160:81-88, US Pat. No. 6602677. The assay may be conducted in 96- or 384-well format, making it amenable to automated high-throughput screening (HTS). *See* Cree et al (1995) *AntiCancer Drugs* 6:398-404. The assay procedure involves adding a single reagent (CellTiter-Glo® Reagent) directly to cultured cells. This results in cell lysis and generation of a luminescent signal produced by a luciferase reaction. The luminescent signal is proportional to the amount of ATP present, which is directly proportional to the number of viable cells present in culture. Data can be recorded by luminometer or CCD camera imaging device. The luminescence output is expressed as relative light units (RLU).

Another assay for cell proliferation is the "MTT" assay, a colorimetric assay that measures the oxidation of 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide to formazan by mitochondrial reductase. Like the CellTiter-Glo™ assay, this assay indicates the number of metabolically active cells present in a cell culture. *See, e.g.*, Mosmann (1983) *J. Immunol. Meth.* 65:55-63, and Zhang et al. (2005) *Cancer Res.* 65:3877-3882.

In one aspect, an antibody of the invention is tested for its ability to induce cell death in vitro. Assays for induction of cell death are well known in the art. In some embodiments, such assays measure, e.g., loss of membrane integrity as indicated by uptake of propidium iodide (PI), trypan blue (*see* Moore et al. (1995) *Cytotechnology*, 17:1-11), or 7AAD. In an exemplary PI uptake assay, cells are cultured in Dulbecco's Modified Eagle Medium (D-MEM):Ham's F-12 (50:50) supplemented with 10% heat-inactivated FBS (Hyclone) and 2 mM L-glutamine. Thus, the assay is performed in the absence of complement and immune effector cells. Cells are seeded at a density of 3×10^6 per dish in 100 x 20 mm dishes and allowed to attach overnight. The medium is removed and replaced with fresh medium alone or medium

containing various concentrations of the antibody or immunoconjugate. The cells are incubated for a 3-day time period. Following treatment, monolayers are washed with PBS and detached by trypsinization. Cells are then centrifuged at 1200 rpm for 5 minutes at 4 °C, the pellet resuspended in 3 ml cold Ca^{2+} binding buffer (10 mM Hepes, pH 7.4, 140 mM NaCl, 2.5 mM $CaCl_2$) and aliquoted into 35 mm strainer-capped 12 x 75 mm tubes (1 ml per tube, 3 tubes per treatment group) for removal of cell clumps. Tubes then receive PI (10 μg/ml). Samples are analyzed using a FACSCAN™ flow cytometer and FACSCONVERT™ CellQuest software (Becton Dickinson). Antibodies which induce statistically significant levels of cell death as determined by PI uptake are thus identified.

In one aspect, an antibody of the invention is tested for its ability to induce apoptosis (programmed cell death) in vitro. An exemplary assay for antibodies or immunconjugates that induce apoptosis is an annexin binding assay. In an exemplary annexin binding assay, cells are cultured and seeded in dishes as discussed in the preceding paragraph. The medium is removed and replaced with fresh medium alone or medium containing 0.001 to 10 μg/ml of the antibody or immunoconjugate. Following a three-day incubation period, monolayers are washed with PBS and detached by trypsinization. Cells are then centrifuged, resuspended in Ca^{2+} binding buffer, and aliquoted into tubes as discussed in the preceding paragraph. Tubes then receive labeled annexin (e.g. annexin V-FITC) (1 μg/ml). Samples are analyzed using a FACSCAN™ flow cytometer and FACSCONVERT™ CellQuest software (BD Biosciences). Antibodies that induce statistically significant levels of annexin binding relative to control are thus identified. Another exemplary assay for antibodies or immunconjugates that induce apoptosis is a histone DNA ELISA colorimetric assay for detecting internucleosomal degradation of genomic DNA. Such an assay can be performed using, e.g., the Cell Death Detection ELISA kit (Roche, Palo Alto, CA).

Cells for use in any of the above in vitro assays include cells or cell lines that naturally express Notch2and/or Jag1 or that have been engineered to express Notch2and/or Jag1. Such cells include tumor cells that overexpress Notch2and/or Jag1 relative to normal cells of the same tissue origin. Such cells also include cell lines (including tumor cell lines) that express Notch2and/or Jag1 and cell lines that do not normally express Notch2and/or Jag1 but have been transfected with nucleic acid encoding Notch2and/or Jag1. Exemplary cell lines provided herein for use in any of the above in vitro assays include NIH-3T3 cells.

In one aspect, an antibody of the invention is tested for its ability to inhibit cell growth or proliferation in vivo. In certain embodiments, an anti-Jag1 antibody thereof is tested for its

ability to inhibit tumor growth in vivo. In certain embodiments, an anti-Notch2 antibody thereof is tested for its ability to inhibit tumor growth in vivo. In vivo model systems, such as xenograft models, can be used for such testing. In an exemplary xenograft system, human tumor cells are introduced into a suitably immunocompromised non-human animal, e.g., an athymic "nude" mouse. An antibody of the invention is administered to the animal. The ability of the antibody to inhibit or decrease tumor growth is measured. In certain embodiments of the above xenograft system, the human tumor cells are tumor cells from a human patient. Such xenograft models are commercially available from Oncotest GmbH (Frieberg, Germany). In certain embodiments, the human tumor cells are cells from a human tumor cell line, such as HepG2, Hep3B, PCL/PRF/5, Snu387, Snu398, Snu423, Snu449, Snu475, Huh-7, HLE, HLF, JHH1, JHH4, JHH5 and JHH7. In certain embodiments, the human tumor cells are introduced into a suitably immunocompromised non-human animal by subcutaneous injection or by transplantation into a suitable site, such as a mammary fat pad.

It is understood that any of the above assays may be carried out using an immunoconjugate of the invention in place of or in addition to an Notch2 signaling inhibitor.

D. Immunoconjugates

The invention also provides immunoconjugates comprising an anti-Notch2 antibody or anti-Jag1 antibody herein conjugated to one or more cytotoxic agents, such as chemotherapeutic agents or drugs, growth inhibitory agents, toxins (e.g., protein toxins, enzymatically active toxins of bacterial, fungal, plant, or animal origin, or fragments thereof), or radioactive isotopes.

In one embodiment, an immunoconjugate is an antibody-drug conjugate (ADC) in which an antibody is conjugated to one or more drugs, including but not limited to a maytansinoid (see U.S. Patent Nos. 5,208,020, 5,416,064 and European Patent EP 0 425 235 B1); an auristatin such as monomethylauristatin drug moieties DE and DF (MMAE and MMAF) (see U.S. Patent Nos. 5,635,483 and 5,780,588, and 7,498,298); a dolastatin; a calicheamicin or derivative thereof (see U.S. Patent Nos. 5,712,374, 5,714,586, 5,739,116, 5,767,285, 5,770,701, 5,770,710, 5,773,001, and 5,877,296; Hinman et al., *Cancer Res.* 53:3336-3342 (1993); and Lode et al., *Cancer Res.* 58:2925-2928 (1998)); an anthracycline such as daunomycin or doxorubicin (see Kratz et al., *Current Med. Chem.* 13:477-523 (2006); Jeffrey et al., *Bioorganic & Med. Chem. Letters* 16:358-362 (2006); Torgov et al., *Bioconj. Chem.* 16:717-721 (2005); Nagy et al., *Proc. Natl. Acad. Sci. USA* 97:829-834 (2000); Dubowchik et al., *Bioorg. & Med. Chem. Letters* 12:1529-1532 (2002); King et al., *J. Med.*

Chem. 45:4336-4343 (2002); and U.S. Patent No. 6,630,579); methotrexate; vindesine; a taxane such as docetaxel, paclitaxel, larotaxel, tesetaxel, and ortataxel; a trichothecene; and CC1065.

