

# **Carbon 14 Decay as a Source of Somatic Point Mutations in Genes Correlated with Cancer Diagnoses**

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## **ABSTRACT**

Carbon-14 decay was identified as a source of point mutations in genes associated with cancer diagnoses in glia, neurons, lymphocytes, adipocytes, vascular endothelial cells, hepatocytes, and bone marrow cells. Cumulative mean  $^{14}\text{C}$  decay in DNA was modeled for multiple tissue types for people born from 1973 to 2013 in the Northern hemisphere, and compared to 73,182 diagnoses of glioma, lymphoma, liposarcoma, vascular endothelial cancer, hepatocellular carcinoma, and bone cancer in the U.S. between 1973 and 2013. Significant correlations ( $p \leq 0.0001$ ) with  $R^2$  from 0.950 to 0.996 were found for several histologies. The relative pathogenic sensitivity of 85 genes with the most frequent mutations was identified from review of 289,322 mutations in sequences from 23,721 samples and diagnoses were correlated with  $^{14}\text{C}$  decay in genes.  $^{14}\text{C}$  decay nitrogen substitution was identified as a source of transcription errors analogous with the two most common point mutations cataloged during genome sequencing.

## **Introduction**

Radioactive carbon-14 decay to nitrogen-14 ( $^{14}\text{C} \rightarrow ^{14}\text{N}$ ) with the release of 156 KeV has long been known to have biological effects, and decay in DNA is a potential source of point mutations due to bond ruptures, strand breakages, and nitrogen substitutions in canonical bases [1,2]. Sequencing of the human genome has identified 6.1 billion base pairs in human DNA, with 119 billion carbon atoms in the DNA of each nucleated cell [3,4]. Recent quantitative analysis of human tissues has estimated 3 trillion nucleated cells in a standard human body with abundance of each tissue [5]. Together, with a known half-life and natural abundance of  $^{14}\text{C}$  in the Northern hemisphere, it is possible to model cumulative DNA decay in people born in the U.S. and correlate this with epidemiology data for the clinical diagnoses of cancer [6]. Furthermore, the genetic sequencing of large numbers of cancerous tissues and tumors enables the identification of the most common point mutations in different tissue types [7,8,9]. Review of the base pairs in each of these genes reveals how many carbon atoms are in each gene, which can be used to calculate the cumulative  $^{14}\text{C}$  decay in the DNA of each gene known to be pathogenic.

## **Results**

### ***Anatomical and Atmospheric Models***

Anatomical fetal models resulted in births at 38 weeks of 3.5 kg with  $1.50 \times 10^{11}$  nucleated cells and  $9.35 \times 10^{17}$  cumulative cell-seconds (i.e., units of one cell living for one second). For births in 1973, by the age of 40, the number of nucleated cells rose to  $3.46 \times 10^{12}$  for males and  $2.86 \times 10^{12}$  for females, with cell-seconds of  $3.19 \times 10^{21}$  and  $2.70 \times 10^{21}$ , respectively. Mean heights and

weights in adulthood increased for births in later years, resulting in higher quantities of cells. For instance, at the age of 20-years-old, comparing births from 1973 to 1993, nucleated cell counts increased 2.2% from  $3.11 \times 10^{12}$  to  $3.18 \times 10^{12}$  for males and increased 7.9% from  $2.56 \times 10^{12}$  to  $2.76 \times 10^{12}$  for females. Similarly, the number of cell-seconds rose 6.5% from  $1.06 \times 10^{21}$  to  $1.13 \times 10^{21}$  for males and rose 7.1% from  $9.88 \times 10^{20}$  to  $1.06 \times 10^{21}$  for females. Adipocytes, bone marrow cells, hepatocytes, lymphocytes, and vascular endothelial cells were assumed to remain constant portions of standard body nucleated cells, while neurons and glia were modeled as non-regenerative tissue with variable brain mass which was estimated to be 3.18% higher than the ratio of brain mass to body mass, as required to coincide with the standard body 5.3% for males at age 20-30. The neurons and glia varied from a maximum 18.7% of nucleated cells in the fetal model at week 20 to 5.3% and 5.6% for males and females at age 25, respectively. (See Extended Data Tab. 1, 2, & 3.)

The abundance of  $^{14}\text{C}$  in the Northern hemisphere was also changing over time, rising from 242.4‰ in 1959 to a peak of 867.6‰ in 1964 and then dropping to 416.7‰ in 1973 and continued to decrease an average of 6.6% per year to 28.0‰ in 2013. This represents a decrease of 27.4% from 1973 to 2013, corresponding to the temporal range of the epidemiology data set. The standard deviation also decreased from 5.2‰ in 1973 to 1.1‰ in 2013. (See Extended Data Tab. 4.)

The mean cumulative decays of  $^{14}\text{C}$  in the DNA of adipocytes, bone marrow cells, hepatocytes, lymphocytes, neurons & glia, and vascular endothelial cells were calculated for live births in the U.S. 1973-2013. The resulting  $^{14}\text{C}$  decays in the DNA of each tissue type depend on the mean quantities of cells in each tissue, the tissue growth over time for each year, and the regeneration rates of each tissue type. (See Extended Data Tab. 5.) As the most abundant tissue with nucleated cells, bone marrow cells receive the most damage, e.g., for 40-year-olds born in 1973, cumulative decays totaled  $2.67 \times 10^8$  for males and  $2.31 \times 10^8$  for females, with Standard Deviations (SD) of  $1.39 \times 10^7$  and  $1.41 \times 10^7$  respectively. Vascular endothelial cells were second, followed by lymphocytes, hepatocytes, and finally adipocytes with the least cumulative decays, e.g., for 40-year-olds born in 1973, mean cumulative decays totaled  $2.17 \times 10^7$  for males and  $1.88 \times 10^7$  for females, with SD of  $1.13 \times 10^6$  and  $1.15 \times 10^6$  respectively. People born years later had a decreasing amount of cumulative decays naturally due to a reduced atmospheric abundance of  $^{14}\text{C}$ . For instance, at the age of 30 years, for people born in 1973 and 1983, mean cumulative decays in the DNA of neurons & glia decreased 10.6% from  $5.55 \times 10^7$  to  $4.96 \times 10^7$  for males and 9.8% from  $5.14 \times 10^7$  to  $4.64 \times 10^7$  for females. The decrease was qualitatively different for regenerative tissues, for instance, in lymphocytes for the same 30-year-olds, the mean cumulative decays decreased 5.1% from  $1.04 \times 10^8$  to  $9.89 \times 10^7$  for males and 3.8% from  $9.20 \times 10^7$  to  $8.86 \times 10^7$  for females.

### ***Clinical Diagnoses***

For births in the U.S. from 1973 to 2013, cumulative diagnoses from 34,604 cases of glioma, neuroepitheliomatous neoplasms, meningioma, and nerve sheath tumors were correlated with modeled  $^{14}\text{C}$  decay in the DNA of neurons and glia cells (Fig. 1.a); cumulative diagnoses from 28,199 cases of malignant lymphoma, Hodgkin's lymphoma, diffuse large mature B-Cell lymphoma, mature T and NK-Cell lymphoma, and precursor cell lymphoblastic lymphoma were

correlated with modeled  $^{14}\text{C}$  decay in the DNA of lymphocytes (Fig. 1.b); cumulative diagnoses from 785 cases of liposarcoma were correlated with modeled  $^{14}\text{C}$  decay in the DNA of adipocytes (Fig. 1.c); cumulative diagnoses from 2,666 cases of vascular endothelial cancer were correlated with modeled  $^{14}\text{C}$  decay in the DNA of vascular endothelial cells (Fig. 1.d); cumulative diagnoses from 1,184 cases of hepatocellular carcinoma were correlated with modeled  $^{14}\text{C}$  decay in the DNA of hepatocytes (Fig. 1.e); and cumulative diagnoses from 5,744 cases of osseous and chondromatous neoplasms, giant cell tumors, miscellaneous bone tumors, and odontogenic tumors were correlated with modeled  $^{14}\text{C}$  decay in the DNA of bone marrow cells (Fig. 1.f). These correlations for all 73,182 cases by histology for each respective tissue are summarized in Tab. 1. Many of the histologies have highly positive and substantive correlations (i.e.,  $R^2 > 0.6$  with  $p \leq 0.0001$ ) for males and females, with Hodgkin's lymphoma being the highest with  $R^2 = 0.924$  for males and 0.903 for females. Hepatocellular carcinoma, malignant lymphoma, mature B-Cell lymphoma, and T & NK-Cell lymphoma all having  $R^2 > 0.7$ . The lowest correlation was with neuroepitheliomatous neoplasms with  $R^2 = 0.013$  for males and  $R^2 = 0.006$  for females.

Further examination of trends in Fig. 1 reveals increased diagnosis rates for many histologies despite a reduced somatic abundance of  $^{14}\text{C}$ , suggesting an adverse environmental change over time has increased pathogenesis in the U.S. population. This can be observed, for instance, in the vertical rise of diagnoses independent of  $^{14}\text{C}$  decay on (but not limited to) Fig. 1.a for gliomas and neuroepitheliomatous neoplasms. This change is most apparent when comparing diagnoses in younger patients. For example, in 10-year-olds born from 1973 to 2003, cumulative diagnoses of gliomas rose dramatically from 26.7 to 117.0 for males and from 27.5 to 114.2 for females, per million live births. Similarly, in a different histology, for 10-year-olds born from 1973 to 2003, cumulative diagnoses of Hodgkin's lymphoma rose from 1.9 to 11.0 for males and from 1.3 to 6.5 for females, per million live births. Qualitatively, this increase appears to start in 1983, increasing in rate to 1998, and only starting to decrease in rate near 2008, and although slowing, the rate of increase does not appear to stop in 2013.

Since this observed trend is variable and independent of  $^{14}\text{C}$  decay, it detrimentally affects correlations that include multiple years of births in the population. Therefore, a subset of live births was selected for comparison. For births in the U.S. in 1988, cumulative diagnoses from 588 cases of glioma were correlated with modeled  $^{14}\text{C}$  decay in the DNA of neurons and glia cells (Fig. 2.a); cumulative diagnoses from 526 cases of Hodgkin's lymphoma were correlated with modeled  $^{14}\text{C}$  decay in the DNA of lymphocytes (Fig. 2.b); cumulative diagnoses from 19 cases of liposarcoma were correlated with modeled  $^{14}\text{C}$  decay in the DNA of adipocytes (Fig. 2.c); cumulative diagnoses from 58 cases of vascular endothelial cancer were correlated with modeled  $^{14}\text{C}$  decay in the DNA of vascular endothelial cells (Fig. 2.d); cumulative diagnoses from 19 cases of hepatocellular carcinoma were correlated with modeled  $^{14}\text{C}$  decay in the DNA of hepatocytes (Fig. 2.e); and cumulative diagnoses from 157 cases of osseous and chondromatous neoplasms were correlated with modeled  $^{14}\text{C}$  decay in the DNA of bone marrow cells (Fig. 2.f). Correlations of these 2,063 cases are summarized in Tab. 2. With this subset of the population, each histology has higher correlations in Tab. 2, except for odontogenic tumors, for which there were no diagnoses as of 2013. Glioma has the highest correlation (for  $n > 5$ ) with  $R^2 = 0.998$  for males and 0.996 for females ( $p < 0.0000$ ). The lowest were angiosarcoma with  $R^2$

$R^2 = 0.741$  and hepatocellular carcinoma with  $R^2 = 0.846$ , both for males, followed by malignant lymphoma in females with  $R^2 = 0.861$ . The mean correlation on Tab. 2 (for  $n > 5$ ) is  $R^2 = 0.946$  vs. 0.613 on Tab. 1.

### ***Mutation Analysis***

The 85 most common genes with mutations found in the histologies above were identified and frequency ranked by review of 289,322 mutations found by targeted screen and full genome sequencing of 23,721 samples, and are summarized in Tab. 3. Sub-histologies of osseous and chondromatous neoplasms were reviewed, including chondroblastoma, chondrosarcoma, and osteosarcoma. Burkitt lymphoma sample results were reviewed as a malignant lymphoma, T-Cell lymphoblastic lymphoma sample results were reviewed as a precursor cell lymphoblastic lymphoma, and neuroblastoma sample results were reviewed as neuroepitheliomatous neoplasms. Thirty of these 85 genes are pathogenic in more than one histology, and many of these are pathogenic in more than one tissue type. For instance, ARID1A mutations were found in cancer samples in hepatocytes, lymphocytes, and neurons & glia cancers; CDKN2A mutations were found in adipocytes, bone marrow cells, and neurons & glia cancers; and CTNNB1 mutations were found in adipocytes, hepatocytes, and lymphocytes. (See Extended Data Tab. 6 for more detail.) Where dependencies between point mutations were observed, they were noted. For instance, from review of full genome sequence data of glioma samples, at least two genes were mutated in each sample suggesting an incomplete point mutation pathogenesis in as follows: (IDH1 and ((TERT or (TP53 and (PTEN or ATRX)) or (other)) or ((other))) where “other” is one or more other genes. (See Extended Data Tab. 7 for more detail.)

Cumulative diagnoses of the histologies above were correlated with mean  $^{14}\text{C}$  decay in the DNA of each of the most common genes with mutations (Fig. 3). (See Extended Data Fig. 1, 2, & 3 for more detail.) Each of these pathogenic genes receives hundreds to thousands of  $^{14}\text{C}$  decays throughout each respective tissue through adulthood. For instance, per modeled cumulative  $^{14}\text{C}$  decay in the DNA of neurons and glia cells, males/females born in 1973 at age 40 would have a mean number of  $^{14}\text{C}$  decays in the five most frequently mutated genes in glioma as follows: TP53: 253/228, TERT: 559/502, TTN: 3,730/3,351, IDH1: 251/226, and ATRX: 3,745/3,364. The genes with similar carbon content or numbers of base pairs receive on average similar quantities of decays (e.g., see the TP53-IDH1 and TTN-ATRX pairs on Fig. 3.a). Further examination of Fig. 3 reveals the frequency mutations are found in histologies (e.g., Extended Data Tab. 6) is not proportional to the cumulative damage that occurs from uniform sources, such as  $^{14}\text{C}$ . This suggests a Relative Pathogenic Sensitivity (RPS) exists for genes, which can be quantified as proportional to the frequency of pathogenic mutations and inversely proportional to the size of the gene, as follows:

$$\text{RPS} = (\% \text{ probability of finding a specific mutated gene in a histology}) /$$

$$(\# \text{ of base pairs in that gene})$$

The RPS was calculated for 85 genes identified above, revealing stratified RPS values across histologies. (See Extended Data Tab. 6 for full details.) RPS values for the same gene can be different in different histologies, suggesting unique roles or dependencies of genes in the

pathogenesis of different histologies and tissues; e.g., TTN has an RSP of  $1.06 \times 10^{-6}$  in hepatocellular carcinoma and  $2.66 \times 10^{-7}$  in osteosarcoma, nearly 25% of the former, suggesting a different pathogenic role for TTN in osteosarcoma (in bone marrow cells) as compared to carcinoma in hepatocytes. Different genes also have similar RPS values in different histologies, suggesting similar roles in pathogenesis of different histologies; e.g., the RPS of MYC is  $8.65 \times 10^{-5}$  in malignant lymphoma, which is identical to the RPS of H3F3A in giant cell tumors; similarly, the RPS of TP53 in glioma is very close to the RPS of IDH1 in chondrosarcoma. Across the histologies reviewed, it was common for genes with the least number of base pairs to be among those with the highest RSP; e.g., in glioma, the three shortest genes among the most common, i.e., TP53, IDH1, and H3F3A, also have the three highest RPS. Also, the genes with the highest frequency of mutations in histologies also tended to have the highest RSP values; e.g., in glioma, three of four of the most common genes with mutations are among the four highest RPS values.

Review of 4,467,131 mutations identified in full genome and targeted screen sequencing of cancer tissues found that transformations between adenine, cytosine, guanine, and thymine (A, C, G, & T) as well as the insertion and deletion of base pairs are not equally frequent, but as follows: A>C 2.57%, A>G 6.56%, A>T 2.53%, C>A 5.78%, C>G 3.32%, C>T 26.46%, G>A 25.67%, G>C 3.60%, G>T 8.96%, T>A 2.39%, T>C 4.75%, T>G 2.23%, insertion 1.73%, and deletion 3.45%. Several findings result from this, which must relate to the fundamental origins of mutations, as well as mechanisms related repairs and attempted repairs. Firstly, C>T and G>A overall account for over 52% of all mutations. Secondly, A>C and A>T are similar in likelihood, whereas A>G is more than twice as likely. Similarly, T>A and T>G are similar in likelihood, whereas T>C is nearly twice as likely to occur. And finally, deletion is twice as likely to occur as an insertion. The first observation above is the most surprising. Review of the structures of cytosine and guanine reveal that when a  $^{14}\text{C}$  decay occurs in the cytosine ring at the carbon atom connected to the amide ( $\text{H}_2\text{N}$ ), a direct transformation to a thymine analog is produced due to nitrogen (N) substitution (Fig. 4.a). Similarly, in adenine when a decay occurs in the adenine ring at the carbon connected to the oxygen (O), a direct transformation to a guanine analog is produced (Fig. 4.b). The products in both cases would appear to be valid but different nitrogenous bases during transcription, suggesting the two mutations which are most commonly observed in the genetic sequencing of cancer tissue samples, i.e., C>T and G>A, can also be directly caused by  $^{14}\text{C}$  decay  $^{14}\text{N}$  substitution in DNA.

## Discussion

Statistically significant positive correlations were found between cumulative  $^{14}\text{C}$  decay in DNA of tissues and related cancer histologies in the U.S. (Tables 1 & 2). This suggests reducing the natural abundance of  $^{14}\text{C}$  from our food chain could reduce DNA damage and “natural” pathogenesis rates. Despite this, there is a dearth of biological studies related to the effects of  $^{14}\text{C}$  abundance on organisms. For instance, one study found an increase of heritable mutations in flies grown in  $^{14}\text{C}$  enriched media [10]. However, no studies have been completed to-date on the effects of a lower than natural abundance of  $^{14}\text{C}$  on organisms. Cancer prevention would seem to necessitate precluding such damage wherever possible. More study of cell and animal models could help clarify what distinguishes “natural” cumulative damage like this from aging.

Unexpectedly, the quantification of cumulative  $^{14}\text{C}$  decay on one axis was found to highlight the effects over time of other carcinogens on diagnosis rates in epidemiological data for the U.S. population (e.g., Fig. 1). Despite a reduced somatic abundance of  $^{14}\text{C}$  from 1973 to 2013, due to a reduced atmospheric abundance, increased diagnosis rates were identified suggesting an increase of carcinogens in the environment independent of  $^{14}\text{C}$  decay. Limiting correlations to one year of birth (e.g., Tab. 2 & Fig. 2) was found to limit the noise caused by these other carcinogenic variables that were found to change dynamically over time, and these changes were only apparent after understanding temporal changes in diagnosis rates independent of  $^{14}\text{C}$  evidenced in Fig. 1.

Correlations of cumulative  $^{14}\text{C}$  decay in DNA to diagnoses were limited by temporal truncation of both the patient birth and diagnosis dates to the year in epidemiology source data. This rounds cumulative damage estimates for each diagnosis to a whole year whereas the actual cumulative damage could be up to  $\pm$  12 months. Correlations could be improved by including actual birth and diagnosis dates in epidemiology source data. Similarly, correlations were limited by a lack of weight and height (or Body Mass Index (BMI)) data for each diagnosis in the epidemiology source data. Availability of these variables would allow for correction of tissue models for each diagnosis (e.g., adjustment of the adipocytes tissue model for liposarcoma cases, as well as others), rather than relying on means of same-sex people born in the same year. Having this data available for each person from birth up to the time of diagnosis would be much better, however, results could also be improved initially with the addition of basic patient weight and height metrics to epidemiology source data.

In general, more accurate tissue models pre- and post-birth are needed to improve cumulative environmental damage modeling. For instance, bone marrow cells and lymphocytes are likely less than the standard body abundance of 22.1% and 13.3%, respectively, since these tissues are rather immature early in life. This is demonstrated in Fig. 2.b and 2.f, where early life-cycle cumulative  $^{14}\text{C}$  damage appears to be overestimated. Although a variable brain mass model was used, it was necessary to estimate the abundance of glia and neurons outside of the brain to utilize a variable brain mass model, and this abundance was assumed to be constant for all ages, since no authoritative studies could be found for this.

Review of full genome sequence data reveals most histologies are dependent on more than one point mutation, and that most samples contain many genes with mutations. For instance, review of 1,195 glioma full genome sequences revealed that 1,013 of the samples (85%) had 10 or more genes with mutations, over 55 samples (4.6%) had 100 or more genes with mutations, and 7 samples had more than 500 genes with mutations. While nitrogen substitution from  $^{14}\text{C}$  decay appears sufficient to produce one point mutation, especially when the decay occurs in specific locations of nitrogenous bases (e.g., Fig. 4), beta particle emission from  $^{14}\text{C}$  decay provides sufficient energy to damage many genes, and full genome sequence data suggests that genetic damage with point mutations to several genes is common.

RPS calculations suggest large genes with low values have resilience against genetic mutations (e.g., CSMD1 with 2,059,683 base pairs and a RPS of  $4.92 \times 10^{-8}$  for hepatocellular carcinoma), with portions of base pairs where a point mutation may have no pathogenic effect. Likewise, small genes with high values (e.g., SOCS1 with 1,766 base pairs and RPS of  $2.60 \times 10^{-4}$  for

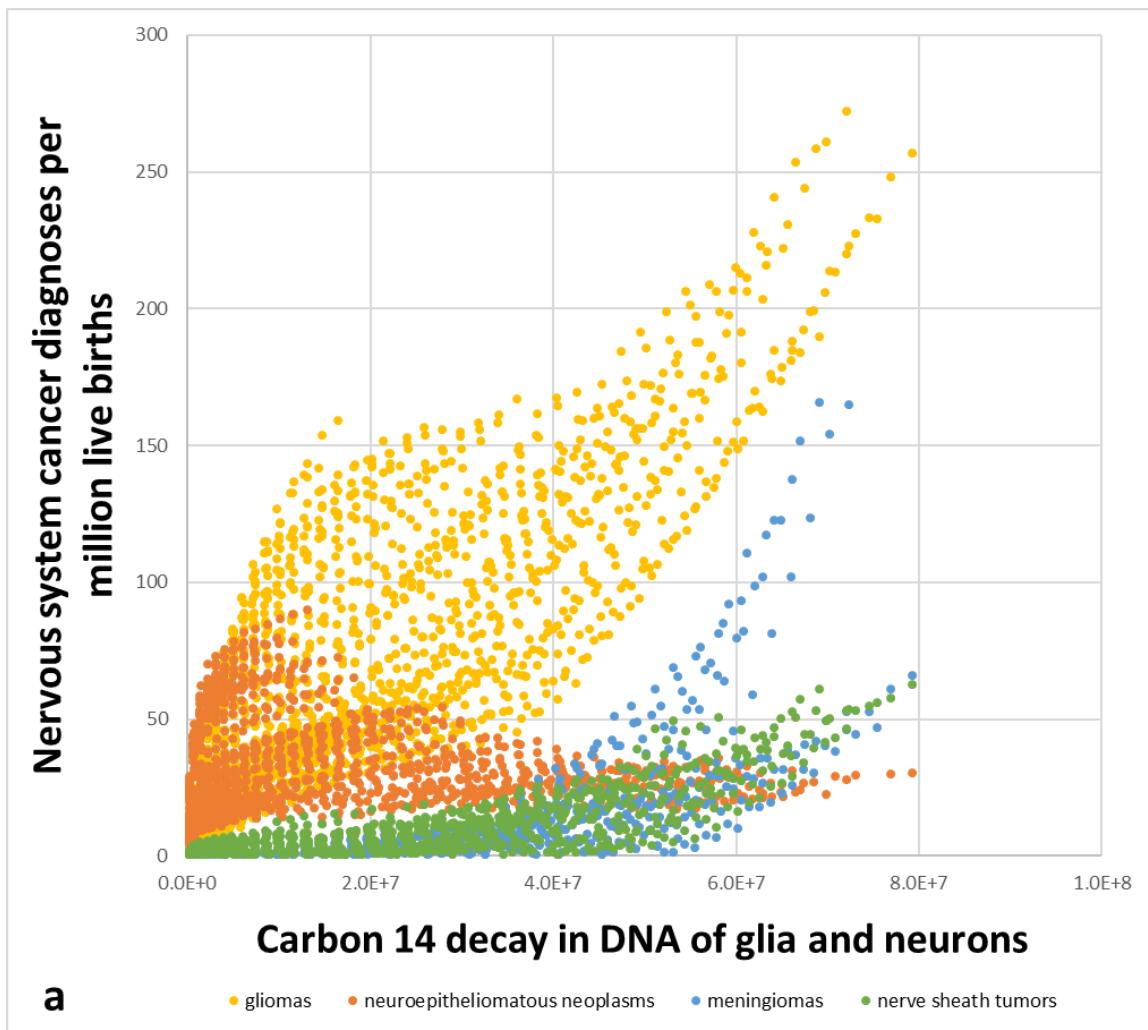
Hodgkin's lymphoma) suggest they are not as resilient against point mutations, having fewer sets of base pairs where a point mutation may have no effect. The RPS values and point mutation pathogenesis are currently limited by a lack of full genome sequence data for Hodgkin's lymphoma, precursor cell lymphoblastic lymphoma, and giant cell tumors. Similarly, full genome sequence data is currently available for only a small number of liposarcoma and angiosarcoma samples. Uncertainty in pathogenesis could also be reduced with more targeted screening for TET2, NRAS, and CTNNB1 in precursor cell lymphoblastic lymphoma, HRAS in giant cell tumors, and DDX3X in T & NK-Cell lymphomas.

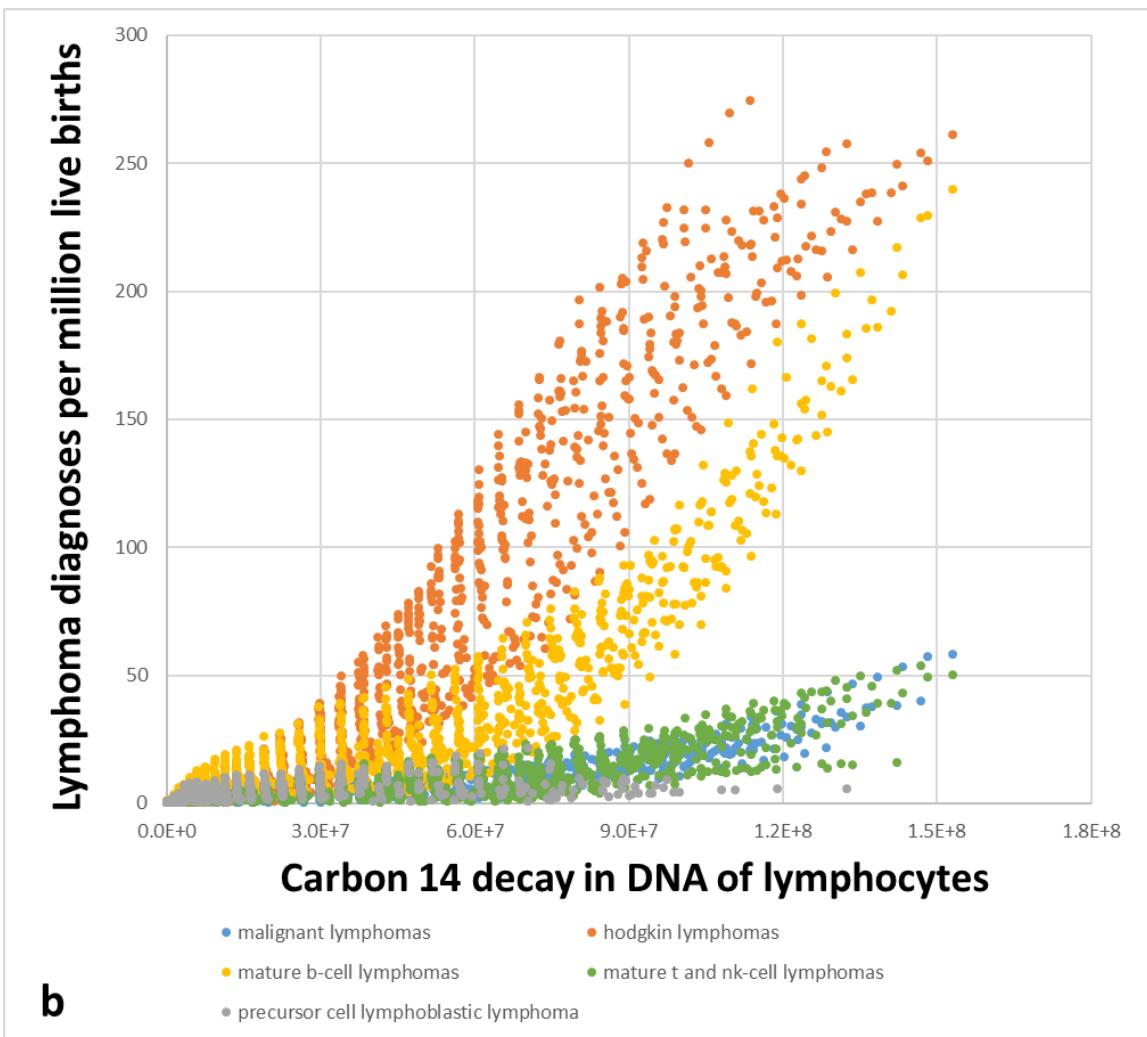
Although direct transformations from cytosine to a thymine analog and from guanine to an adenine analog were identified due to  $^{14}\text{C}$  decay  $^{14}\text{N}$  substitution (Fig. 4), and these two mutations (i.e., C>T & G>A) represent over 52% of all point mutations cataloged, it is not clear what portion of these cataloged mutations are caused by  $^{14}\text{C}$  nitrogen substitution or subsequent transcriptions. Cytosine and guanine are subject to chemical deamination reactions in DNA which can have an identical result (e.g., G>A), as well as other environmental carcinogens and mechanisms [11]. Further study of cell and animal models could improve our understanding of how  $^{14}\text{C}$  decay contributes to nitrogenous base ring breakage and transcription errors. For instance, some carcinogens may depend on weakened strands and nitrogenous bases that have been damaged by nitrogen substitution, and precluding  $^{14}\text{C}$  decay in DNA could impart a resistance to these carcinogens.

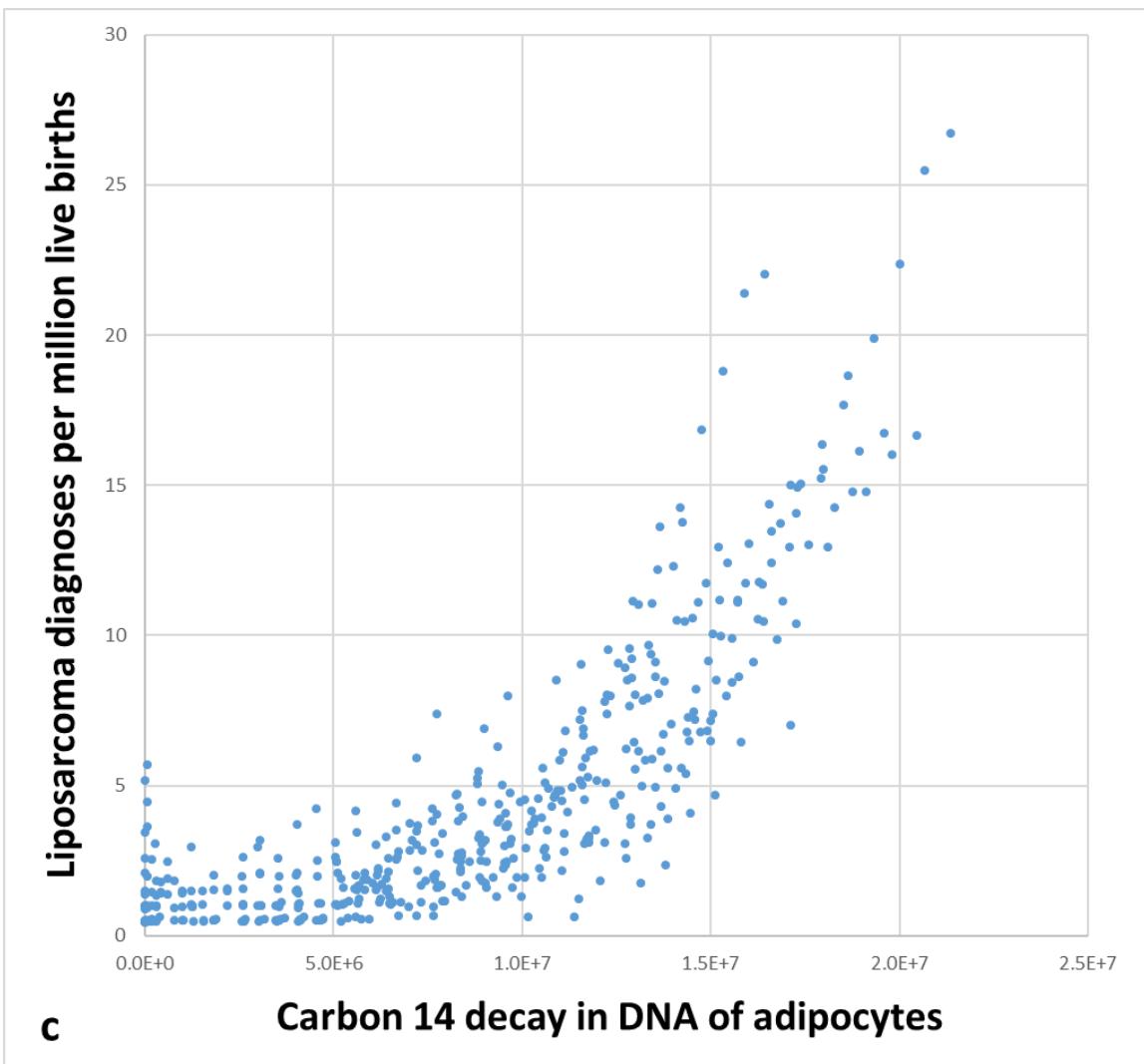
While the natural abundance of  $^{14}\text{C}$  in the atmosphere complicates removal from our food chain, centrifugal filtration of carbon dioxide with  $^{14}\text{C}$  from atmospheric gases could be achieved with high efficiency compared to heavy uranium isotope separation, due to the substantial mass difference between the relatively light carbon isotopes (e.g.,  $^{12}\text{C}$  and  $^{14}\text{C}$  differ in mass by 16.7% whereas  $^{235}\text{U}$  and  $^{238}\text{U}$  differ by 1.3%). Agricultural products grown in controlled environments with such filtration would radiocarbon date-test to many thousands of years old, and as a food source would reduce somatic abundance of  $^{14}\text{C}$  and preclude decay in DNA. Since lymphocytes are generated continuously, within weeks of such a dietary change, cumulative damage due to  $^{14}\text{C}$  decay in the DNA of lymphocytes could be halted, with additional damage to regenerative tissues slowing over time. Future generations could be spared millions of  $^{14}\text{C}$  decays in their DNA each year, precluding this source of spontaneous point mutations.