In another embodiment, an immunoconjugate comprises an antibody as described herein conjugated to an enzymatically active toxin or fragment thereof, including but not limited to diphtheria A chain, nonbinding active fragments of diphtheria toxin, exotoxin A chain (from Pseudomonas aeruginosa), ricin A chain, abrin A chain, modeccin A chain, alpha-sarcin, Aleurites fordii proteins, dianthin proteins, Phytolaca americana proteins (PAPI, PAPII, and PAP-S), momordica charantia inhibitor, curcin, crotin, sapaonaria officinalis inhibitor, gelonin, mitogellin, restrictocin, phenomycin, enomycin, and the tricothecenes.

In another embodiment, an immunoconjugate comprises an antibody as described herein conjugated to a radioactive atom to form a radioconjugate. A variety of radioactive isotopes are available for the production of radioconjugates. Examples include At^{211}, I^{131}, I^{125}, Y^{90}, Re^{186}, Re^{188}, Sm^{153}, Bi^{212}, P^{32}, Pb^{212} and radioactive isotopes of Lu. When the radioconjugate is used for detection, it may comprise a radioactive atom for scintigraphic studies, for example tc99m or I123, or a spin label for nuclear magnetic resonance (NMR) imaging (also known as magnetic resonance imaging, mri), such as iodine-123 again, iodine-131, indium-111, fluorine-19, carbon-13, nitrogen-15, oxygen-17, gadolinium, manganese or iron.

Conjugates of an antibody and cytotoxic agent may be made using a variety of bifunctional protein coupling agents such as N-succinimidyl-3-(2-pyridyldithio) propionate (SPDP), succinimidyl-4-(N-maleimidomethyl) cyclohexane-1-carboxylate (SMCC), iminothiolane (IT), bifunctional derivatives of imidoesters (such as dimethyl adipimidate HCl), active esters (such as disuccinimidyl suberate), aldehydes (such as glutaraldehyde), bis-azido compounds (such as bis (p-azidobenzoyl) hexanediamine), bis-diazonium derivatives (such as bis-(p-diazoniumbenzoyl)-ethylenediamine), diisocyanates (such as toluene 2,6-diisocyanate), and bis-active fluorine compounds (such as 1,5-difluoro-2,4-dinitrobenzene). For example, a ricin immunotoxin can be prepared as described in Vitetta et al., *Science* 238:1098 (1987). Carbon-14-labeled 1-isothiocyanatobenzyl-3-methyldiethylene triaminepentaacetic acid (MX-DTPA) is an exemplary chelating agent for conjugation of radionucleotide to the antibody. See WO94/11026. The linker may be a "cleavable linker" facilitating release of a cytotoxic drug in the cell. For example, an acid-labile linker, peptidase-sensitive linker, photolabile linker, dimethyl linker or disulfide-containing linker (Chari et al., *Cancer Res.* 52:127-131 (1992); U.S. Patent No. 5,208,020) may be used.

The immunuoconjugates or ADCs herein expressly contemplate, but are not limited to such conjugates prepared with cross-linker reagents including, but not limited to, BMPS, EMCS, GMBS, HBVS, LC-SMCC, MBS, MPBH, SBAP, SIA, SIAB, SMCC, SMPB, SMPH, sulfo-EMCS, sulfo-GMBS, sulfo-KMUS, sulfo-MBS, sulfo-SIAB, sulfo-SMCC, and sulfo-SMPB, and SVSB (succinimidyl-(4-vinylsulfone)benzoate) which are commercially available (e.g., from Pierce Biotechnology, Inc., Rockford, IL., U.S.A).

E. Methods and Compositions for Diagnostics and Detection

In certain embodiments, any of the antibodies provided herein is useful for detecting the presence of a Notch2 or fragment thereof, or a Jag1 or fragment thereof, in a biological sample. The term "detecting" as used herein encompasses quantitative or qualitative detection. In certain embodiments, a biological sample comprises a cell or tissue, such as hepatocyte, liver cancer cell and liver tumor tissue.

In one embodiment, an anti-Notch2 antibody for use in a method of diagnosis or detection is provided. In a further aspect, a method of detecting the presence of Notch2 in a biological sample is provided. In certain embodiments, a method of detecting the presence of Notch2 intracellular domain (ICD) in a biological sample is provided. In certain embodiments, the method comprises contacting the biological sample with an anti-Notch2 antibody as described herein under conditions permissive for binding of the anti-Notch2 antibody to Notch2, and detecting whether a complex is formed between the anti-Notch2 antibody and Notch2. Such method may be an *in vitro* or *in vivo* method. In one embodiment, an anti-Notch2 antibody is used to select subjects eligible for therapy with an anti-Notch2 antibody, as described above, e.g. where Notch2, in particular activated Notch2, is a biomarker for selection of patients.

In one embodiment, an anti-Jag1 antibody for use in a method of diagnosis or detection is provided. In a further aspect, a method of detecting the presence of Jag1 in a biological sample is provided. In certain embodiments, a method of detecting the presence of Jag1 intracellular domain (ICD) in a biological sample is provided. In certain embodiments, the method comprises contacting the biological sample with an anti-Jag1 antibody as described herein under conditions permissive for binding of the anti-Jag1 antibody to Jag1, and detecting whether a complex is formed between the anti-Jag1 antibody and Jag1. Such method may be an *in vitro* or *in vivo* method. In one embodiment, an anti-Jag1antibody is used to select subjects eligible for therapy with an anti-Jag1 antibody, as described above, e.g. where Jag1 is a biomarker for selection of patients.

Exemplary disorders that may be diagnosed using an antibody of the invention include liver cancer, specifically, hepatocellular carcinoma.

In certain embodiments, labeled anti-Notch2 or anti-Jag1 antibodies are provided. Labels include, but are not limited to, labels or moieties that are detected directly (such as fluorescent, chromophoric, electron-dense, chemiluminescent, and radioactive labels), as well as moieties, such as enzymes or ligands, that are detected indirectly, e.g., through an enzymatic reaction or molecular interaction. Exemplary labels include, but are not limited to, the radioisotopes ^{32}P, ^{14}C, ^{125}I, ^{3}H, and ^{131}I, fluorophores such as rare earth chelates or fluorescein and its derivatives, rhodamine and its derivatives, dansyl, umbelliferone, luceriferases, e.g., firefly luciferase and bacterial luciferase (U.S. Patent No. 4,737,456), luciferin, 2,3-dihydrophthalazinediones, horseradish peroxidase (HRP), alkaline phosphatase, β-galactosidase, glucoamylase, lysozyme, saccharide oxidases, e.g., glucose oxidase, galactose oxidase, and glucose-6-phosphate dehydrogenase, heterocyclic oxidases such as uricase and xanthine oxidase, coupled with an enzyme that employs hydrogen peroxide to oxidize a dye precursor such as HRP, lactoperoxidase, or microperoxidase, biotin/avidin, spin labels, bacteriophage labels, stable free radicals, and the like.