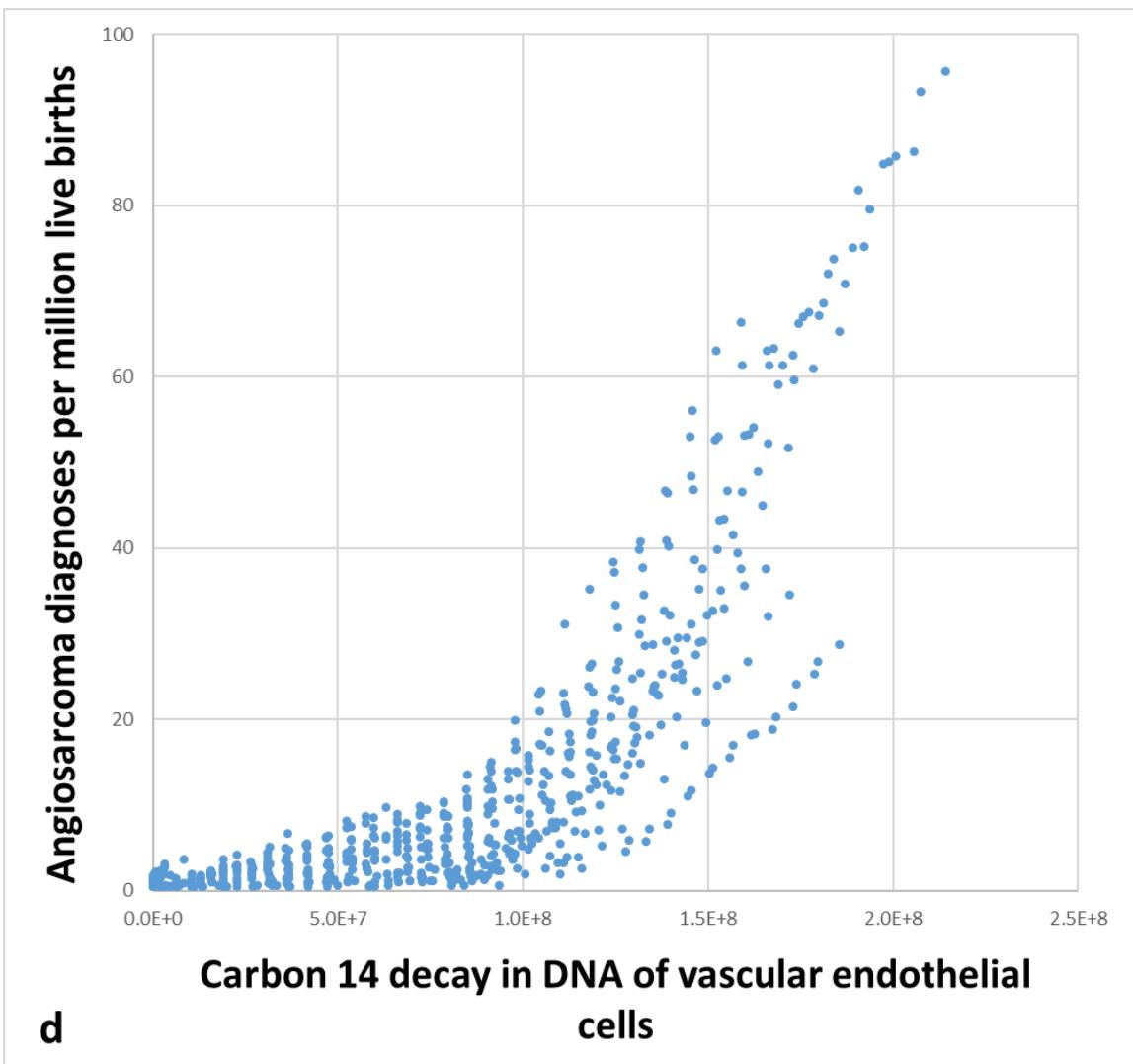
**Figure 1: Cumulative cancer histology diagnoses in U.S. 1973-2013 correlated with carbon-14 decay in DNA of related tissues (births in 1973-2013)**

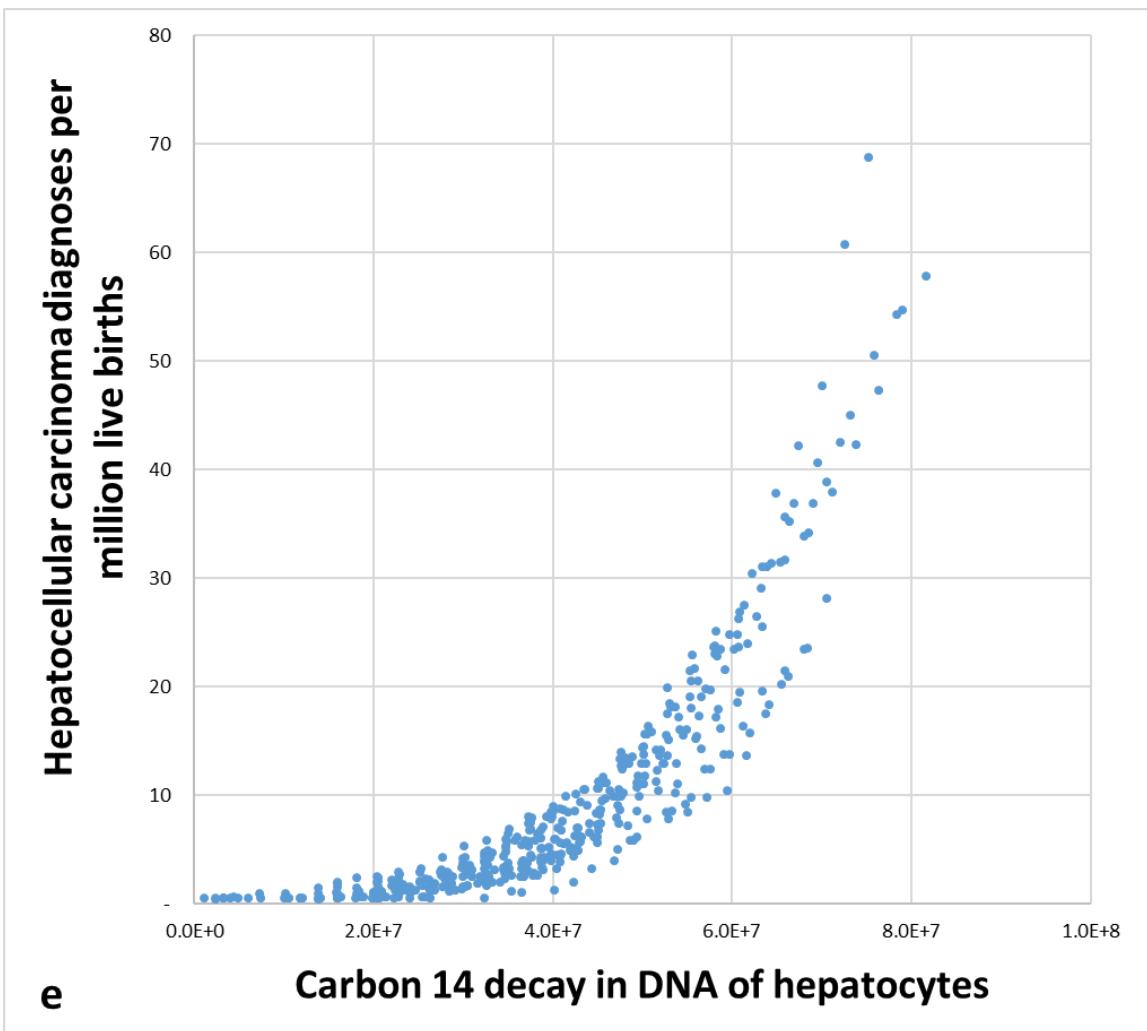
Cumulative diagnoses from 1973 to 2013 of (a) nervous system cancer (gliomas, neuroepitheliomatous neoplasms, meningiomas, and nerve sheath tumors) diagnoses vs.  $^{14}\text{C}$  decay in DNA of glia and neurons; (b) lymphoma diagnoses vs.  $^{14}\text{C}$  decay in DNA of lymphocytes; (c) liposarcoma diagnoses vs.  $^{14}\text{C}$  decay in DNA of adipocytes; (d) vascular endothelial cancer diagnoses vs.  $^{14}\text{C}$  decay in DNA of vascular endothelial cells; (e) hepatocellular carcinoma diagnoses vs.  $^{14}\text{C}$  decay in DNA of hepatocytes; (f) bone cancer diagnoses (osseous and chondromatous neoplasms, giant cell tumors, miscellaneous bone tumors, and odontogenic tumors) vs.  $^{14}\text{C}$  decay in DNA of bone marrow cells.