F. Pharmaceutical Formulations

Pharmaceutical formulations of an anti-Notch2 or anti-Jag1 antibody as described herein are prepared by mixing such antibody having the desired degree of purity with one or more optional pharmaceutically acceptable carriers (*Remington's Pharmaceutical Sciences* 16th edition, Osol, A. Ed. (1980)), in the form of lyophilized formulations or aqueous solutions. Pharmaceutically acceptable carriers are generally nontoxic to recipients at the dosages and concentrations employed, and include, but are not limited to: buffers such as phosphate, citrate, and other organic acids; antioxidants including ascorbic acid and methionine; preservatives (such as octadecyldimethylbenzyl ammonium chloride; hexamethonium chloride; benzalkonium chloride; benzethonium chloride; phenol, butyl or benzyl alcohol; alkyl parabens such as methyl or propyl paraben; catechol; resorcinol; cyclohexanol; 3-pentanol; and m-cresol); low molecular weight (less than about 10 residues) polypeptides; proteins, such as serum albumin, gelatin, or immunoglobulins; hydrophilic polymers such as polyvinylpyrrolidone; amino acids such as glycine, glutamine, asparagine, histidine, arginine, or lysine; monosaccharides, disaccharides, and other carbohydrates including glucose, mannose, or dextrins; chelating agents such as EDTA; sugars such as sucrose, mannitol, trehalose or sorbitol; salt-forming counter-ions such as sodium; metal complexes (*e.g.* Zn-

protein complexes); and/or non-ionic surfactants such as polyethylene glycol (PEG). Exemplary pharmaceutically acceptable carriers herein further include insterstitial drug dispersion agents such as soluble neutral-active hyaluronidase glycoproteins (sHASEGP), for example, human soluble PH-20 hyaluronidase glycoproteins, such as rHuPH20 (HYLENEX®, Baxter International, Inc.). Certain exemplary sHASEGPs and methods of use, including rHuPH20, are described in US Patent Publication Nos. 2005/0260186 and 2006/0104968. In one aspect, a sHASEGP is combined with one or more additional glycosaminoglycanases such as chondroitinases.

Exemplary lyophilized antibody formulations are described in US Patent No. 6,267,958. Aqueous antibody formulations include those described in US Patent No. 6,171,586 and WO2006/044908, the latter formulations including a histidine-acetate buffer.

The formulation herein may also contain more than one active ingredients as necessary for the particular indication being treated, preferably those with complementary activities that do not adversely affect each other. For example, it may be desirable to further provide a chemotherapeutic agent or another therapeutic antibody with the anti-Notch2 or anti-Jag1antibody. In some embodiments, a formulation may contain an anti-Notch2 antibody and an anti-Jag1 antibody. Such active ingredients are suitably present in combination in amounts that are effective for the purpose intended.

Active ingredients may be entrapped in microcapsules prepared, for example, by coacervation techniques or by interfacial polymerization, for example, hydroxymethylcellulose or gelatin-microcapsules and poly-(methylmethacylate) microcapsules, respectively, in colloidal drug delivery systems (for example, liposomes, albumin microspheres, microemulsions, nano-particles and nanocapsules) or in macroemulsions. Such techniques are disclosed in *Remington's Pharmaceutical Sciences* 16th edition, Osol, A. Ed. (1980).

Sustained-release preparations may be prepared. Suitable examples of sustained-release preparations include semipermeable matrices of solid hydrophobic polymers containing the antibody, which matrices are in the form of shaped articles, *e.g.* films, or microcapsules.

The formulations to be used for *in vivo* administration are generally sterile. Sterility may be readily accomplished, e.g., by filtration through sterile filtration membranes.

G. Therapeutic Compositions

Also provided herein are article of manufacture is provided comprising (a) a container; (b) a composition of matter contained within the container comprising an anti-Notch2 antibody

or an anti-Jagged1 antibody and a carrier for the treatment of liver cancer; and (c) a label affixed to the container, or a package insert included with the container, referring to the use of the composition of matter for the therapeutic treatment of or the diagnostic detection of a liver cancer.

Antibodies of the invention can be used either alone or in combination with other agents in a therapy. For instance, an antibody of the invention may be co-administered with at least one additional therapeutic agent. In certain embodiments, an additional therapeutic agent is a chemotherapeutic agent.

Such combination therapies noted above encompass combined administration (where two or more therapeutic agents are included in the same or separate formulations), and separate administration, in which case, administration of the antibody of the invention can occur prior to, simultaneously, and/or following, administration of the additional therapeutic agent or agents. In one embodiment, administration of the anti-Notch2 or Jag1 antibody and administration of an additional therapeutic agent occur within about one month, or within about one, two or three weeks, or within about one, two, three, four, five, or six days, of each other. Antibodies of the invention can also be used in combination with radiation therapy.

An antibody of the invention (and any additional therapeutic agent) can be administered by any suitable means, including parenteral, intrapulmonary, and intranasal, and, if desired for local treatment, intralesional administration. Parenteral infusions include intramuscular, intravenous, intraarterial, intraperitoneal, or subcutaneous administration. Dosing can be by any suitable route, e.g. by injections, such as intravenous or subcutaneous injections, depending in part on whether the administration is brief or chronic. Various dosing schedules including but not limited to single or multiple administrations over various time-points, bolus administration, and pulse infusion are contemplated herein.

Antibodies of the invention would be formulated, dosed, and administered in a fashion consistent with good medical practice. Factors for consideration in this context include the particular disorder being treated, the particular mammal being treated, the clinical condition of the individual patient, the cause of the disorder, the site of delivery of the agent, the method of administration, the scheduling of administration, and other factors known to medical practitioners. The antibody need not be, but is optionally formulated with one or more agents currently used to prevent or treat the disorder in question. The effective amount of such other agents depends on the amount of antibody present in the formulation, the type of disorder or treatment, and other factors discussed above. These are generally used in the same dosages and with administration routes as described herein, or about from 1 to 99% of the dosages

described herein, or in any dosage and by any route that is empirically/clinically determined to be appropriate.

For the prevention or treatment of disease, the appropriate dosage of an antibody of the invention (when used alone or in combination with one or more other additional therapeutic agents) will depend on the type of disease to be treated, the type of antibody, the severity and course of the disease, whether the antibody is administered for preventive or therapeutic purposes, previous therapy, the patient's clinical history and response to the antibody, and the discretion of the attending physician. The antibody is suitably administered to the patient at one time or over a series of treatments. For repeated administrations over several days or longer, depending on the condition, the treatment would generally be sustained until a desired suppression of disease symptoms occurs. An initial higher loading dose, followed by one or more lower doses may be administered. However, other dosage regimens may be useful. The progress of this therapy is easily monitored by conventional techniques and assays.

It is understood that any of the above formulations or therapeutic methods may be carried out using an immunoconjugate of the invention in place of or in addition to an anti-Notch2 or anti-Jag1 antibody.

H. Articles of Manufacture

In another aspect of the invention, an article of manufacture containing materials useful for the treatment, prevention and/or diagnosis of the disorders described above is provided. The article of manufacture comprises a container and a label or package insert on or associated with the container. For example, an article of manufacture is provided comprising (a) a container; (b) a composition of matter contained within the container comprising an anti-Notch2 antibody or an anti-Jagged1 antibody and a carrier for the treatment of liver cancer; and (c) a label affixed to the container, or a package insert included with the container, referring to the use of the composition of matter for the therapeutic treatment of or the diagnostic detection of a liver cancer.

Suitable containers include, for example, bottles, vials, syringes, IV solution bags, etc. The containers may be formed from a variety of materials such as glass or plastic. The container holds a composition which is by itself or combined with another composition effective for treating, preventing and/or diagnosing the condition and may have a sterile access port (for example the container may be an intravenous solution bag or a vial having a stopper pierceable by a hypodermic injection needle). At least one active agent in the composition is a Notch2 signaling inhibitor, e.g., an anti-Notch2 antibody or anti-Jag1 antibody. The label or

package insert indicates that the composition is used for treating a proliferative disorder of the liver, such as liver cancer. Moreover, the article of manufacture may comprise (a) a first container with a composition contained therein, wherein the composition comprises an antibody of the invention; and (b) a second container with a composition contained therein, wherein the composition comprises a further cytotoxic or otherwise therapeutic agent. The article of manufacture in this embodiment of the invention may further comprise a package insert indicating that the compositions can be used to treat a proliferative disorder of the liver, such as liver cancer. Alternatively, or additionally, the article of manufacture may further comprise a second (or third) container comprising a pharmaceutically-acceptable buffer, such as bacteriostatic water for injection (BWFI), phosphate-buffered saline, Ringer's solution and dextrose solution. It may further include other materials desirable from a commercial and user standpoint, including other buffers, diluents, filters, needles, and syringes.

It is understood that any of the above articles of manufacture may include an immunoconjugate of the invention in place of or in addition to an anti-Notch2 or anti-Jag1 antibody.

III. EXAMPLES

The following are examples of methods and compositions of the invention. It is understood that various other embodiments may be practiced, given the general description provided above.

Example 1

Murine model of liver cancer

FVB-N mice (Charles River, Hollister) were subjected to hydrodynamic tail vein injection of Ras, AKT, and Sleeping Beauty transposase encoding plasmids as previously described (Ho et al., C., Hepatology 55:833-845 (2012)). Briefly, 10ug of pT3-CAGGS-NRasV12, 10ug of pT3-EF1A-AKT, and 0.8ug CMV-SB (Ho et al., Hepatology 55:833-845 (2012); Yant et al., Mol. Cell. Biol. 24:9239-9247 (2004)) were diluted in approximately 2mL of Saline Solution (0.9% NaCl) and injected into the lateral tail vein of FVB-N mice in 5 to 8 seconds.

To model the development of liver cancer, mice were subjected to hydrodynamic tail vein injection of plasmids encoding oncogenic Ras and constitutively active AKT along with Sleeping Beauty transposase, as described above and as previously described (Ho et al., C., Hepatology 55:833-845 (2012)). This model allows for efficient and stable transfection of

hepatocytes and reliable expression of the transfected oncogenes. Within 5 weeks following hydrodynamic tail vein injection, mice developed numerous intrahepatic tumor masses. Much of the normal liver parenchyma was displaced by tumor epithelium and livers of these mice expanded to as much as ten times their original size. Consistent with previous reports, the tumors that developed in these mice comprised a wide spectrum of liver tumor types, including hepatocellular carcinoma (HCC) and cholangiocarcinoma (CC). Approximately 80% of tumor nodules met the histopathological criteria for hepatocellular carcinoma and 20% met histopathological criteria for identification as cholangiocarcinoma.

Each liver comprised dozens of tumors each of which expressed a given marker or combination of markers, such as AFP (FIG. 1A) and EpCAM (FIG. 1C). Some tumors express both AFP and EpCAM (FIG. 1B). Tumors in this model varied in their expression of HCC- and CC-specific tumor markers (FIG. 1A). Expression of alpha-Fetoprotein (AFP), specific for HCC, was detected in about 12.8% of cells in tumor-bearing livers (FIG. 1D), compared to less than 1% in normal non-tumor-bearing livers. Expression of EpCAM (Fig. 1B), a marker of cholangiocarcinoma, was less prevalent in this model, detected in an average of about 5% of all liver cells, compared to about 1% in normal non-tumor-bearing livers. Tumors expressing both HCC- and CC-specific markers were also observed (FIG. 1C). These combined HCC-CC (cHCC-CC) tumors are characterized by particularly aggressive clinical features (American-Cancer-Society. 2012. Cancer Facts & Figures 2012. Atlanta: American Cancer Society) and share gene expression patterns with liver progenitor cells (Coulouarn et al., Carcinogenesis 33:1791-1796 (2012)).

Example 2

Activation of Notch2 signaling

To determine if liver cancer is associated with Notch2 activation, immunofluorescense analysis was performed on tumors arising in the livers of AKT/Ras HTV mice. Liver tissues were embedded and frozen in O.C.T.™ freezing medium (TISSUE-TEK®), and cryosectioned at 8μm. Sections were fixed in 4% paraformaldehyde (PFA) and stained using primary antibodies for Notch2 (Cell Signaling Technology), EpCAM (BioLegend), and AFP (R&D Systems). For image analysis, immunofluorescence-stained slides were scanned using an Ariol slide scanning system (Leica).

High levels of Notch2 activation, as determined by immunofluorescence detection of nuclear Notch2, was observed in $AFP^+/EpCAM^+$ tumors (FIG. 1E) and to a lesser extent in $EpCAM^+$ tumors (FIG. 1E, FIG.1F). Less prominent staining for activated Notch2 was observed in other tumor cell types (FIG. 1E).

Example 3

Generation of antibodies

To determine if Notch2 signaling was important for driving the development or growth of liver cancer, specifically in double positive tumors, mice were subjected to hydrodynamic tail vain injection with the AKT/Ras construct as described in Example 1, and treated with an anti-Notch2 antibody, anti-Jag1 antibody or isotype control (anti-Ragweed) antibody.

a. Library Sorting and Screening to Identify anti-Jagged 1 Antibodies

Human phage antibody libraries with synthetic diversities in the selected complementarity determining regions, mimicking the natural diversity of human IgG repertoire, were used for panning Fab fragments displayed on the surface of M13 bacteriophage particles. Human Jag1-DSL-EGF1-4 (FIG. 10) was used as antigen for library sorting. Nunc 96 well Maxisorp immunoplates were coated overnight at 4°C with target antigen (10μg/ml) and were blocked for 1 hour at room temperature with phage blocking buffer PBST (phosphate-buffered saline (PBS) and 1% (w/v) bovine serum albumin (BSA) and 0.05% (v/v) tween-20). Antibody phage libraries VH (see, e.g., Lee et al., J. Immunol. Meth. 284:119-132, 2004) and VH/VL (see Liang et al., JMB. 366: 815-829, 2007) were added to antigen plates separately and incubated overnight at room temperature. The following day antigen-coated plates were washed ten times with PBT (PBS with 0.05% Tween-20), and bound phage were eluted with 50mM HCl and 500mM NaCl for 30 minutes and neutralized with an equal volume of 1 M Tris base (pH7.5). Recovered phages were amplified in *E. coli* XL-1 Blue cells. During the subsequent selection rounds, incubation of antibody phage with the antigen-coated plates was reduced to 2-3 hours, and the stringency of plate washing was gradually increased.