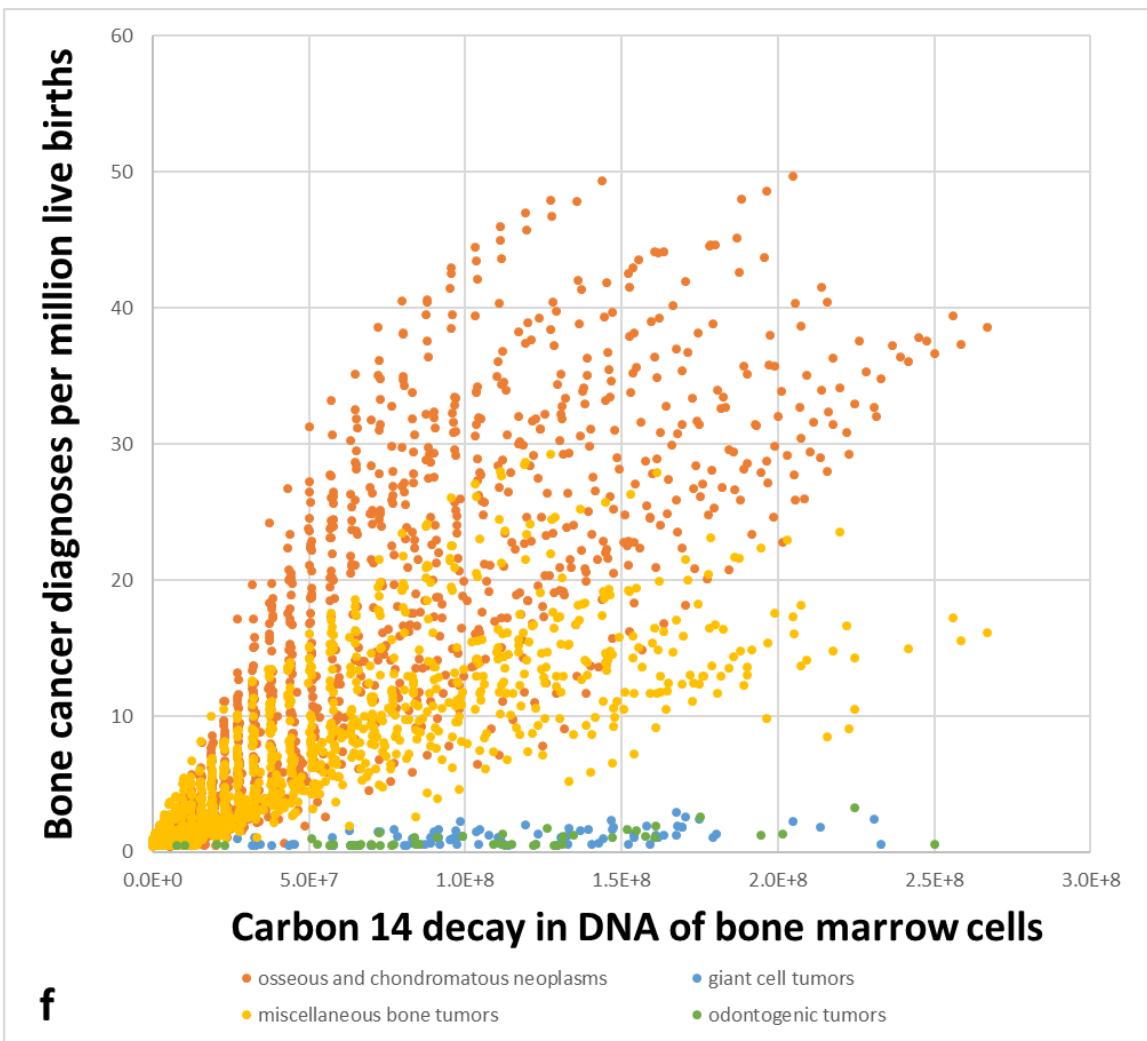






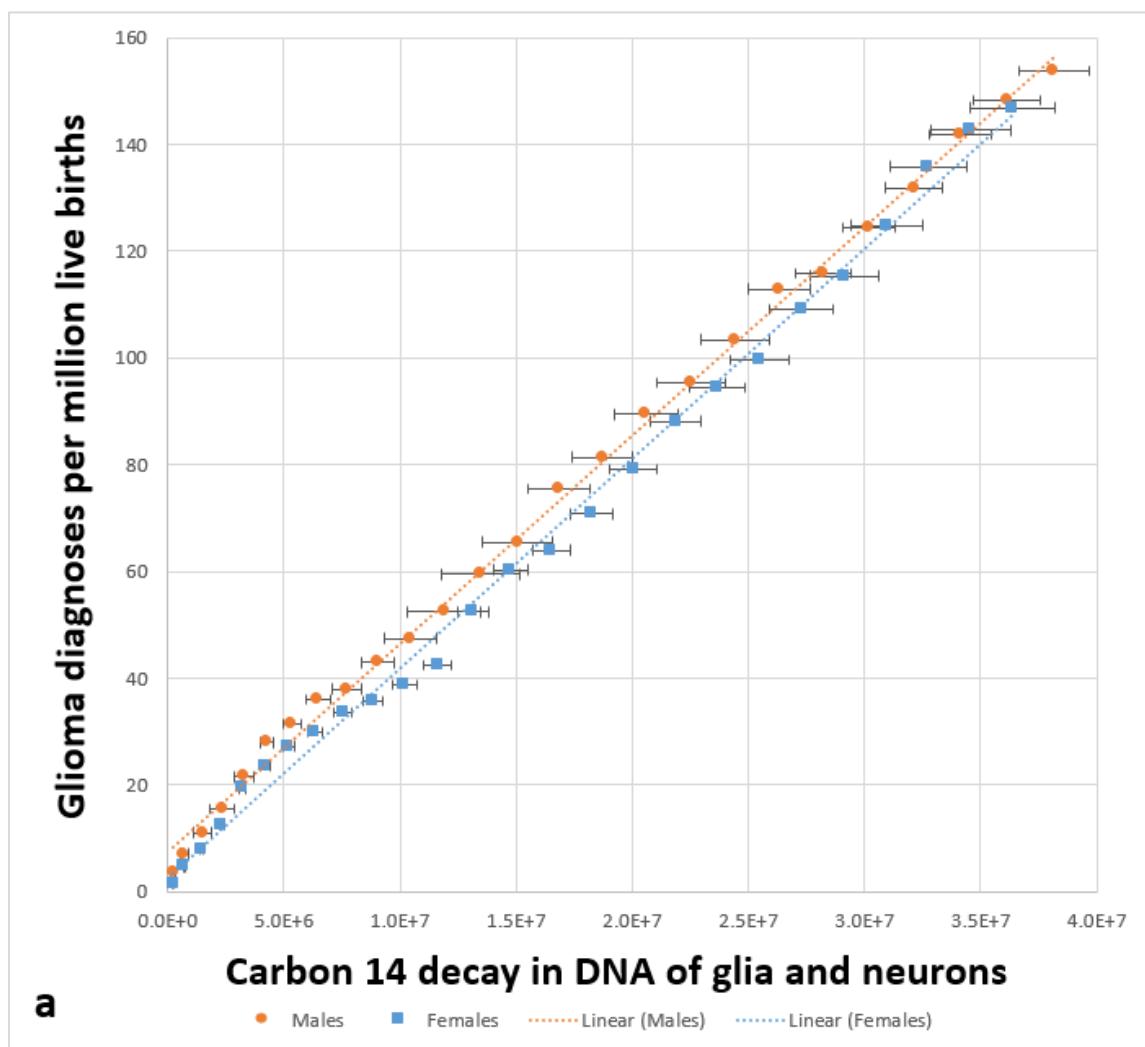


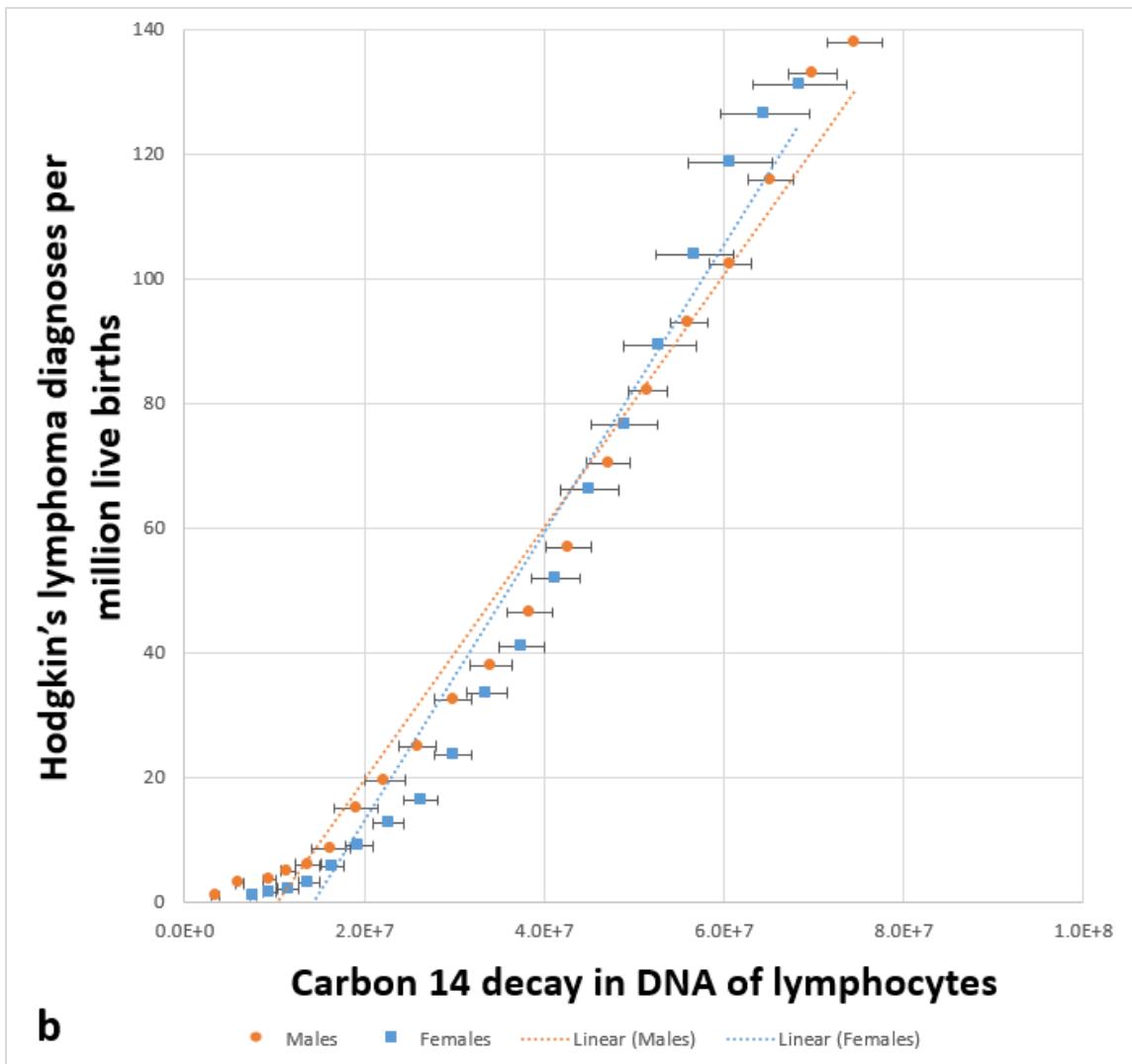


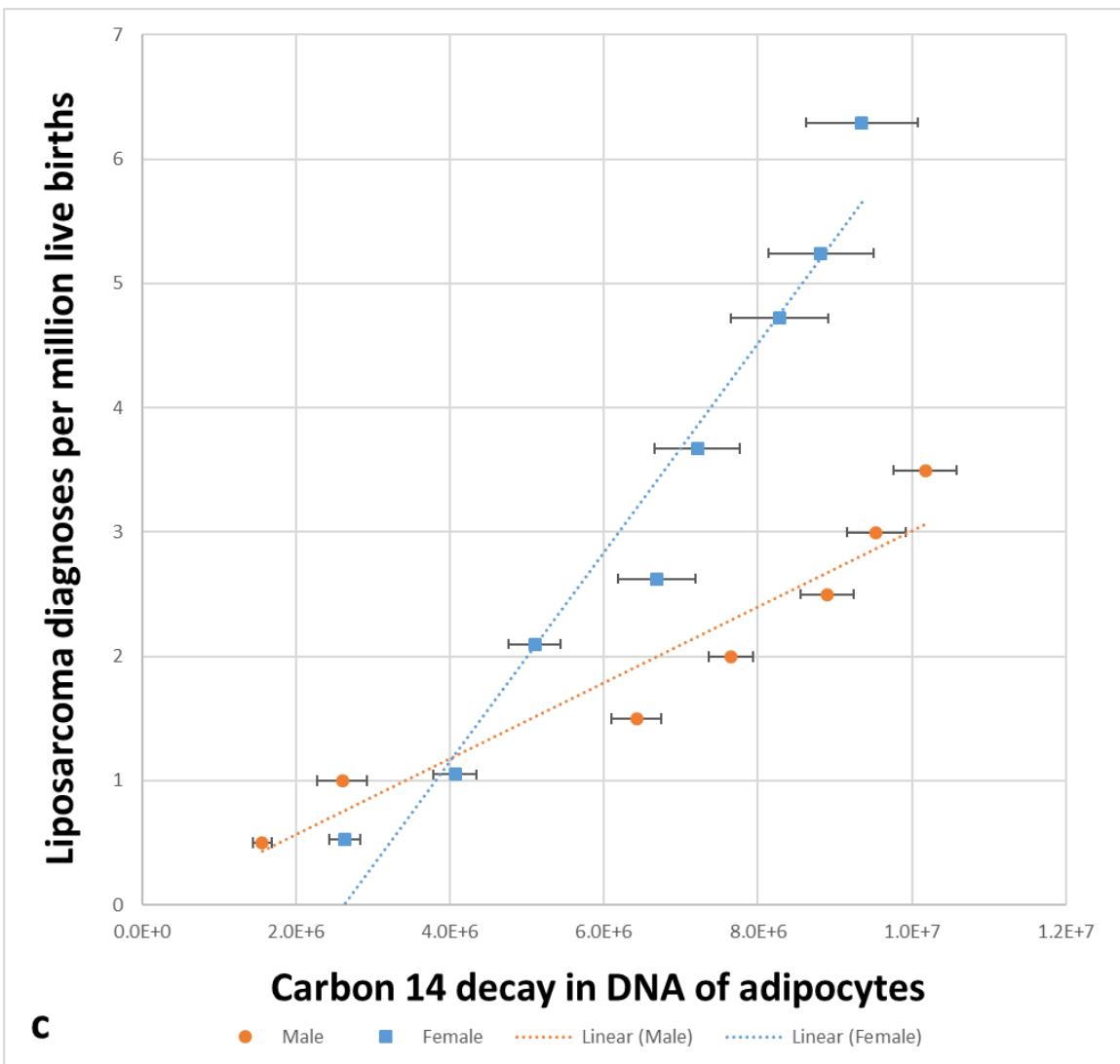


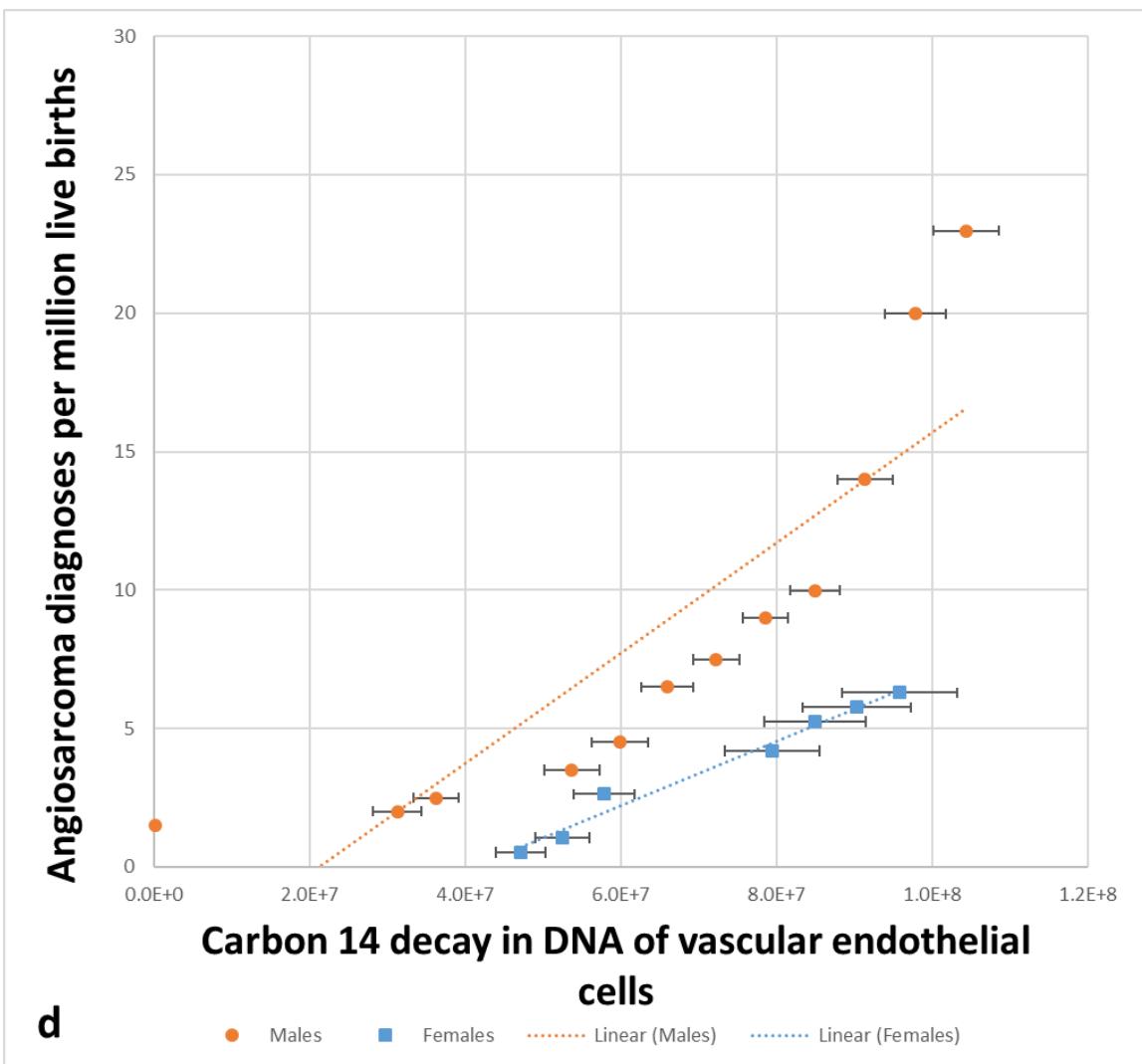
**Figure 2: Cumulative cancer histology diagnoses in U.S. 1988-2013 correlated with carbon-14 decay in DNA of related tissues (births in 1988)**

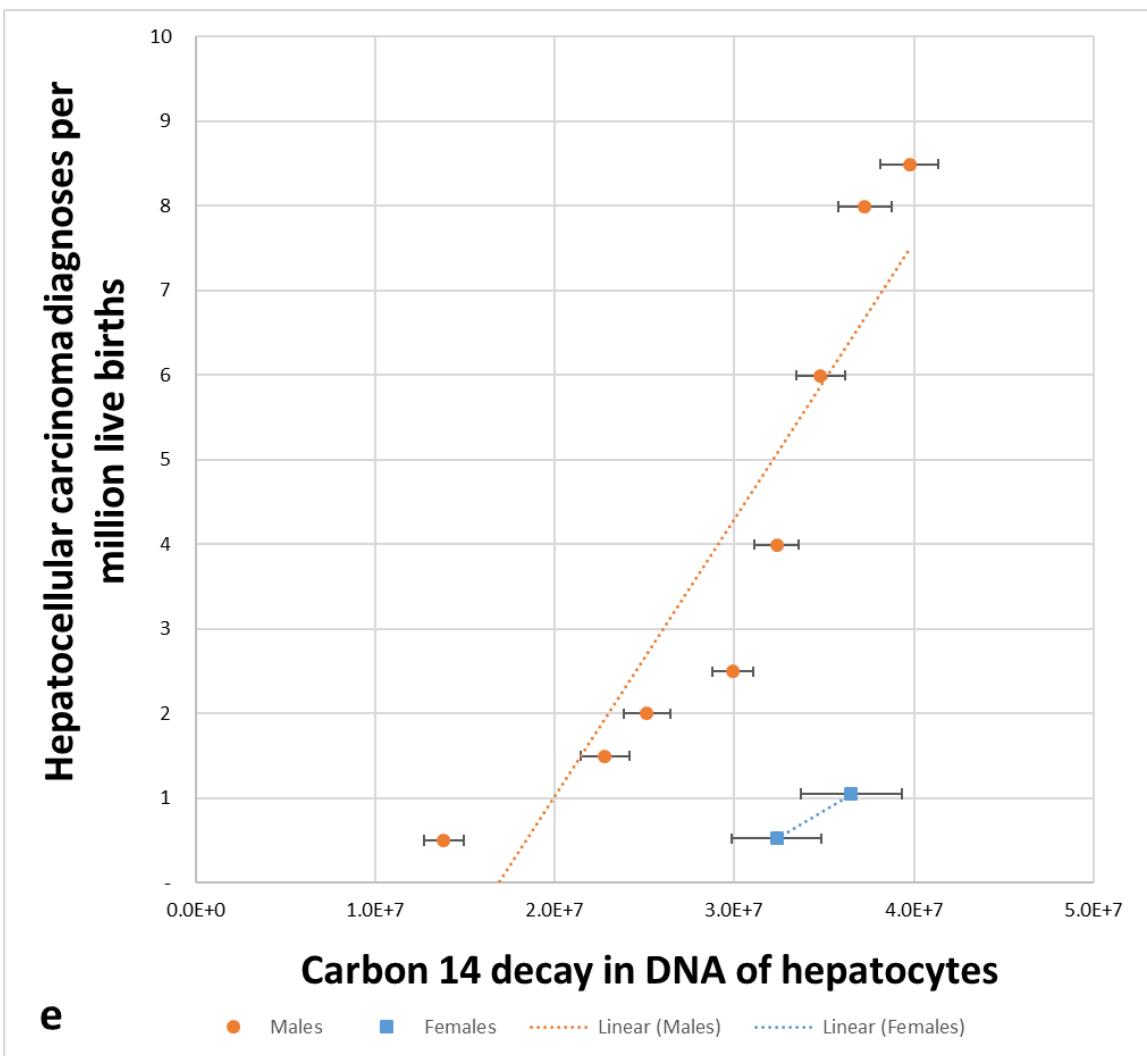
Cumulative diagnoses from 1988 to 2013 of (a) glioma diagnoses vs.  $^{14}\text{C}$  decay in DNA of glia and neurons; (b) Hodgkin's lymphoma diagnoses vs.  $^{14}\text{C}$  decay in DNA of lymphocytes; (c) liposarcoma diagnoses vs.  $^{14}\text{C}$  decay in DNA of adipocytes; (d) angiosarcoma diagnoses vs.  $^{14}\text{C}$  decay in DNA of vascular endothelial cells; (e) hepatocellular carcinoma diagnoses vs.  $^{14}\text{C}$  decay in DNA of hepatocytes; (f) osseous and chondromatous neoplasm diagnoses vs.  $^{14}\text{C}$  decay in DNA of bone marrow cells. Error bars = 1 Standard Deviation.

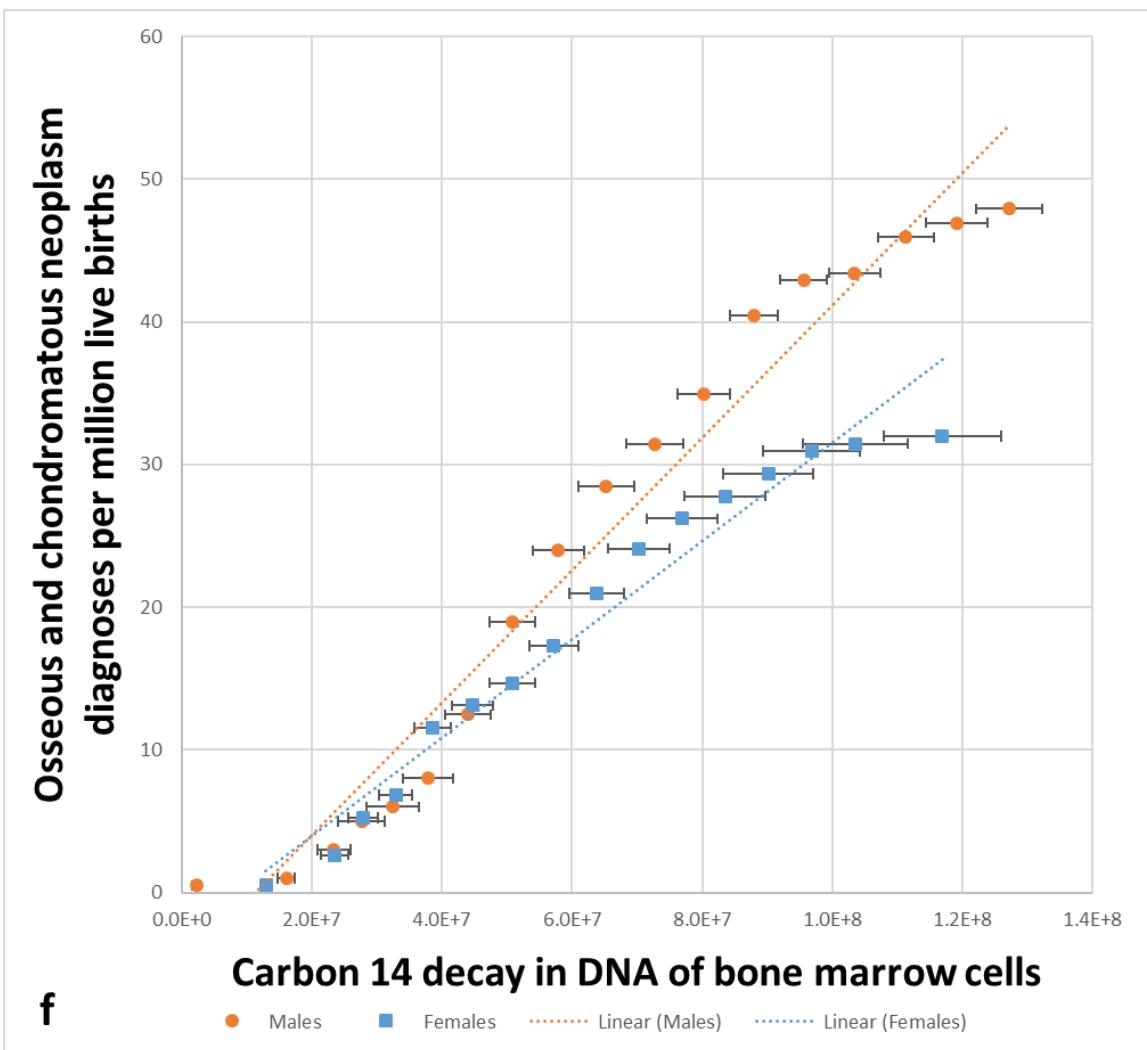






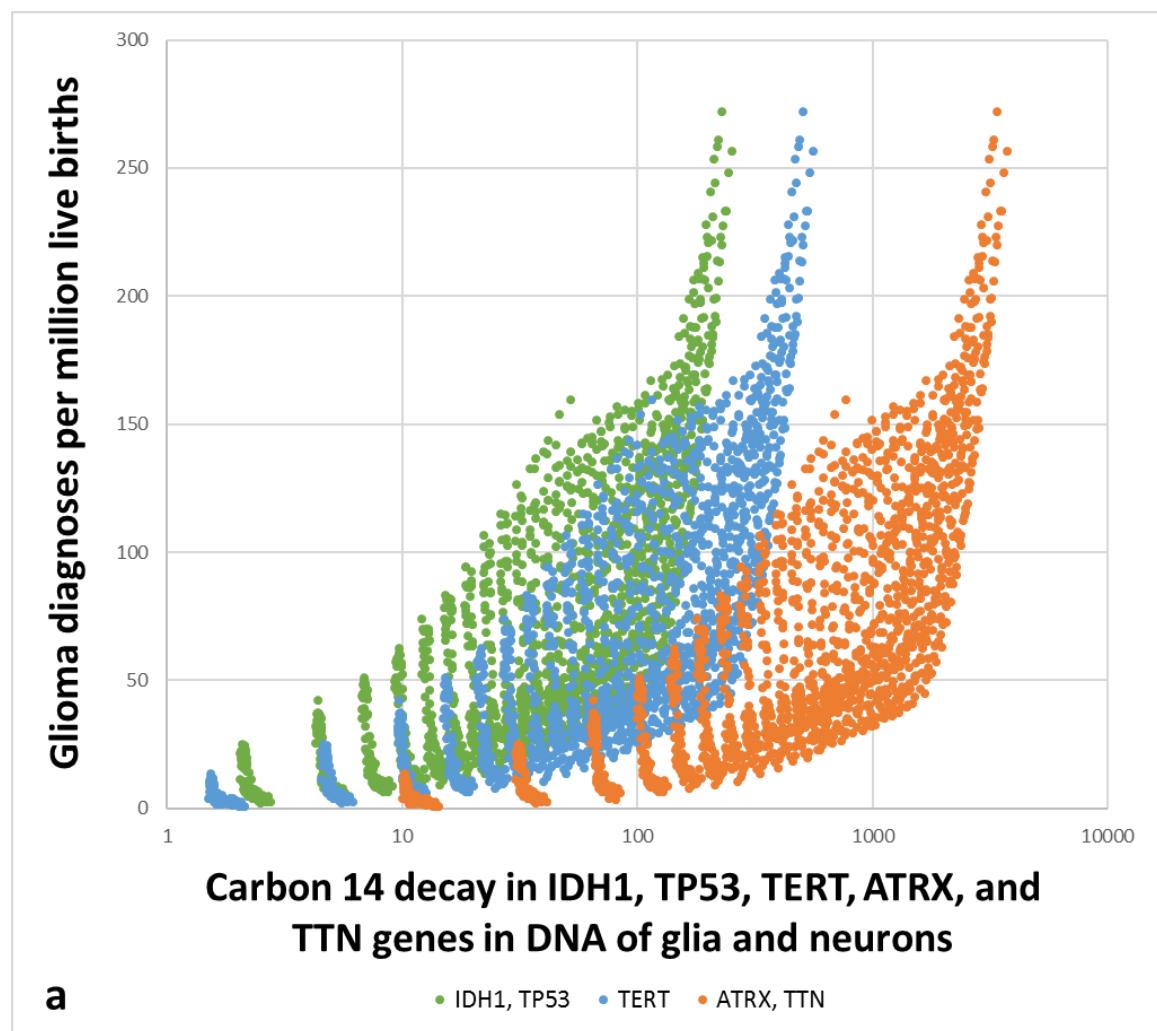


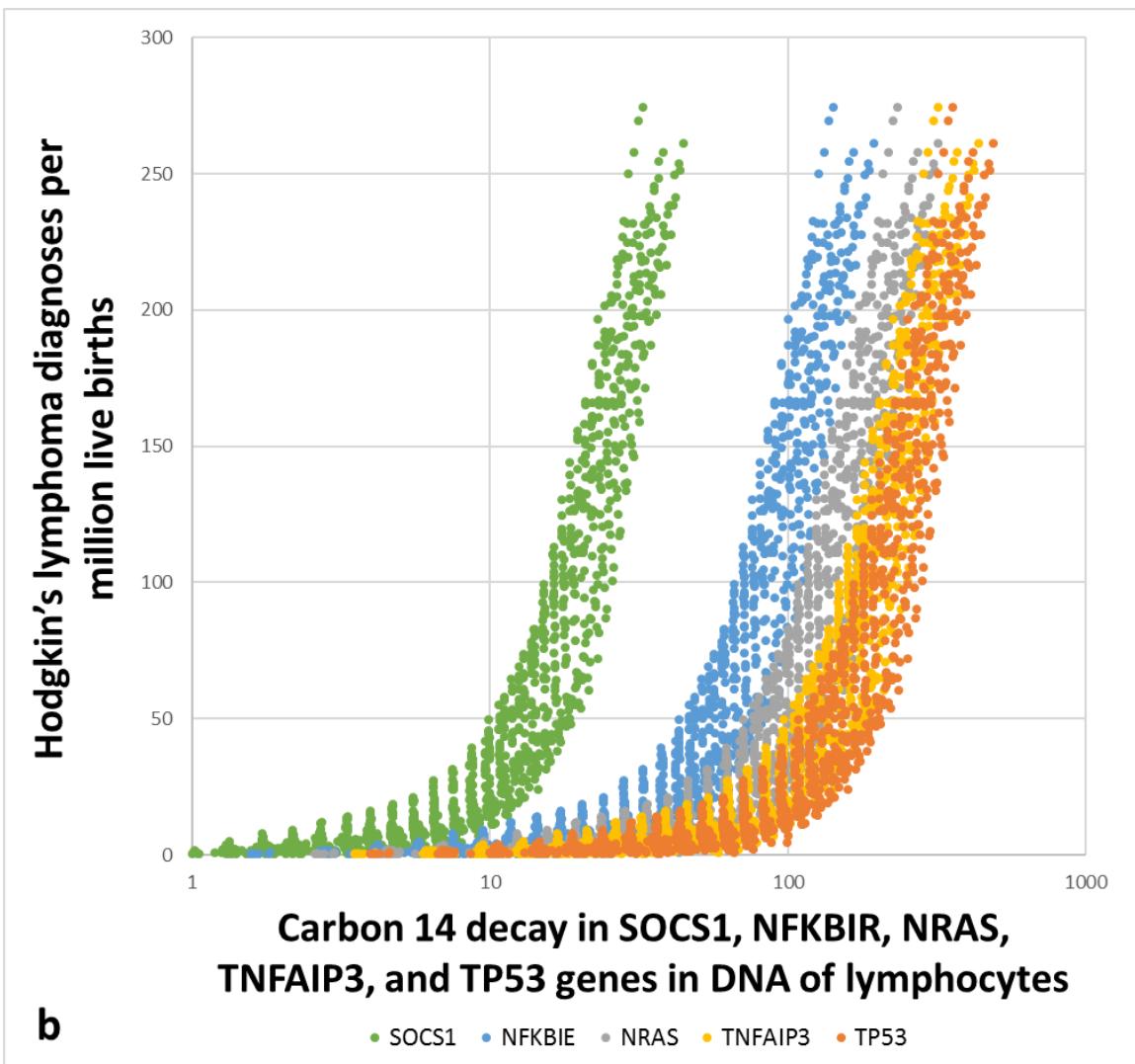


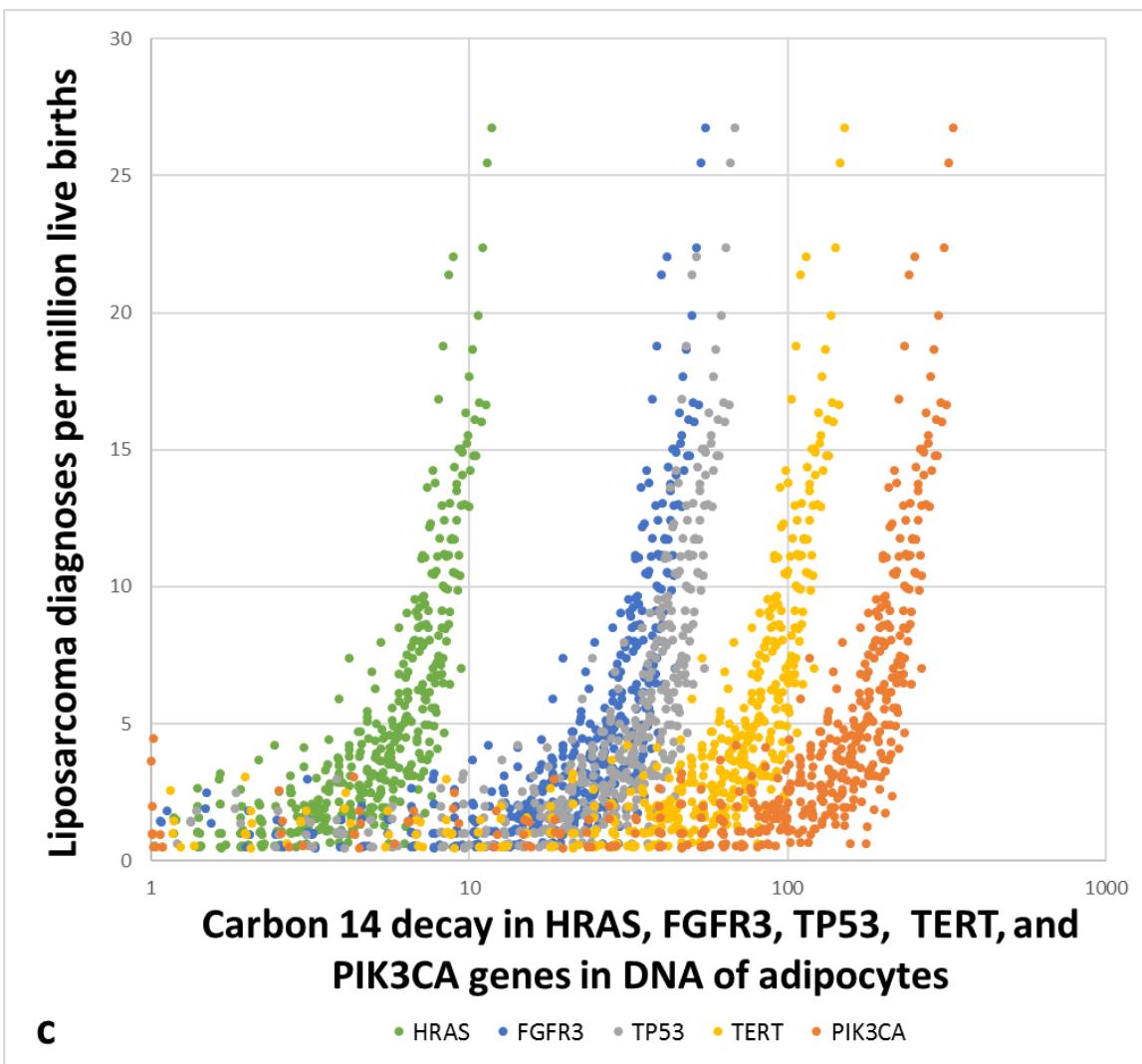


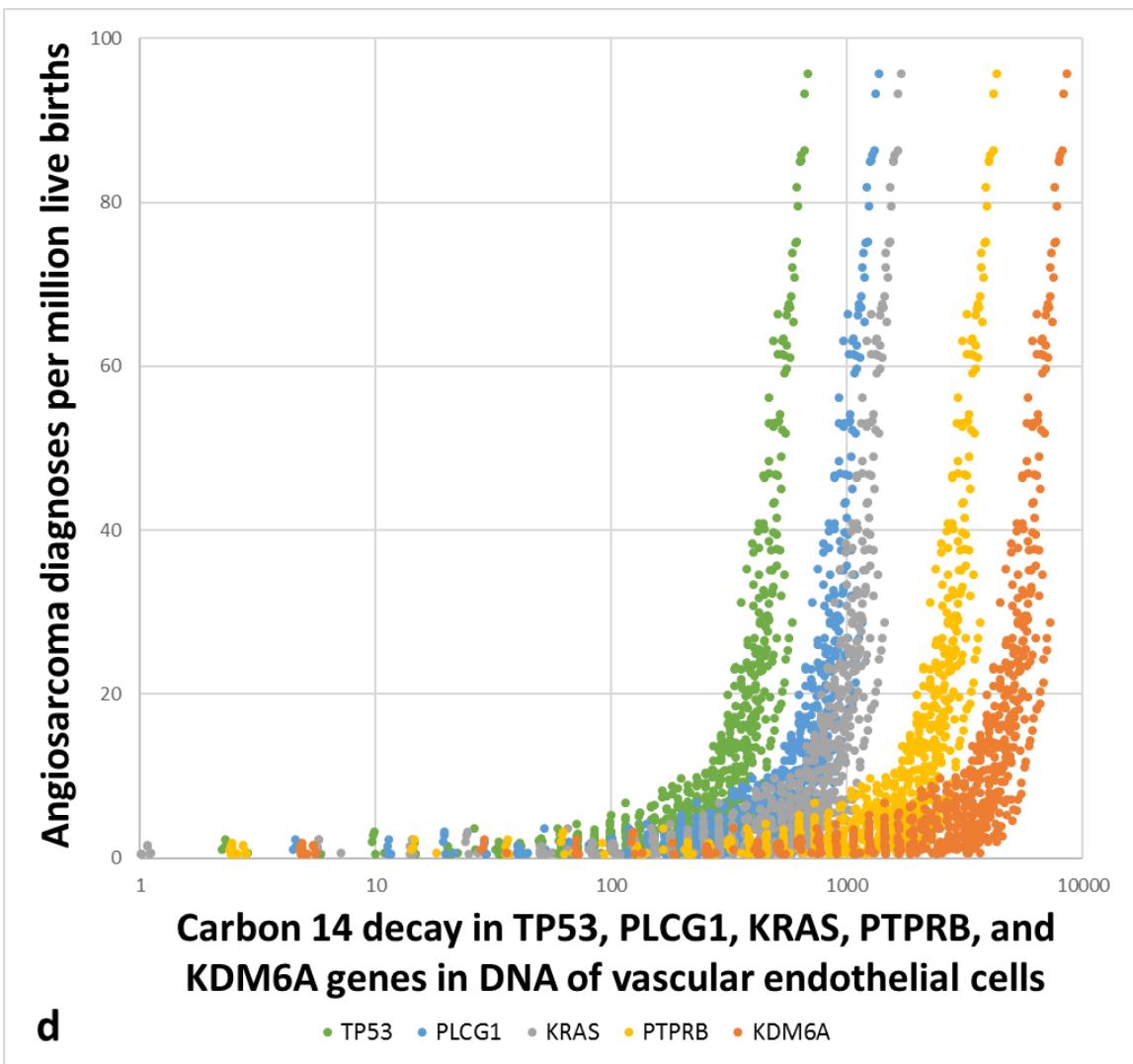
**Figure 3: Cumulative cancer histology diagnoses in U.S. 1973-2013 correlated with carbon-14 decay in DNA of pathogenic genes in related tissues (births in 1973-2013)**

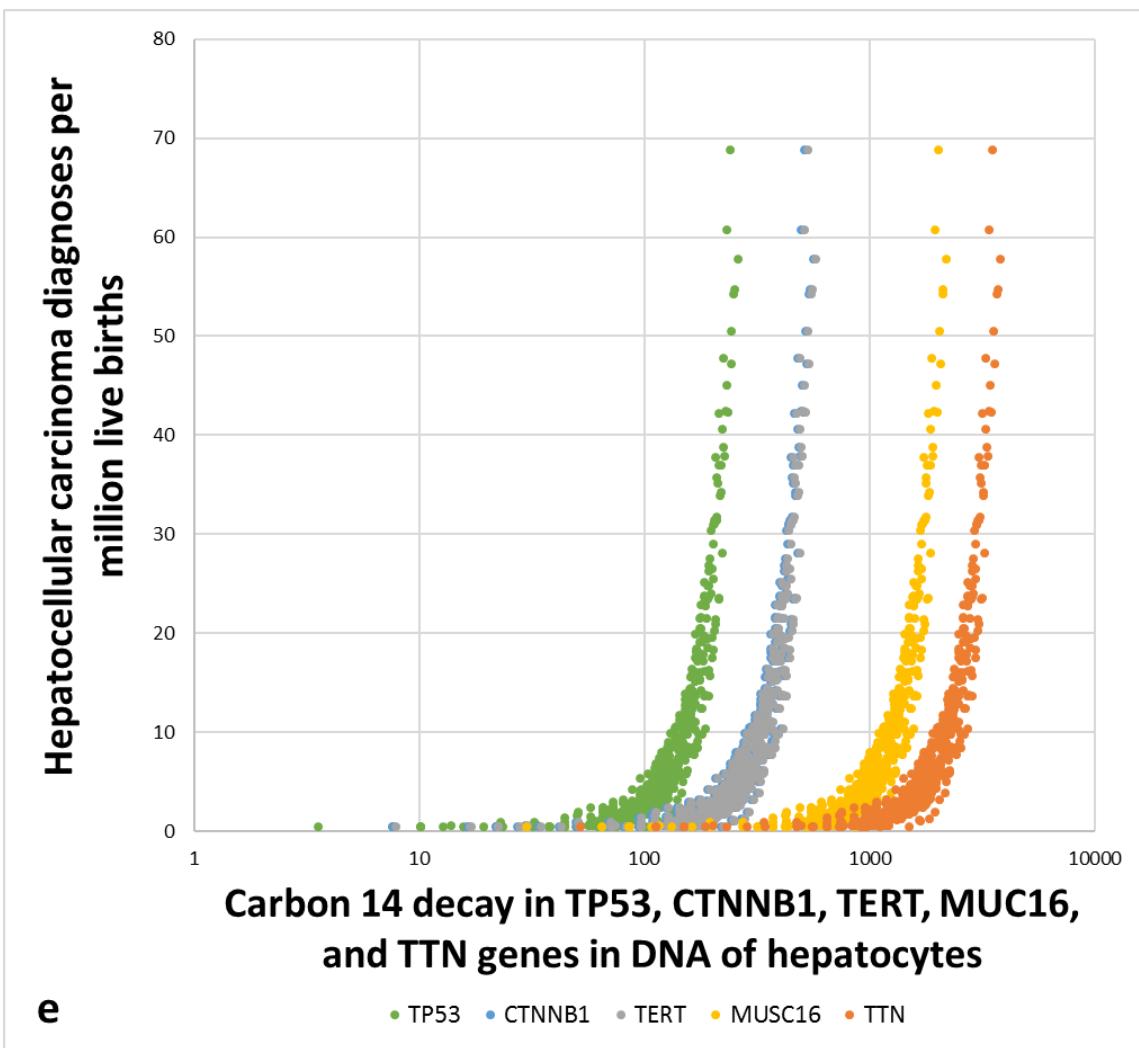
Comparisons of cumulative diagnoses and cumulative  $^{14}\text{C}$  decay in DNA of genes in related tissues between 1973 and 2013: (a) gliomas correlated with cumulative  $^{14}\text{C}$  decay in IDH1, TP53, TERT, ATRX, and TTN genes in glia and neurons; (b) Hodgkin's lymphoma diagnoses correlated with cumulative  $^{14}\text{C}$  decay in SOCS1, NFKBIE, NRAS, TNFAIP3, and TP53 genes in lymphocytes; (c) liposarcoma correlated with cumulative  $^{14}\text{C}$  decay in HRAS, FGFR3, TP53, TERT, and PIK3CA genes in adipocytes; (d) correlated with cumulative  $^{14}\text{C}$  decay in TP53, PLCG1, KRAS, PTPRB, and KDM6A genes in vascular endothelial cells; (e) hepatocellular carcinoma correlated with cumulative  $^{14}\text{C}$  decay in TP53, CTNNB1, TERT, MUC16, and TTN genes in hepatocytes; (f) osseous and chondromatous neoplasm diagnoses correlated with cumulative  $^{14}\text{C}$  decay in H3F3B, TP53, IDH1, COL2A1, MUC4, and MUC16 genes in bone marrow cells.