After 4 rounds of panning, significant enrichment was observed. 96 clones were picked each from VH and VH/VL library sorting to determine whether they specifically bound to human Jagged 1. The variable regions of these clones were PCR sequenced to identify unique sequence clones. The affinities of phage antibodies were ranked using spot competition ELISA. The phage antibody IC50 values were further determined using competitive phage-binding ELISA. Unique phage antibodies that bind specifically to human Jagged 1 (and not Jagged 2), or to both Jagged 1 and Jagged 2 were chosen and reformatted to full-length IgGs for evaluation in *in vitro* cell assays.

Clones of interest were reformatted into IgGs by cloning V_L and V_H regions of individual clones into a pRK mammalian cell expression vector (pRK.LPG3.HumanKappa) containing the human kappa constant domain, and expression vector (pRK.LPG4.HumanHC) encoding the full-length human IgG1 constant domain, respectively (Shields et al., *J Biol Chem*

2000; 276: 6591-6604). The antibodies were then transiently expressed in mammalian CHO cells, and purified with a protein A column.

b. Construction of libraries for affinity improvement of clones derived from the V_H or V_HV_L libraries

Phagemid pW0703, derived from phagemid pV0350-2b (Lee et al., *J. Mol. Biol* 340, 1073-1093 (2004), containing stop codon (TAA) in all CDR-L3 positions and displaying monovalent Fab on the surface of M13 bacteriophage) served as the library templates for grafting heavy chain variable domains (V_H) of clones of interest from the V_H library for affinity maturation. Both hard and soft randomization strategies were used for affinity maturation. For hard randomization, one light chain library with selected positions of the three light chain CDRs was randomized using amino acids designed to mimic natural human antibodies and the designed DNA degeneracy was as described in Lee et al. (*J. Mol. Biol* 340, 1073-1093 (2004)). To achieve the soft randomization conditions, which introduced the mutation rate of approximately 50% at the selected positions, the mutagenic DNA was synthesized with 70-10-10-10 mixtures of bases favoring the wild type nucleotides (Gallop et al., *J.Med. Chem.* 37:1233-1251 (1994)). For soft randomization, residues at positions 91-96 of CDR-L3, 30-33, 35 of CDR-H1, 50, 52, 53-54, and 56 of CDR-H2, 95-98 of CDR-H3 were targeted; and three different combinations of CDR loops, H1/L3, H2/L3, and H3/L3, were selected for randomization.

For clones originated from V_HV_L library, phagemids containing 4 stop codons (TAA) in each CDR and displaying monovalent Fab on the surface of M13 bacteriophage were generated individually, and served as the templates for kunkel mutagenesis for the construction of affinity maturation libraries. Only soft randomization strategy was used for clones derived from V_HV_L library, as diversity of CDR-L3 was built into the naïve library. To achieve the soft randomization conditions, residues at positions 28-31 of CDR-L1, 50, 53-55 of CDR-L2, 91-96 of CDR-L3, 30-35 of CDR-H1, 50-56 of CDR-H2, 95-100 of CDR-H3 were targeted; and four different combinations of CDR loops, H1/L3*, H2/L3*, and H3/L3* and L1/L2/L3* (where * denotes the position of stop codons on the template), were selected for randomization.

c. Phage Sorting Strategy to Generate Affinity Improvement

For affinity improvement selection, Jag1 antigens were first biotinylated under limiting reagent condition. Phage libraries were subjected to one round of plate sorting and five rounds of solution sorting with increasing stringency. For the first round of plate sorting, 10ug/ml antigen was first coated on Maxisorp plate and preblocked with blocking buffer (1% BSA and 0.05% Tween20 in PBS). 3 O.D./ml in blocking buffer of phage input were incubated to

antigen plates for 3 hours. The wells were washed with PBS-0.05% Tween20 ten times. Bound phage was eluted with 150ul/well 50mM HCl, 500mM KCl for 30 minutes, and subsequently neutralized by 50ul/well of 1M Tris pH8, titered, and propagated for the next round. For subsequent rounds, panning of the phage libraries was done in solution phase, where phage library was incubated with 100 nM biotinylated target protein (the concentration is based on parental clone phage IC50 value) in 100µl buffer containing 1% Superblock (Pierce Biotechnology) and 0.05% Tween20 for 2 hours at room temperature. The mixture was further diluted 10X with 1% Superblock, and 100µl/well was applied to neutravidin-coated wells (10µg/ml) for 30 minutes at room temperature with gentle shaking. To determine background binding, control wells containing phage were captured on neutravidin-coated plates. Bound phage was then washed, eluted and propagated as described for first round. Five more rounds of solution sorting were carried out together with increasing selection stringency. The first couple rounds of which is for on-rate selection by decreasing biotinylated target protein concentration from 100nM to 0.1nM, and the last two rounds of which is for off-rate selection by adding excess amounts of non-biotinylated target protein (300 to 1000 fold more) to compete off weaker binders at room temperature.

d. High Throughput Affinity Screening ELISA (Single Spot Competition)

Colonies were picked from the sixth round of screening. Colonies were grown overnight at 37°C in 150µl/well of 2YT media with 50µg/ml carbenicillin and 1x 10^{10}/ml M13KO7 in 96-well plate (Falcon). From the same plate, a colony of XL-1 infected parental phage was picked as control. 96-well Nunc Maxisorp plates were coated with 100µl/well of either Jag1 or Jag2 (0.5µg/ml) in PBS at 4°C overnight. The plates were blocked with 150µl of 1% BSA and 0.05% Tween20 in PBS 20 for 1 hour.

35µl of the phage supernatant was diluted with 75µl of ELISA (enzyme linked immunosorbent assay) buffer (PBS with 0.5% BSA, 0.05% Tween20) with or without 5nM Jag1 or Jag2 and let incubate for 1 hour at room temperature in an F plate (NUNC). 95µl of mixture was transferred side by side to the antigen coated plates. The plate was gently shaken for 15 min and was washed ten times with PBS-0.05% Tween 20. The binding was quantified by adding horseradish peroxidase (HRP)-conjugated anti-M13 antibody in ELISA buffer (1:2500) and incubated for 30 minutes at room temperature. The plates were washed with PBS-0.05% Tween 20 ten times. Next, 100µl/well of Peroxidase substrate was added to the well and incubated for 5 minutes at room temperature. The reaction was stopped by adding 100µl 0.1M Phosphoric Acid (H_3PO_4) to each well and allowed to incubate for 5 minutes at room temperature. The O.D. (optical density) of the yellow color in each well was determined

using a standard ELISA plate reader at 450 nm. In comparison to the OD_{450nm} reduction (%) of the well of parental phage (100%), clones that had the OD_{450nm} reduction (%) lower than 50% were picked for sequence analysis. Unique clones were selected for phage preparation to determine binding affinity (phage IC50) against Jag1 by comparison to respective parental clones. Then the most affinity-improved clones were reformatted into human IgG1 for antibody production.

Parent antibody A and affinity matured antibodies A-1 and A-2 specifically bound to human and murine Jag1, specifically, to Jag1 DSL-EGF1-4, but not human or murine Jag 2.

The generation and characterization of certain anti-Notch2 NRR antibodies have been previously described. See PCT Application No. PCT/US09/059028.