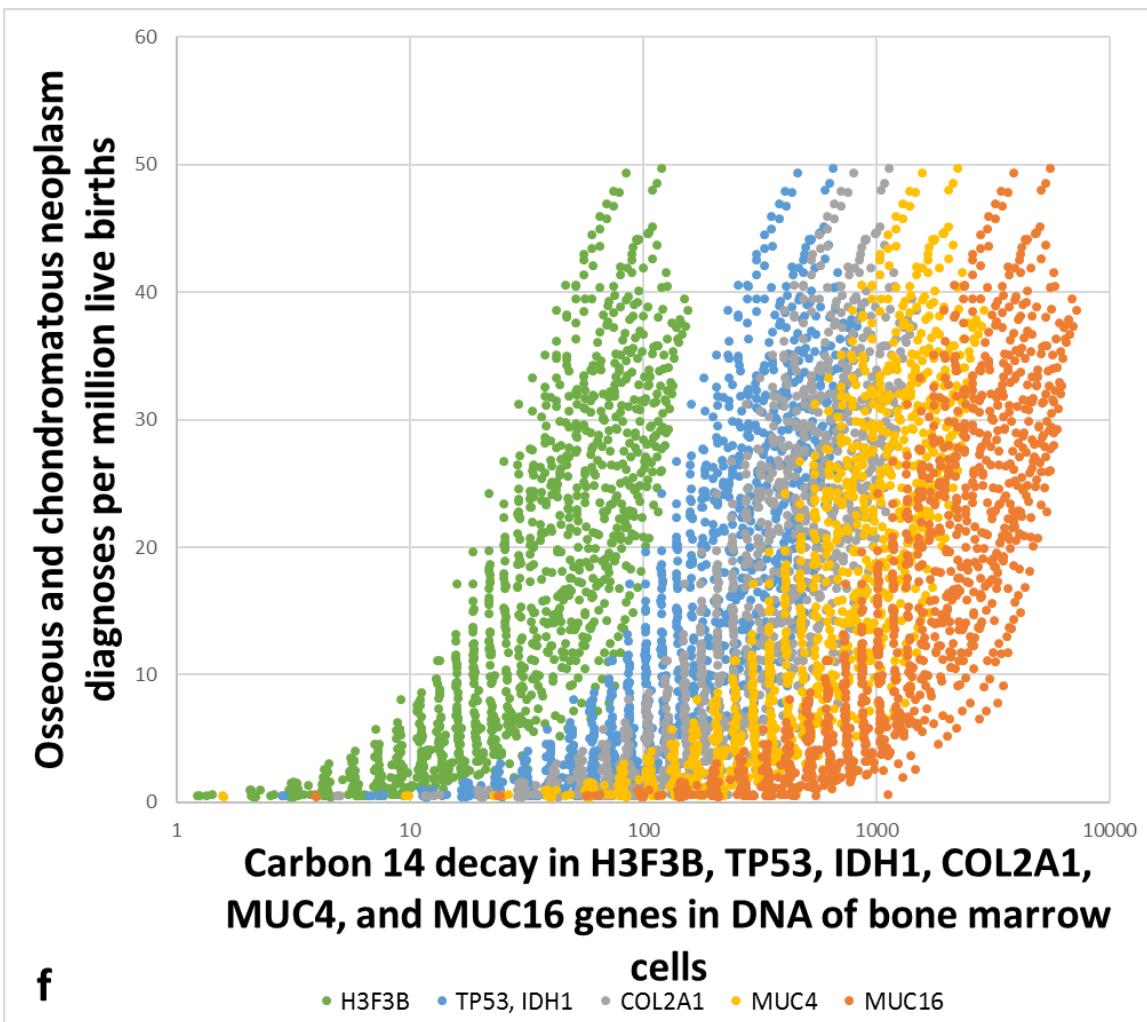






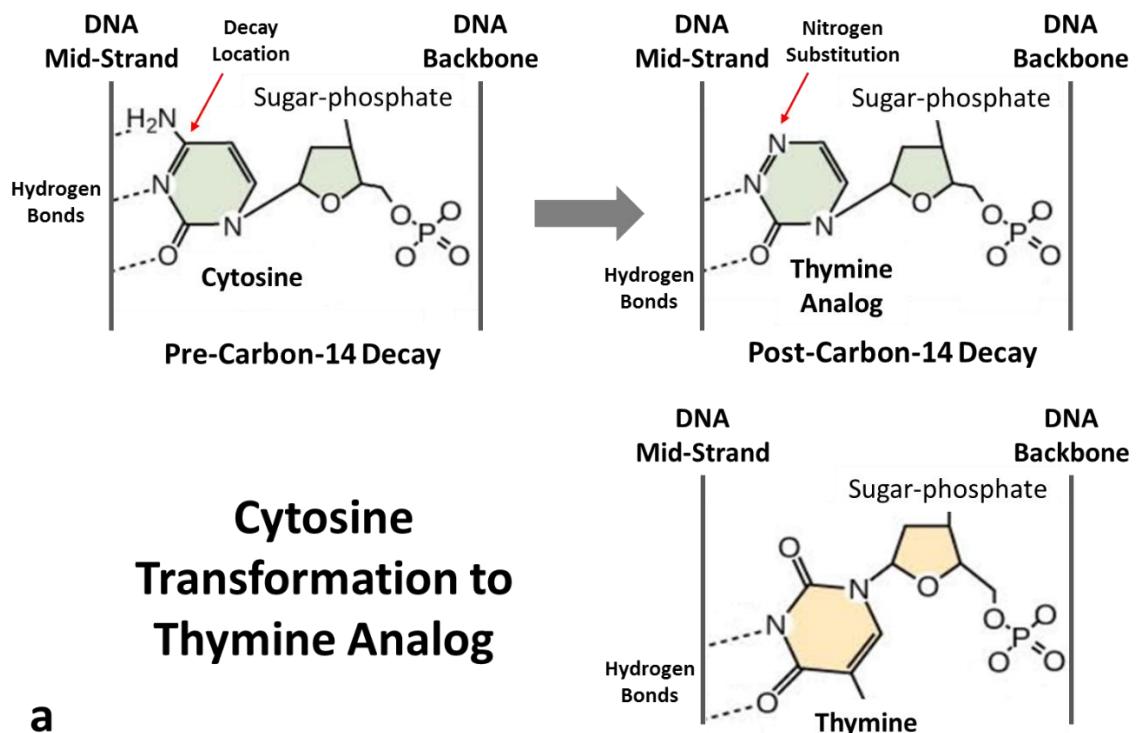


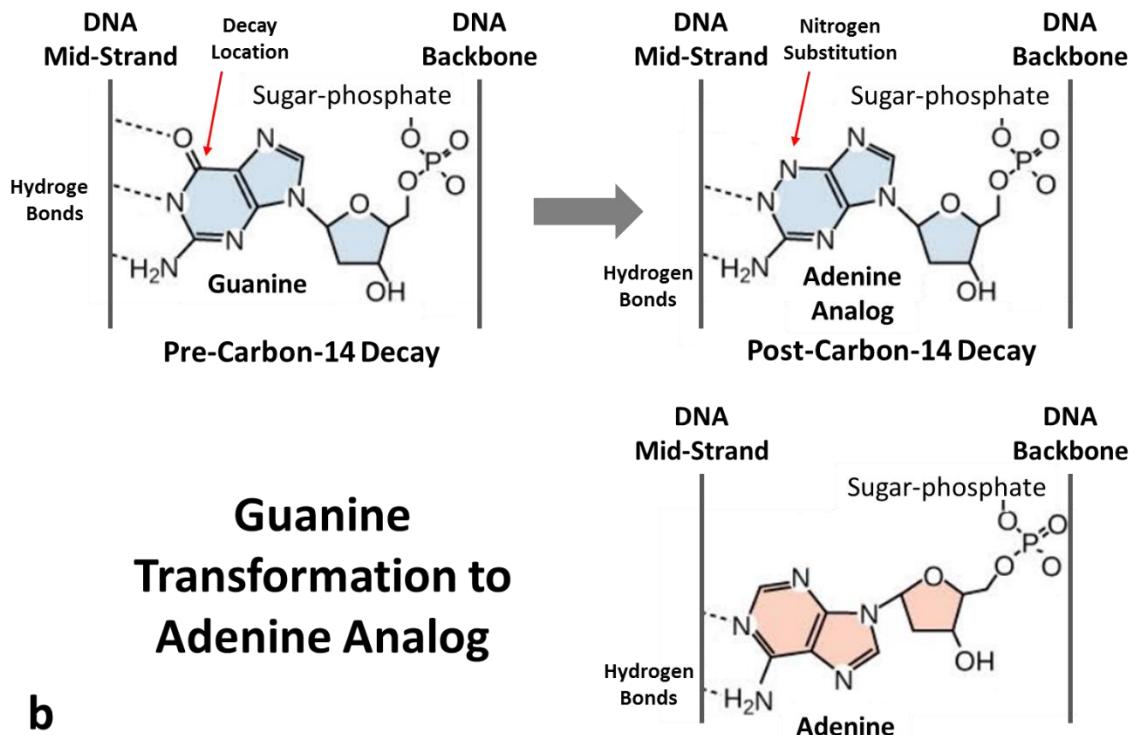




**Figure 4: Carbon-14 decay a source of the two most common transcription errors in DNA**

Carbon-14 decay nitrogen substitution in DNA provides a single-step transformation for the two most common somatic point mutations identified in the genome sequencing of cancer tissues (a) cytosine to thymine analog resulting in C>T transcription errors (26.46% of all mutations); (b) guanine to adenine analog resulting in G>A transcription errors (25.67% of all mutations).





**Table 1: Correlation of cumulative cancer diagnoses in U.S. 1973-2013 with cumulative carbon-14 decay in DNA by tissue, histology and gender (births in 1973-2013)**

Aggregated cumulative diagnoses correlated with cumulative  $^{14}\text{C}$  decay in DNA for each of 73,182 diagnoses in the U.S. 1973-2013 for all patients born on or after 1973.

Tissue	Histology	Male				Female			
		Diagnoses	Correlation w/ Carbon-14 Decay			Diagnoses	Correlation w/ Carbon-14 Decay		
			R	t	p		R	t	p
Adipocytes	Liposarcoma	391	0.815	21.28	0.0000	394	0.787	20.05	0.0000
	Osseous and Chondromatous Neoplasms	2076	0.814	33.46	0.0000	1574	0.779	29.06	0.0000
Bone Marrow Cells	Giant Cell Tumor	44	0.551	4.18	0.0002	61	0.654	6.41	0.0000
	Miscellaneous Bone Tumors	1156	0.742	25.31	0.0000	780	0.793	27.67	0.0000
	Odontogenic Tumors	27	0.397	2.03	0.0547	26	0.838	7.52	0.0000
Hepatocytes	Hepatocellular Carcinoma	839	0.879	30.01	0.0000	345	0.890	26.55	0.0000
	Malignant Lymphoma	893	0.919	49.67	0.0000	511	0.893	34.66	0.0000
	Hodgkin's Lymphoma	7708	0.961	89.34	0.0000	7245	0.950	73.71	0.0000
Lymphocytes	Mature B-Cell Lymphoma	5189	0.919	62.63	0.0000	3089	0.887	46.70	0.0000
	Precursor Cell Lymphoblastic Lymphoma	842	0.779	26.47	0.0000	379	0.539	10.57	0.0000
	T & NK-Cell Lymphoma	1348	0.858	36.17	0.0000	995	0.852	33.03	0.0000
Neurons & Glia	Glioma	11566	0.835	44.37	0.0000	9542	0.797	38.61	0.0000
	Meningioma	1055	0.805	22.62	0.0000	2121	0.778	21.02	0.0000
	Nerve Sheath Tumors	1516	0.807	28.60	0.0000	1395	0.803	27.41	0.0000
Vascular Endothelial Cells	Angiosarcoma	1815	0.853	30.87	0.0000	851	0.799	23.49	0.0000

**Table 2: Correlation of cumulative cancer diagnoses in U.S. 1988-2013 with cumulative carbon-14 decay in DNA by tissue, histology and gender (births in 1988)**

Cumulative diagnoses correlated with cumulative  $^{14}\text{C}$  decay in DNA for each of 2,069 diagnoses in the U.S. 1988-2013 for all patients born in 1988. Correlations by specific year of birth minimize the variable effects of environmental carcinogens independent of  $^{14}\text{C}$  on the population.

Tissue	Histology	Diagnoses	Male			Female				
			Correlation w/ Carbon-14 Decay			Diagnoses	Correlation w/ Carbon-14 Decay			
			R	t	p		R	t	p	
Adipocytes	Liposarcoma	7	0.959	7.54	0.0006	12	0.977	11.15	0.0000	
	Osseous and Chondromatous Neoplasms	96	0.982	20.62	0.0000	61	0.981	18.70	0.0000	
Bone Marrow Cells	Giant Cell Tumor	3	1.000	-	-	2	1.000	-	-	
	Miscellaneous Bone Tumors	44	0.984	21.83	0.0000	29	0.983	21.17	0.0000	
	Odontogenic Tumors	0	-	-	-	0	-	-	-	
Hepatocytes	Hepatocellular Carcinoma	17	0.920	5.74	0.0012	2	1.000	-	-	
	Malignant Lymphoma	28	0.992	28.78	0.0000	17	0.928	6.59	0.0003	
	Hodgkin's Lymphoma	276	0.987	25.86	0.0000	250	0.979	19.90	0.0000	
	Mature B-Cell Lymphoma	129	0.992	35.71	0.0000	79	0.967	15.14	0.0000	
	Precursor Cell Lymphoblastic Lymphoma	27	0.967	13.62	0.0000	16	0.989	21.60	0.0000	
Lymphocytes	T & NK-Cell Lymphoma	46	0.973	15.90	0.0000	28	0.990	23.66	0.0000	
	Glioma	308	0.999	109.56	0.0000	280	0.998	77.40	0.0000	
	Meningioma	29	0.999	57.25	0.0000	25	0.954	7.83	0.0002	
	Nerve Sheath Tumors	46	0.983	17.90	0.0000	31	0.988	21.65	0.0000	
Neurons & Glia	Neuroepitheliomatous Neoplasms	74	0.971	18.22	0.0000	43	0.964	14.51	0.0000	
	Vascular Endothelial Cells	Angiosarcoma	46	0.861	5.35	0.0003	12	0.990	15.34	0.0000

**Table 3: Most common gene mutations identified and ranked per histology**

Review of 289,322 mutations found in 23,721 samples by targeted screen and full genome sequencing identified the most common gene mutations with rank by frequency for several histology and tissue types.

Tissue	Histology	Sub-Histology	Samples	Mutations	Most Common Genes (ranked left to right)
Adipocytes	Liposarcoma		121	269	TERT, PIK3CA, TP53, HRAS, FGFR3, CDKN2A, KRAS, CTNNB1, KIT, and NF1.
Bone Marrow Cells	Osseous and Chondromatous Neoplasms	Chondroblastoma	80	124	H3F3B and H3F3A.
		Chondrosarcoma	418	2,595	IDH1, COL2A1, TP53, TNN, RYR2, MUC16, MUC17, IDH2, CDKN2A, and PTCH1.
	Osteosarcoma		225	8,132	TP53, MUC16, MUC4, ATRX, CDKN2A, RB1, TTN, and APOB.
Hepatocytes	Giant Cell Tumor		113	114	H3F3A, HRAS, BRAF, IDH2, IDH1, and H3F3B.
	Hepatocellular Carcinoma		3,563	144,430	TNN, TP53, TERT, CTNNB1, MUC16, OBSCN, AXIN1, ARID1A, PCLO, RYR2, CSMD1, and SYNE1.
	Malignant Lymphoma	Burkitt lymphoma	148	981	MYC, ID3, TP53, FBXO11, SMARCA4, GNA13, ARID1A, DDX3X, PTEN, and RHOA.
Lymphocytes	Hodgkin's Lymphoma		52	57	SOCS1, TNFAIP3, NFKBIE, NRAS, and TP53.
	Mature B-Cell Lymphoma		1,348	21,268	BCL2, KMT2D, TP53, CREBBP, PIM1, MYD88, SOCS1, B2M, EZH2, GNA13, SGK1, and TNFAIP3.
	Precursor Cell Lymphoblastic Lymphoma	T-Cell lymphoblastic lymphoma	122	171	NOTCH1, FBXW7, TET2, NRAS, CTNNB1, and WT1.
	T & NK-Cell Lymphoma		237	667	DDX3X, TP53, JAK3, CTNNB1, BCOR, KIT, KMT2C, AMER1, RHOA, and STAT3.
	Glioma		15,031	98,138	TP53, TERT, TTN, IDH1, ATRX, MUC16, H3F3A, CDKN2A, PTEN, CIC, EGFR, and PIK3CA.
Neurons & Glia	Meningioma		791	1,640	NF2, TRAF7, KLF4, AKT1, TTN, CDKN2A, TERT, SMO, SMARCB1, and TP53.
	Nerve Sheath Tumors		603	735	NF2, NF1, CDKN2A, TP53, TERT, SMARCB1, PDGFRA, and BRAF.
	Neuroepitheliomatous Neoplasms	Neuroblastoma	783	8,678	ALK, MUC16, TTN, FLG, LRP1B, RYR1, AHNAK2, AHNAK, HMCN1, MUC17, MUC4, and ARID1A.
Vascular Endothelial	Angiosarcoma		86	1,323	TP53, PTPRB, KRAS, TTN, DNAH8, PCLO, KDM6A, CASP8, PLCG1, TMPRSS6, KIAA0825, and KDR.

## Methods

### *Anatomical and Atmospheric Models*

The cumulative  $^{14}\text{C}$  decay in the DNA of nucleated cells of males and females born in the U.S. from 1973 to 2013 was modeled for multiple regenerative and non-regenerative tissues as follows.

The mean weight of male and female children and teens aged 2 months through 17 years old, and adults aged 18 through 67, were collected for each year of age from U.S. vital health statistics and anthropometric reference data sources [12,13,14]. Means for each age and gender were utilized from 1963-65, 1966-70, 1971-74, 1976-80, 1988-94, 1999-2002, 2003-06, and 2007-10. Weight charts provided additional data points for children aged 2 months to 1 year old for 1977 [15]. The standard error of measurements (SEM) was generally  $\pm 1\%$  to  $\pm 2\%$  ages 0 to 19 and  $\pm 1\%$  to  $\pm 1.5\%$  for people over 20. Bilinear extrapolation of these means was utilized to generate mean weight model for ages 2 months to 67 years old for each year from 1973 to 2013.

Anatomical data and an embryo/fetus dosimetry model were utilized to calculate mass for 19 data points from conception to birth 38 weeks later with an initial mass of zero to 3.5 kg [16,17]. The embryo/fetus mass models were assumed to be equivalent for both genders. Live birth totals of males and females in the U.S. were utilized from vital statistics reports for each year from 1973 through 2013 to provide a population model for clinical data [18,19,20,21].

Due to global distribution, seasonal variation and atmospheric mixing, the natural abundance of  $^{14}\text{C}$  in the atmosphere of the Northern hemisphere from 1959 to 2013 was modeled using the mean for each year from multiple measurements from data sources in the Northern hemisphere [22,23,24,25,26,27,28]. The SEM for  $\Delta^{14}\text{C}$  was generally  $\pm 2$  to  $\pm 4\text{\textperthousand}$ . A mean of the annual natural abundance of  $^{14}\text{C}$  in the Northern hemisphere for each year was deemed sufficient for the subject analysis for several reasons that follow. Although regional intrahemispheric variance has been observed in  $^{14}\text{C}$  abundance in North America due to fossil fuel emissions, especially near urban centers [29,30], the global commoditization and distribution of agricultural products would tend to diffuse a strong correlation between variance in the local atmospheric abundance of  $^{14}\text{C}$  and the biomass of the local U.S. population. Since each person constitutes a biomass reservoir for  $^{14}\text{C}$ , individual dietary choices and the origin of those products would appear to be a more relevant factor in determining the abundance of  $^{14}\text{C}$  in an individual than the local atmospheric abundance. The population of the U.S. is distributed geographically over a large area in the Northern hemisphere, and is very mobile, with the average family relocating every several years, complicating any general correlation that a diagnosis in one location implies life-long residence at that location. The clinical diagnosis data utilized for the U.S. population is also truncated temporally by year of birth, in place of birth dates, and by year of diagnosis, in place of diagnosis date, to protect the identity of patients [6]. This precludes the comparison of sub-annual cumulative  $^{14}\text{C}$  decays in the DNA of tissues with actual diagnosis dates of patients, thereby precluding the utility of a sub-annual model of  $^{14}\text{C}$  abundance for this analysis.

Although neurogenesis has recently been demonstrated in the hippocampal neurons, this represents only about 700 new neurons in each hippocampus per day, therefore the glia and neurons, representing 5.3% of standard body nucleated cells, were modeled as a non-

regenerative tissue [31,32]. To correct for higher portions of glia and neurons in the fetus and adolescents over the standard body model, and a decrease of brain mass later in life, fetal and post-birth growth models were developed to include variable brain mass by interpolation of mean brain weights at different ages [33,34]. The SEM for brain weights was 0.00 kg (less than < 1%). Lymphocytes include a large variety of cell types, representing 13.3% of nucleated cells. Since most lymphocytes have a limited life span and are continuously produced, a continuously regenerative model (i.e., regenerating every year for purposes of  $^{14}\text{C}$  abundance determination) was utilized [35]. Adipocytes, representing 1.8% of nucleated cells, were modeled using a 10-year regenerative model [36]. Vascular endothelial cells represent 18.6% of nucleated cells and were modeled using a continuously regenerative model [37]. Hepatocytes represent 7.1% of nucleated cells and were also modeled using a continuously regenerative model, due to their short life span [38,39]. Bone marrow cells represent 22.1% of nucleated cells, and includes several types of cells, including osteoblasts, pre-osteoblasts, osteocytes, osteoclasts, and pre-osteoclasts. Osteoblasts are known to have a short life span, while osteocytes are known to have a life span near ten years. Since osteocytes are the most abundant cell type in bone marrow tissue, a 10-year regenerative model was utilized [40,41].

For each tissue model above, the mean number of nucleated cells and mean  $^{14}\text{C}$  decays were calculated for each year 1973-2013, for each year of age for both males and females. The mean natural abundance of  $^{14}\text{C}$  in the Northern Hemisphere for each respective prior year was utilized to model the  $^{14}\text{C}$  content in the DNA for new tissue growth and tissues replaced at their respective regeneration rates.

### ***Diagnoses and Mutation Analysis***

For each clinical diagnosis of gliomas, neuroepitheliomatous neoplasms, meningiomas, and nerve sheath tumors, the cumulative  $^{14}\text{C}$  decay in the DNA of glia and neurons was calculated. For each clinical diagnosis of malignant lymphomas, Hodgkin's lymphomas, mature B-cell lymphomas, mature T and NK-cell lymphomas, and precursor cell lymphoblastic lymphoma, the cumulative  $^{14}\text{C}$  decay in the DNA of lymphocytes was calculated. For each clinical diagnosis of liposarcoma, the cumulative  $^{14}\text{C}$  decay in the DNA of adipocytes was calculated. For each clinical diagnosis of vascular endothelial cancer, the cumulative  $^{14}\text{C}$  decay in the DNA of vascular endothelial cells was calculated. For each clinical diagnosis of carcinoma, the cumulative  $^{14}\text{C}$  decay in the DNA of hepatocytes was calculated. For each clinical diagnosis of osseous and chondromatous neoplasms, giant cell tumors, miscellaneous bone tumors, and odontogenic, the cumulative  $^{14}\text{C}$  decay in the DNA of bone marrow cells was calculated. Cumulative diagnoses were then correlated with the cumulative  $^{14}\text{C}$  decay in DNA for each respective tissue type.

For each histology above, the most common genes with point mutations were identified from the catalog of somatic mutations in cancer (COSMIC) genome screens and complete targeted screens mutant exports, version 80, dated 13 February 2017. The frequency of point mutations identified in the sequencing of each histology was identified, and any apparent dependency between point mutations in genes required for pathogenesis was noted. The mean cumulative  $^{14}\text{C}$  decay in these genes within the DNA of respective tissue types was calculated utilizing the mean  $^{14}\text{C}$  decay for the gender, year of birth, age, and tissue type, as modeled above, and multiplying

by the number of carbon atoms in each gene, derived by review of each genetic sequence, including numbers of base pairs and types of base pairs, and dividing by the number of carbon atoms in the DNA for each gender, respectively.

#### ***Data Availability***

Several datasets generated or analyzed during this study are included in this published article (see Extended Data Tables 1-7). Additional datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request. Epidemiology data supporting the findings of this study are available from U.S. Department of Health and Human Services but restrictions apply to the availability of these data, which were used under a research data agreement for the current study, and so are not publicly available. Genome sequence data supporting the findings of this study are available from Genome Research Limited, but restrictions apply to the availability of these data, which were used under a user agreement for the current study, and so are not publicly available.

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## Author Contributions

Both authors contributed to data collection, analysis, and writing this report.

### **Competing Financial Interests**

The authors declare no competing financial interests.

**Carbon 14 Decay as a Source of Somatic Point Mutations in Genes Correlated with Cancer Diagnoses**

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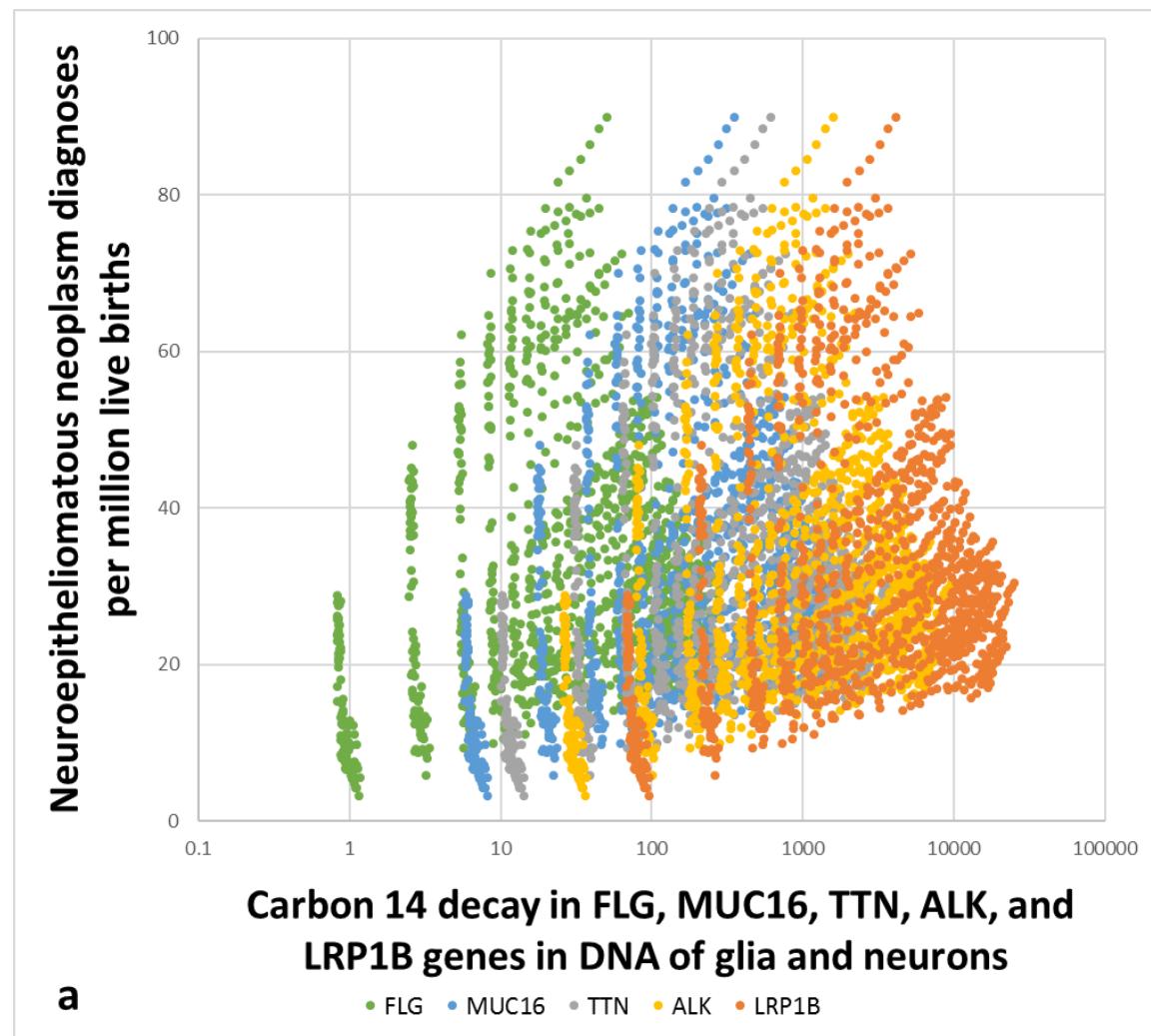
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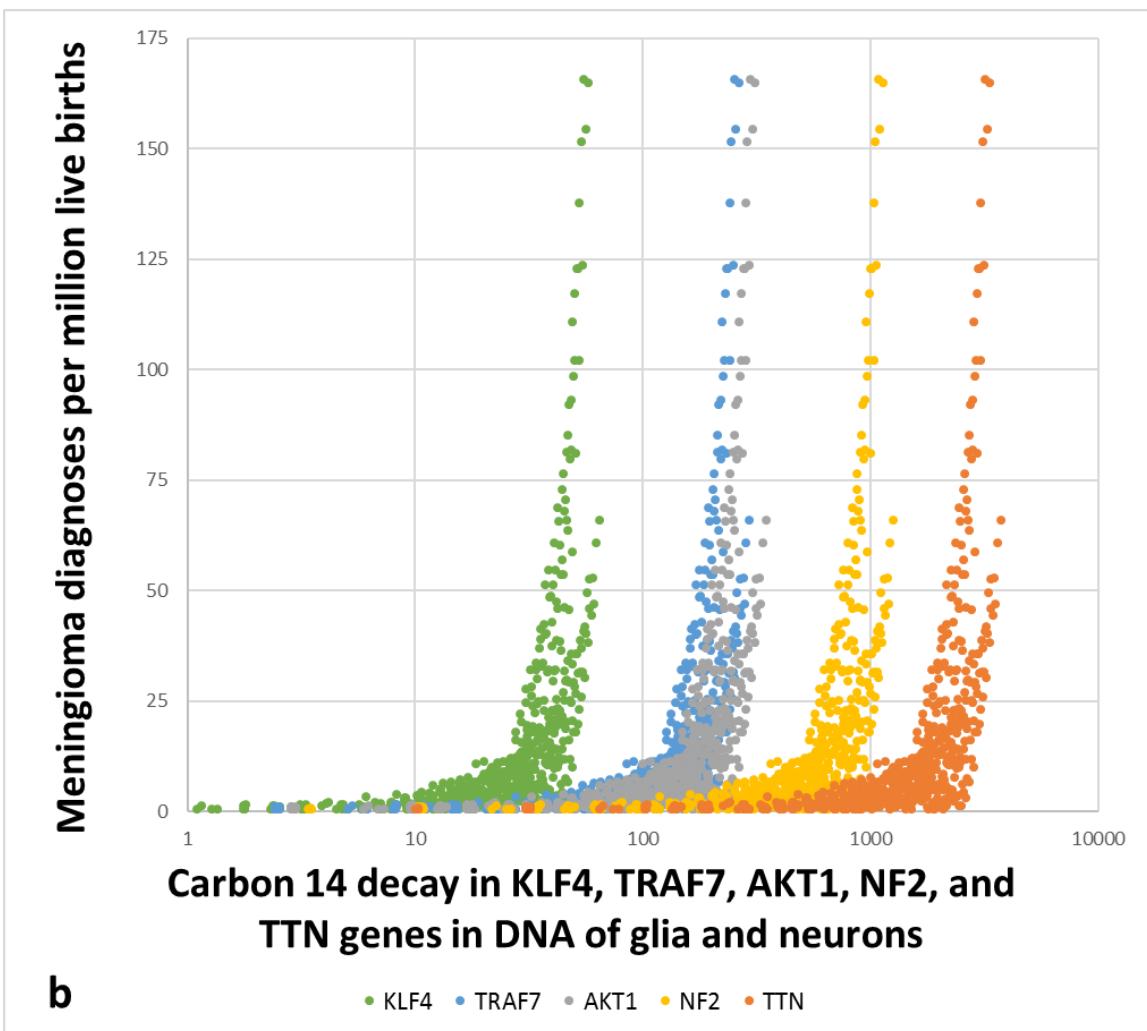
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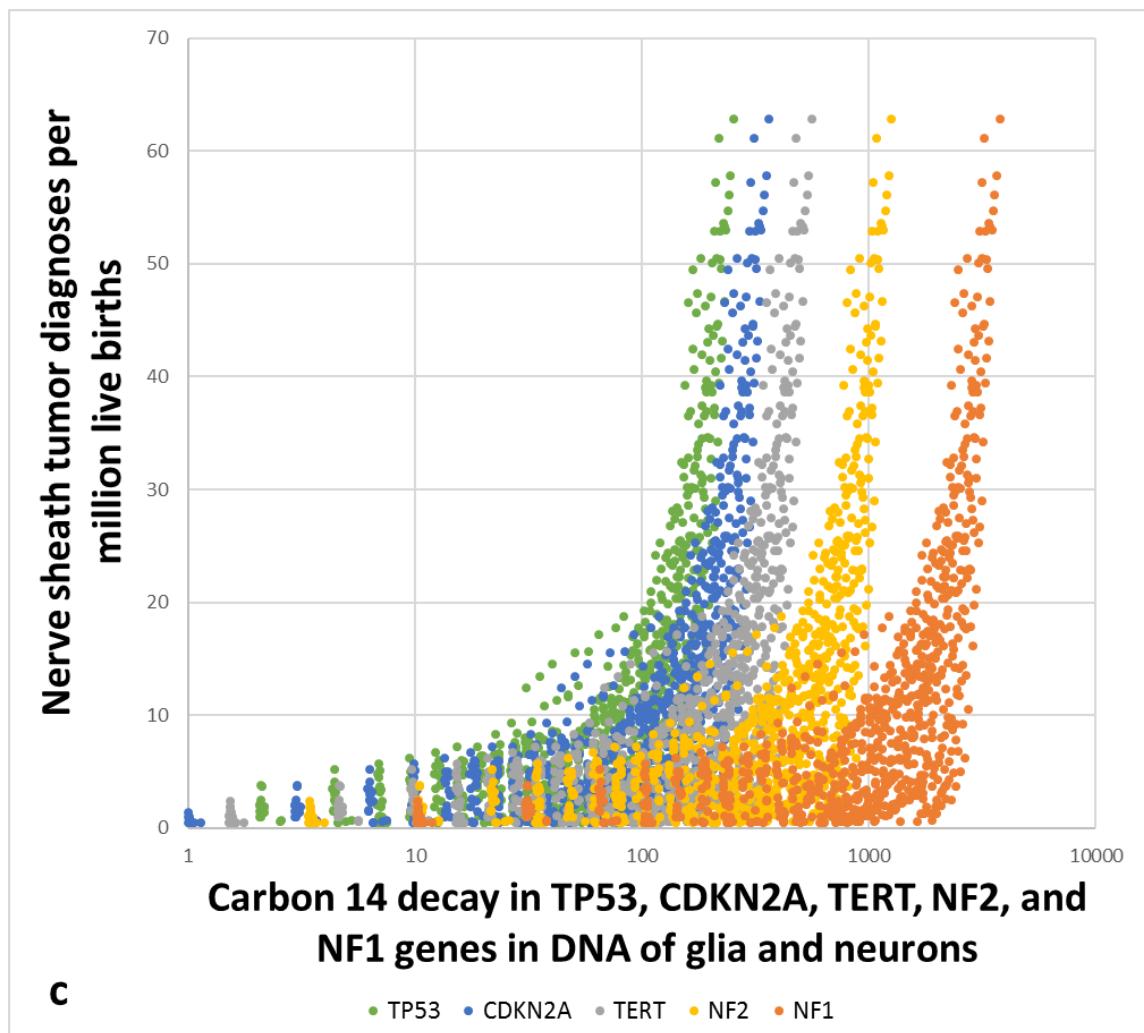
**Supplementary Information File**

**Extended Data Figure 1: Neuroepitheliomatous neoplasm, meningioma and nerve sheath tumor diagnoses correlated with carbon-14 decay in DNA of glia and neurons with point mutations in genes found in related tumors**

Comparisons of cumulative diagnoses between 1973 and 2013: (a) neuroepitheliomatous neoplasms correlated with cumulative  $^{14}\text{C}$  decay in FLG, MUC16, TTN, ALK, and LRP1B genes in glia and neurons; (b) meningiomas correlated with cumulative  $^{14}\text{C}$  decay in KLF4, TRAF7, AKT1, NF2, and TTN genes in glia and neurons; (c) nerve sheath tumors correlated with cumulative  $^{14}\text{C}$  decay in TP53, CDKN2A, TERT, NF2, and NF1 genes in glia and neurons.