Example 4

Treatment with Notch2 signaling inhibitor reduces tumor burden

AKT/Ras HTV mice as described in Example 1 were treated with an anti-Notch2 antibody (15mg/kg, 1x/week), anti-Jag1 antibody (10mg/kg, 1x/week) or isotype control antibody beginning the day of the hydrodynamic tail vain injection. Livers were imaged and weighed at necropsy on a standard laboratory balance. Mice treated with the control antibody developed a heavy tumor burden (FIG. 2A) five weeks following hydrodynamic tail vain injection, with their livers increasing in size to about 8.9g or approximately 31% of body weight, up from 1.2g or 5.8% of body weight (FIG. 2B) in normal, non-tumor-bearing mice. Treatment with either anti-Notch2 or anti-Jag1 antibody significantly impeded tumor development (FIG. 2A and B; $p<0.0001$, $n>8$). Mice treated with anti-Notch2 antibody developed a significantly smaller tumor burden with their livers growing to an average of 5.1g or 19.3% of body weight (FIG. 2B). Anti-Jag1 treatment had an even greater effect. In these mice final liver weights averaged 4.3g or 15.8% of body weight (FIG. 2B).

$EpCAM^+$ and $AFP^+/EpCAM^+$ subsets of tumors (FIG. 1E), in which Notch2 signaling was more highly activated than in $EpCAM^-$ tumors as determined by detection of nuclear Notch2 by immunofluorescence, were highly susceptible to Notch2 pathway inhibition. $EpCAM^+$ tumors ($AFP^-/EpCAM^+$ and $AFP^+/EpCAM^+$ tumors) were significantly reduced in area following treatment with either anti-Notch2 antibody or anti-Jag1 antibody (FIG. 3A, FIG. 3B). Notch2 signaling was not as highly activated in $AFP^+/EpCAM^-$ tumors (FIG. 1E), suggesting that these tumors might not be affected by Notch2 pathway inhibition. However, contrary to expectation, both anti-Notch2 treatment and anti-Jag1 treatment led to significant reduction in AFP^+ tumor area (FIG. 3C). Taken together, these results demonstrate that anti-Notch2 or anti-Jag1 antibody treatment blocks the development of a broad range of liver

tumors in this model of liver cancer. Successful treatment with anti-Notch2 and anti-Jag1 antibodies resulted in reduction of overall tumor burden including both HCC-like and cholangiocarcinoma-like tumors as indicated by significant reductions in AFP and EpCAM staining following anti-Notch2 and anti-Jag1 antibody treatment.

Example 5

Inhibition of Notch1 and Notch3

Inhibition of Jag1 had a similar effect as inhibition of Notch2, suggesting that Jag1 and Notch2 are acting in the same pathway, specifically, that Jag1 acts as the ligand for Notch2 in supporting tumor formation. To determine if inhibition of other Notch receptors could also reduce liver cancer formation or growth, mice were subjected to hydrodynamic tail vain injection with the Ras/AKT construct as described in Example 1 and treated with an anti-Notch1 antagonist antibody (10mg/kg, 1x/week) or an anti-Notch3 antagonist antibody (30mg/kg, 3x/week). Treatment with the anti-Notch1 antibody reduced liver weight in Ras/AKT HTV mice, compared to isotype controls, while treatment with an anti-Notch3 antibody did not significantly affect liver weight (FIG. 2D; $p<0.02$, $n\geq7$). While anti-Notch2 or anti-Jag1 treatment decreased the level of EpCAM transcript (FIG. 3E, $p<0.005$, $n\geq7$), inhibition of Notch1increased the cross-sectional area of EpCAM positive tumors in the liver (FIG. 3D, FIG. 3E, $p<0.02$, $n\geq7$) and increased the expression of the cholangiocarcinoma marker Cytokeratin 19 (CK19; FIG. 3F). Treatment with antagonist antibodies to anti-Notch1 or anti-Notch3 did not affect expression of Sox9, a liver progenitor cell and progenitor cell-like tumor marker and cholangiocarcinoma-like tumor marker, while treatment with an anti-Notch2 or anti-Jag1 antibody drastically decreased Sox9 at both the mRNA (FIG. 3G) and protein level (FIG. 3H).

Thus, treatment with anti-Notch1 or anti-Notch3 antibodies did not significantly decrease tumor burden. In fact, inhibition of Notch1 caused an increase in the number and cross-sectional area occupied by $EpCAM^+$ cholangiocarcinoma-like tumors. These results, taken together with the observation of increased cholangiocarcinoma-like lesions following anti-Notch1 treatment, further supported the conclusion that there are opposing roles for Notch2 and Notch1 in liver cancer.

Example 6

Anti-Notch2 or anti-Jag1 antibody treatment reduces Notch2 activation

For immunohistochemical analysis, tissues were fixed in 10% Neutral Buffered Formalin, embedded in paraffin, and sectioned. 4 μm-thick formalin-fixed paraffin embedded human tissues were subject to staining. For Jag1 IHC staining, all steps were carried out on the

Ventana Discovery XT autostainer using Ventana detection reagents (Ventana Medical Systems, Tucson, AZ). Tissue sections were deparaffinized in EZPrep solution and pretreatment was done with Cell Conditioner 1 using standard incubation time. Tissue sections were then incubated with goat polyclonal anti-Jag1 primary antibody (Santa Cruz Biotechnology Inc, Santa Cruz, CA; Cat# sc-6011) at 0.2 μg/ml for 32 minutes at room temperature followed by incubation with biotinylated rabbit anti-goat IgG antibody (Vector Labs, Burlingame, CA) at 7.5 μg/ml for 32 minutes at room temperature. Both primary and secondary antibodies were diluted in 10% normal human serum (Jackson ImmunoResearch) in 3% BSA. The sections were subsequently incubated with anti-Rabbit OmniMAP-HRP reagent for 16 minutes at room temperature.

For Notch 2 IHC, all steps were carried out on the Ventana Discovery XT Platform utilizing Ventana detection reagents (Ventana Medical Systems, Tuscon, AZ). Sections were deparaffinized using EZ Prep and pretreatment was accomplished with Cell Conditioner 1 using standard incubation time. Sections were then incubated with rabbit monoclonal anti-Notch2 primary antibody (Clone D76A6, Cell Signaling Technologies, Beverley, MA) at 8 μg/ml for 60 minutes at 37 °C, followed by incubation with anti-Rabbit OMNIMAP- HRP reagent for 32 minutes.

For Hes1, all steps were carried out on the Dako autostainer using DAKO wash buffer and DAKO Target Retrieval Solution. Sections were deparaffinized, re-hydrated then incubated with DAKO Target Retrieval Solution at 99 °C for 20 min, quenched with 3%H2O2 for 4 minutes then blocked with Avidin Biotin Blocking Kit (Vector Laboratories: cat#sp-2001). Sections were incubated 45 min at RT with 1ug/ml anti-HES-1 (clone NM1; MBL International) then 5ug/ml secondary antibody Bt-Dk anti-Rat (JacksonImmunoResearch) 15 minutes followed by Biotinylated-Tyramide (1:50) in amplification diluent for 3 minutes. Sections were subsequently incubated with DAB and Hematoxylin II reagents for chromogenic detection and counterstaining. Slides were dehydrated, cleared in xylenes and coverslipped. All Sections were subsequently incubated with DAB and Hematoxylin II reagents for chromogenic detection and counterstaining. Slides were dehydrated, cleared in xylenes and coverslipped. For image analysis, immunohistochemistry slides were scanned using the Nanozoomer slide scanning system (Hamamatsu).

Quantitative real-time PCR (QRTPCR) was performed using the TaqMan One-Step RT-PCR Kit for one step reactions using the 7900 HT RT-PCR system (Applied Biosystems) with TaqMan probes (Applied Biosystems). Probes used were Notch1 (Mm00435245_m1, Hs01062014_m1), Notch2 (Mm00803077_m1, Hs01050719_m1), Notch3 (Mm00435270_m1,

Hs01128541_m1), Notch4 (Mm00440525), Jag1 (Mm00496902_m1), Jag2 (Mm01325629_m1), DLL1 (Mm01279269_m1), DLL3 (Mm00432854_m1), DLL4 (Mm00444619), Hey1 (Mm00516555_m1), CK19 (Mm00492980_m1) and Sox9 (Mm00448840_m1).

In keeping with the broader effect of Notch2 and Jag1 inhibition on tumor formation, Notch2 signaling, as determined by detection of nuclear Notch2 protein by immunofluorescence, was significantly reduced throughout the tumor-bearing livers following treatment with either anti-Notch2 or anti-Jag1 (FIG. 4A; $p<0.05$, $n\geq7$). This reduction appeared to be due to a direct effect on activation of the Notch2 protein, as overall levels of Notch2 expression, as determined by quantitative RT-PCR, did not change. Consistent with anti-Notch2 or anti-Jag1 antibody treatment blocking Notch2 activation, immunostaining was reduced for Hes1, a downstream transcriptional target of the Notch2 signaling pathway. Control-treated Ras/AKT HTV livers showed high levels of Hes1 staining in (FIG. 4D). However, treatment with anti-Notch2 or anti-Jag1 antibody significantly reduced Hes1 staining, consistent with effective blockade of Notch2 signaling in the antibody- treated livers (FIG. 4C, FIG. 4D, $p\leq0.0001$, $n>10$). Confirming that Notch2 signaling was blocked, quantitative RT-PCR analysis revealed that the Notch pathway target gene HeyL was also strongly decreased with either anti-Notch2 or anti-Jag1 antibody treatment (FIG. 4E, $p<0.0001$, $n>7$).

In each case, anti-Jag1 antibody treatment had the same effect as anti-Notch2 antibody treatment, further supporting the conclusion that Jag1 is acting primarily through, i.e. as a ligand for, Notch2 in supporting liver cancer formation and growth. Taken together, these results demonstrate that treatment with either anti-Notch2 or anti-Jag1 antibody resulted in a reduction of Notch2 activation.

Example 7

Effect of Notch inhibitory antibodies on expression of Notch signaling pathway components

Mice subjected to AKT/Ras HTV were treated with antagonistic antibodies to Notch1 (10mg/kg, 1x/week), Notch2 (10mg/kg, 2x/week), Notch3 (30mg/kg, 3x/week), or Jag1 (10mg/kg, 1x/week). An anti-Ragweed antibody was administered at 30mg/kg, 3x/week as a negative control. After 5 weeks, livers were harvested and quantitative real-time PCR was performed on the isolated RNA to determine the effect of treatment on transcripts of Notch signaling pathway components. Inhibition of individual Notch family receptors did not lead to a compensatory increase in the expression of other Notch receptor family members.

As described above, inhibition of individual Notch receptors, Notch1, Notch2, and Notch3, had distinct effects in the AKT/Ras model of liver tumor development. This result suggests that the individual Notch receptors do not necessarily compensate for one another in liver cancer. To determine the effect of inhibition of individual Notch receptors and ligands on expression of Notch receptor family members, expression was assessed following treatment of mice injection with the AKT/Ras construct as described in Example 1 with either an anti-Notch1, anti-Notch2, anti-Notch3, anti-Jag1 antibody or isotype control antibody. No increase in receptor transcript expression for any of the individual Notch receptors was observed upon inhibition with any of the three inhibitory antibodies (FIG. 5 A-C). On the contrary Notch2 inhibition with a specific inhibitory antibody led to a significant decrease in expression levels of both Notch3 and Notch4 ($p<0.05$, $n\geq7$). Inhibition of Notch3 also led to a decrease in its own expression ($p<0.005$, $n\geq7$). This is consistent with previous observations that both Notch2 and Notch3 control the transcription of Notch3 (Wang et al., PLoS ONE 7:e37365 (2012); Liu et al., Circulation Research 107:860-870 (2010)). The effect of treatment with the antagonist antibodies was even greater with respect to expression of Notch ligands Jag1 and DLL1. Notch2 inhibition led to a significant decrease in Jag1 expression (FIG. 5E), likely as a result of the decrease in Jag1-expressing cholangiocarcinoma and progenitor-like tumors in these livers. Jag1 inhibition had a similar effect, further confirming that Jag1 and Notch2 are acting together in this tumor model. In contrast inhibition of Notch1 significantly increased the expression of the Notch ligands Jag2 and DLL1 (FIG. 5 F, FIG. 5G). This result might, at least in part, help to explain the observed increase in cholangiocarcinoma-like lesions in livers treated with an anti-Notch1 antagonist antibody.

In summary, a compensatory increase in expression of other Notch receptors upon Notch2 inhibition was not observed, suggesting that successful treatment with anti-Notch2 or anti-Jag1 antibodies will not lead to resistance through upregulation of alternative Notch signaling components. In fact, treatment with either Notch2 or Jag1 antagonist antibodies actually led to a decrease in Jag1 ligand expression, and treatment with anti-Notch2 led to a decrease in Notch3 expression.

Example 8

Anti-Notch2 or anti-Jag1 antibody treatment blocks progenitor-like and cholangiocarcinoma-like liver tumor growth

To address the mechanisms by which Notch2 inhibition is leading to decreased tumor burden, high throughput RNA sequencing analysis was performed. Mice subjected to AKT/Ras HTV were treated with antagonistic antibodies to Notch2 (10mg/kg, 2x/week), Jag1

(10mg/kg, 1x/week), or anti-Ragweed control (30mg/kg, 3x/week). After 5 weeks, livers were harvested and RNA was subjected to high-throughput sequencing.

Progenitor-cell and cholangiocarcinoma-like HCC expression signature gene expression was down-regulated in tumor-bearing livers following anti-Notch2 and anti-Jag1 antibody treatment. EpCAM and CK19 expression was significantly down-regulated, as was expression of CD133/Prom1 (FIG. 6A and data not shown) and Spp1 (FIG. 6B), both markers of liver progenitor cells. Because FoxM1 has previously been shown to play a role in HCC proliferation in general (Xia et al., Carcinogenesis 33:2250-2259 (2012)) and in the Ras/Akt model of liver cancer specifically (Ho et al., Hepatology 55:833-845 (2012)), we examined its expression and were able to show that both Notch2 and Jag1 inhibition lead to a decrease in FoxM1 expression(FIG. 6C). Moreover, FoxM1 target genes (Laoukili et al., Nat Cell Biol 7:126-136 (2005)), PLK1 (FIG. 6D), Ccnb1 (FIG. 6E), and Aurkb (FIG. 6F) were also decreased in tumor-bearing livers treated with either anti-Notch2 or anti-Jag1 antibody compared to controls. Markers of Wnt signaling were increased upon Notch2 or Jag1 inhibition. Specifically, Wnt2 ligand was increased (FIG. 6G) as was the Wnt-pathway target geneAxin2 (FIG. 6H). The expression of Glutamine synthetase (Glul; FIG. 6I), a marker of a subset of terminally differentiated hepatocytes, was also increased in tumor-bearing livers treated with either anti-Notch2 or anti-Jag1 antibody compared to controls. These observations are consistent with Notch2 inhibition inducing a decrease in tumor cell proliferation through downregulation of FoxM1 and inducing a differentiated hepatocyte fate through induction of Wnt-signaling (Boulter et al., Nat. Med. 18(4):572 (2012)). It is possible that Notch2 signaling inhibition in liver cancer effects terminal differentiation of tumor cells into hepatocytes. Consistent with this hypothesis, Notch2 and Jag1 inhibition led to an increase in transcriptional markers of terminally differentiated hepatocytes as well as Wnt signaling, which is known to be important in differentiation of hepatocytes from progenitor cells (Boulter et al., Nat. Med. 18(4):572 (2012)). Notch2 and Jag1 inhibition may also be acting by decreasing proliferation and increasing tumor cell death.

Example 9

Expression and activation of Notch2 in human hepatocellular carcinoma

Human HCC cell lines and primary human HCC tumors were analyzed using quantitative reverse transcription polymerase chain reaction (qRT-PCR) for expression of Notch signaling components. HCC cell lines HepG2, Hep3B, PCL/PRF/5, Snu387, Snu398, Snu423, Snu449, Snu475 were acquired from ATCC (Manassas, Virginia). HCC cell lines Huh-7, HLE, HLF, JHH1, JHH4, JHH5, JHH7 were acquired from the Japanese Collection of

Bioresources Cell Bank (Osaka, Japan). Whole stained tissue sections were analyzed using Definiens software.

Notch2 was expressed at higher levels than either Notch1 or Notch3 in 15 of 16 cultured HCC cell lines (FIG. 7A). In many cases, Notch2 expression exceeded that of the other Notch family members by more than 10 fold when expression was normalized to a reference gene (RPL19, FIG. 7A). Consistent with this result, prominent expression of Notch2 was observed in 28 of 76 (37%) human primary HCC samples as determined by IHC. In 15 of these 28 human primary HCC samples (54%) Notch2 showed varying degrees of nuclear localization (FIG. 7B) indicating Notch2 pathway activation. Jag1 expression, evaluated by IHC, was observed in 34 of 59 (57%) human primary HCC samples examined (FIG. 7B). Of the 56 human primary HCC samples evaluated for both Notch2 and Jag1, 15 (27%) were found to have expression of both Notch2 and Jag1. Of those 15 tissues with overlapping expression, 11 (73%) showed some degree of Notch2 nuclear localization indicating active Notch2 signaling.

Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity of understanding, the descriptions and examples should not be construed as limiting the scope of the invention. The disclosures of all patent and scientific literature cited herein are expressly incorporated in their entirety by reference.

WHAT IS CLAIMED IS:

1. Use of an anti-Jagged1 (anti-Jag1) antibody in the manufacture of a medicament for treating a liver cancer in an individual in need thereof, wherein the liver cancer comprises cells that express EpCAM.

2. The use of claim 1, wherein the liver cancer is selected from the group consisting of hepatocellular carcinoma, hepatoma, cholangiocarcinoma, hepatoblastoma, hepatic carcinoma, hepatic angiosarcoma, and metastatic liver cancer.

3. The use of claim 1, wherein the anti-Jag1 antibody is a monoclonal antibody.

4. The use of claim 3, wherein the anti-Jag1 antibody is an IgG1 or IgG2a antibody.

5. The use of claim 3, wherein the anti-Jag1 antibody is a chimeric antibody, a humanized antibody, or a human antibody.

6. The use of claim 1, wherein the anti-Jag1 antibody comprises:

a) heavy chain hypervariable region 1 (HVR-H1) comprising the amino acid sequence of SEQ ID NO:81; heavy chain hypervariable region 2 (HVR-H2) comprising the amino acid sequence of SEQ ID NO:84; heavy chain hypervariable region 3 (HVR-H3) comprising the amino acid sequence of SEQ ID NO:87; light chain hypervariable region 1 (HVR-L1) comprising the amino acid sequence of SEQ ID NO:88; light chain hypervariable region 2 (HVR-L2) comprising the amino acid sequence of SEQ ID NO:89; and light chain hypervariable region 3 (HVR-L3) comprising the amino acid sequence of SEQ ID NO:92; or

b) HVR-H1 comprising the amino acid sequence of SEQ ID NO:81; HVR-H2 comprising the amino acid sequence of SEQ ID NO:82; HVR-H3 comprising the amino acid sequence of SEQ ID NO:85; HVR-L1 comprising the amino acid sequence of SEQ ID NO:88; HVR-L2 comprising the amino acid sequence of SEQ ID NO:89; and HVR-L3 comprising the amino acid sequence of SEQ ID NO:90; or

c) HVR-H1 comprising the amino acid sequence of SEQ ID NO:81; HVR-H2 comprising the amino acid sequence of SEQ ID NO:82; HVR-H3 comprising the amino acid sequence of SEQ ID NO:86; HVR-L1 comprising the amino acid sequence of SEQ ID NO:88; HVR-L2 comprising the amino acid sequence of SEQ ID NO:89; and HVR-L3 comprising the amino acid sequence of SEQ ID NO:91; or

d) HVR-H1 comprising the amino acid sequence of SEQ ID NO:81; HVR-H2 comprising the amino acid sequence of SEQ ID NO:83; HVR-H3 comprising the amino acid sequence of SEQ ID NO:85; HVR-L1 comprising the amino acid sequence of SEQ ID NO:88;

HVR-L2 comprising the amino acid sequence of SEQ ID NO:89; and HVR-L3 comprising the amino acid sequence of SEQ ID NO:90.

7. The use of claim 1, wherein the anti-Jag1 antibody comprises:

a) a heavy chain variable region(VH) sequence of SEQ ID NO:93 and a light chain variable region (VL) sequence of SEQ ID NO:96; or

b) a VH sequence of SEQ ID NO:94 and a VL sequence of SEQ ID NO:97; or

c) a VH sequence of SEQ ID NO:95 and a VL sequence of SEQ ID NO:98.

8. The use of claim 1, wherein the anti-Jag1 antibody is conjugated to a cytotoxic agent.

9. The use of claim 8, wherein the cytotoxic agent is selected from toxins, antibiotics, radioactive isotopes and nucleolytic enzymes.

10. The use of claim 1, wherein the liver cancer comprises cells that express at least one of AFP, Notch2, Jag1, Sox9, CK19, Ras, Prom1, Spp1, FoxM1, Plk1, ccnb1, Aurkb, Wnt2, Axin2, or Glul.

11. The use of claim 1, wherein the liver cancer comprises cells having nuclear Notch2.

12. The use of claim 1, wherein the liver cancer comprises cells having activated Ras.

13. The use of claim 1, wherein administration of the anti-Jag1 antibody results in a decrease in EpCAM expression in the cells.

14. The use of claim 1, wherein the liver cancer comprises cells that express AFP and wherein administration of the anti-Jag1 antibody results in a decrease in AFP expression in the cells.

15. The use of claim 1, wherein administration of the anti-Jag1 antibody results in a decrease in expression, compared to expression prior to administration of the inhibitor, in the liver cancer of at least one of Prom1, Spp1, FoxM1, Plk1, ccnb1 and Aurkb.

16. The use of claim 1, wherein administration of the anti-Jag1 antibody results in an increase in expression in the liver cancer of at least one of Wnt2, Axin2 and Glul.

17. The use of claim 1, wherein the liver cancer is at least in part dependent upon a growth potentiating effect of Notch2 signaling.