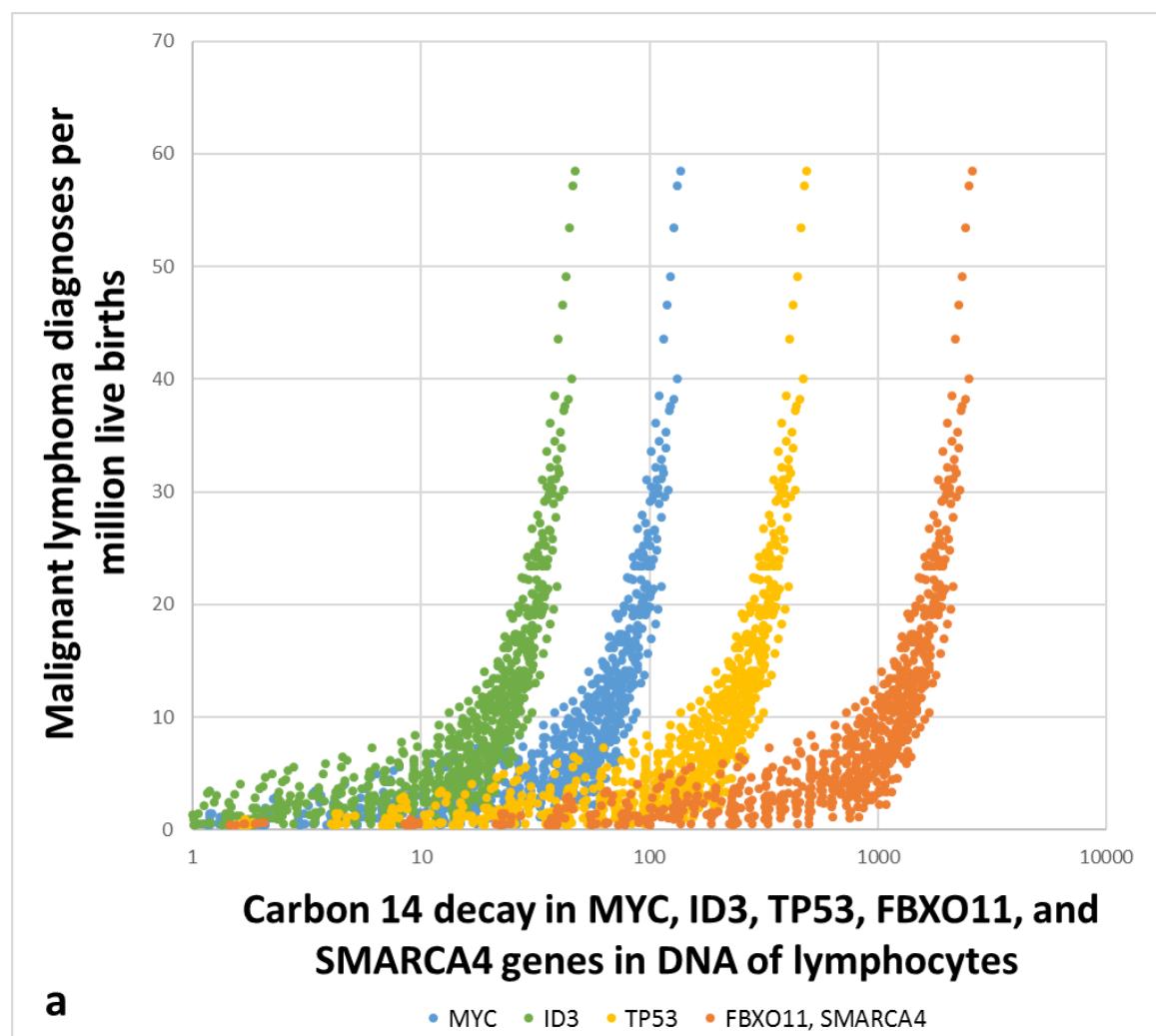


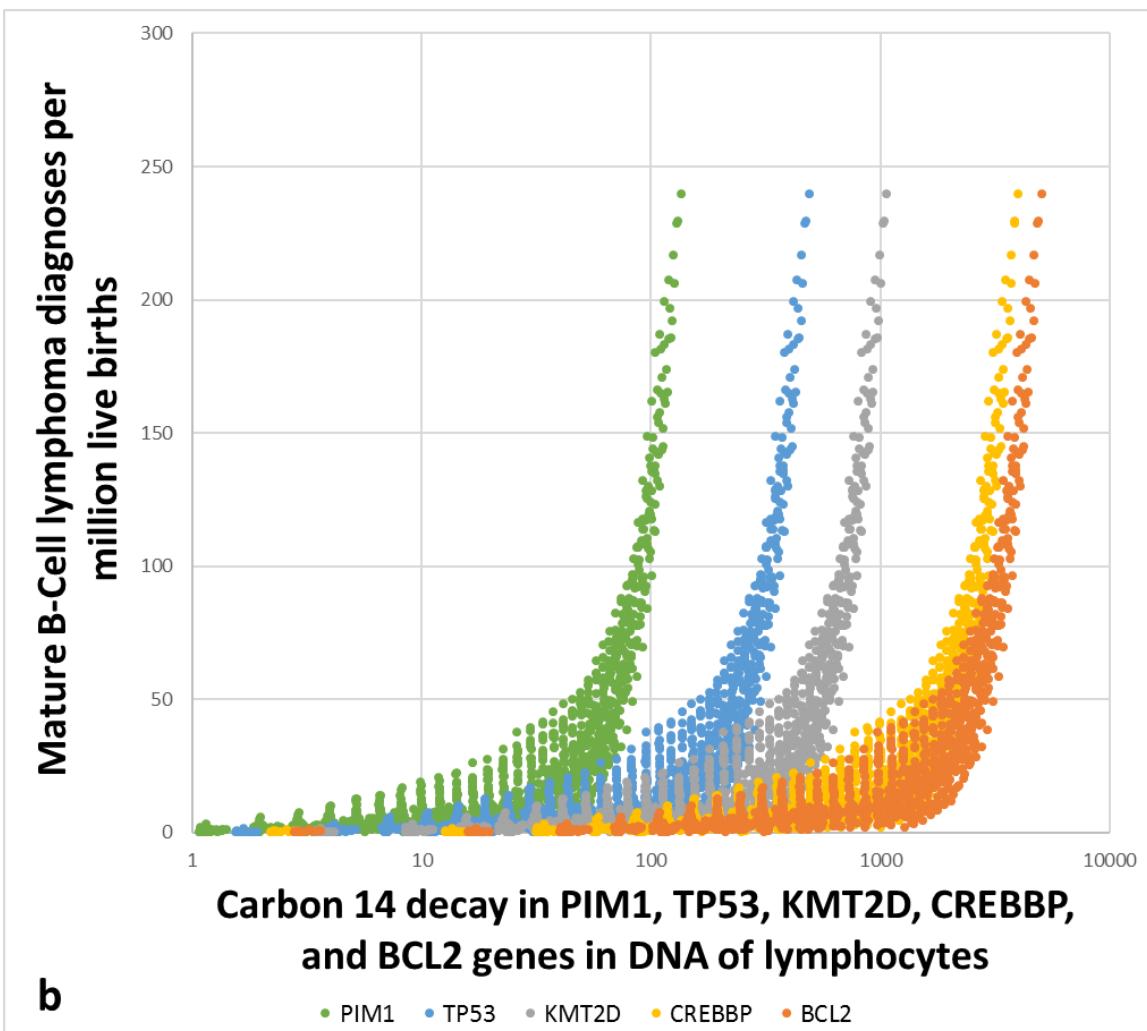


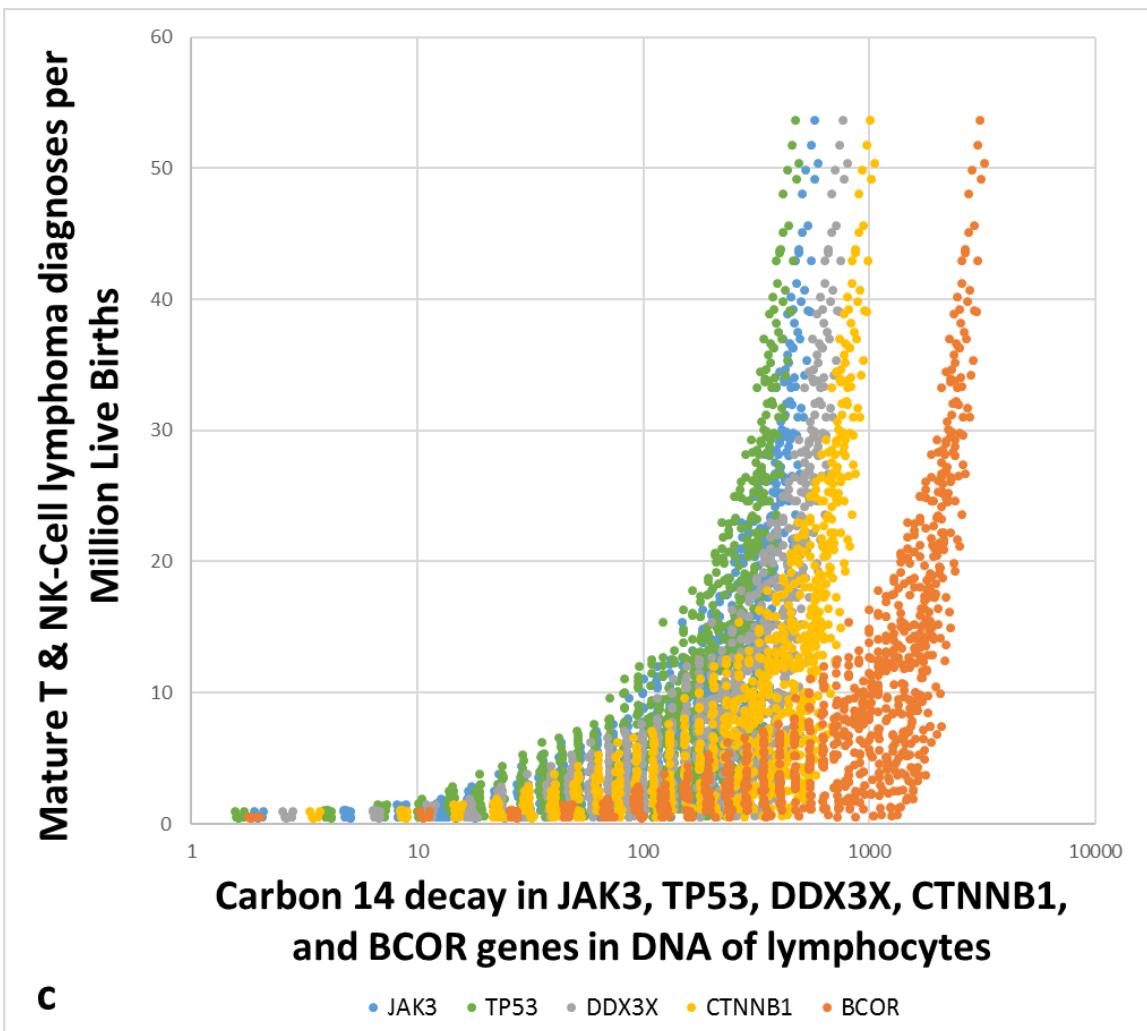


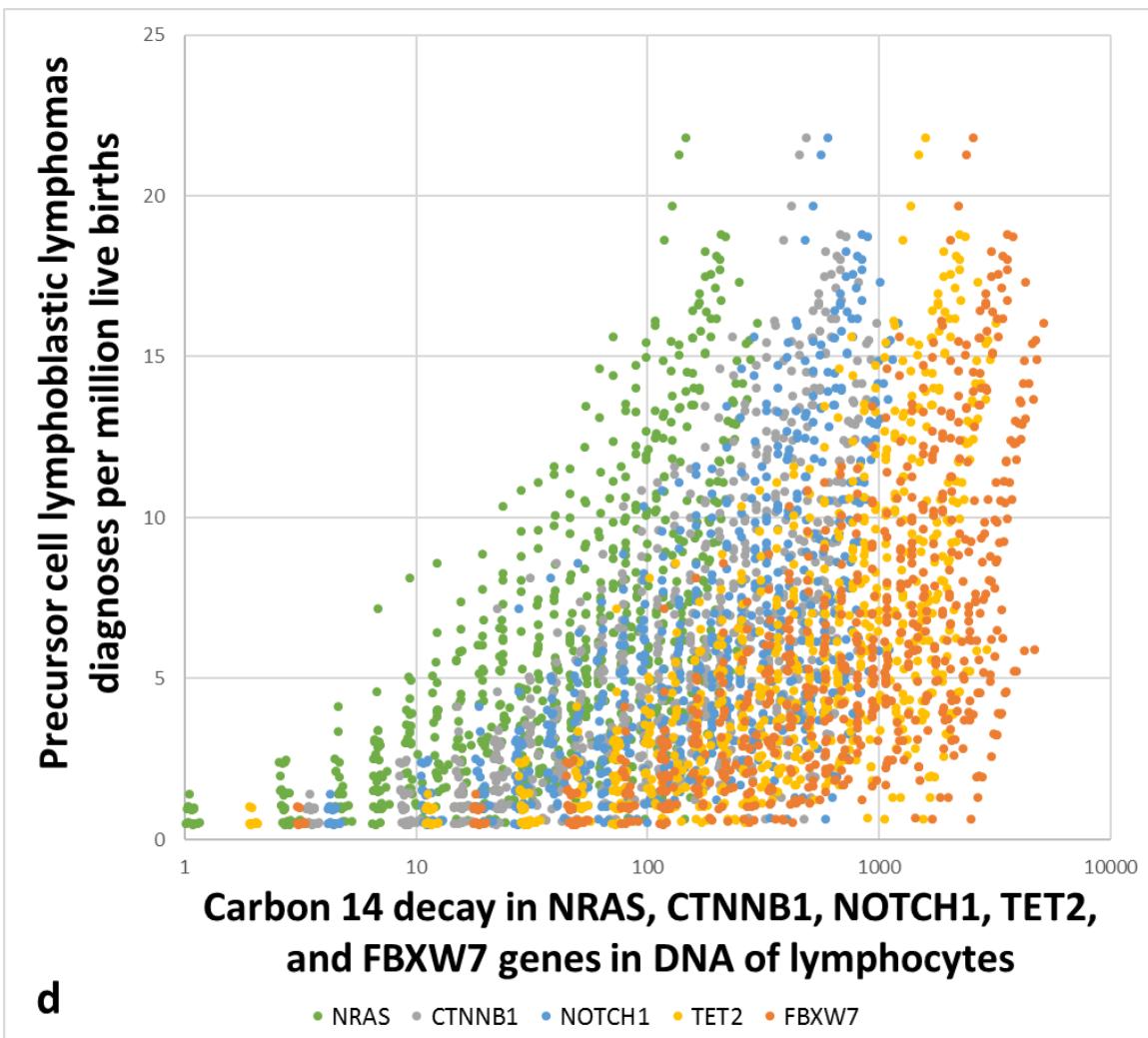
**Extended Data Figure 2: Lymphoma diagnoses correlated with carbon-14 decay in DNA of lymphocytes and point mutations in genes found in lymphomas**

Comparisons of cumulative diagnoses between 1973 and 2013: (a) Malignant lymphoma diagnoses correlated with cumulative  $^{14}\text{C}$  decay in MYC, ID3, TP53, FBXO11, and SMARCA4 genes in lymphocytes; (b) Mature B-Cell lymphoma diagnoses correlated with cumulative  $^{14}\text{C}$  decay in PIM1, TP53, KMT2D, CREBBP and BCL2 genes in lymphocytes; (c) Mature T and NK-Cell lymphoma diagnoses correlated with cumulative  $^{14}\text{C}$  decay in JAK3, TP53, DDX3X, CTNNB1, and BCOR genes in lymphocytes; (d) precursor cell lymphoblastic lymphoma diagnoses correlated with cumulative  $^{14}\text{C}$  decay in NRAS, CTNNB1, NOTCH1, TET2, and FBXW7 genes in lymphocytes.



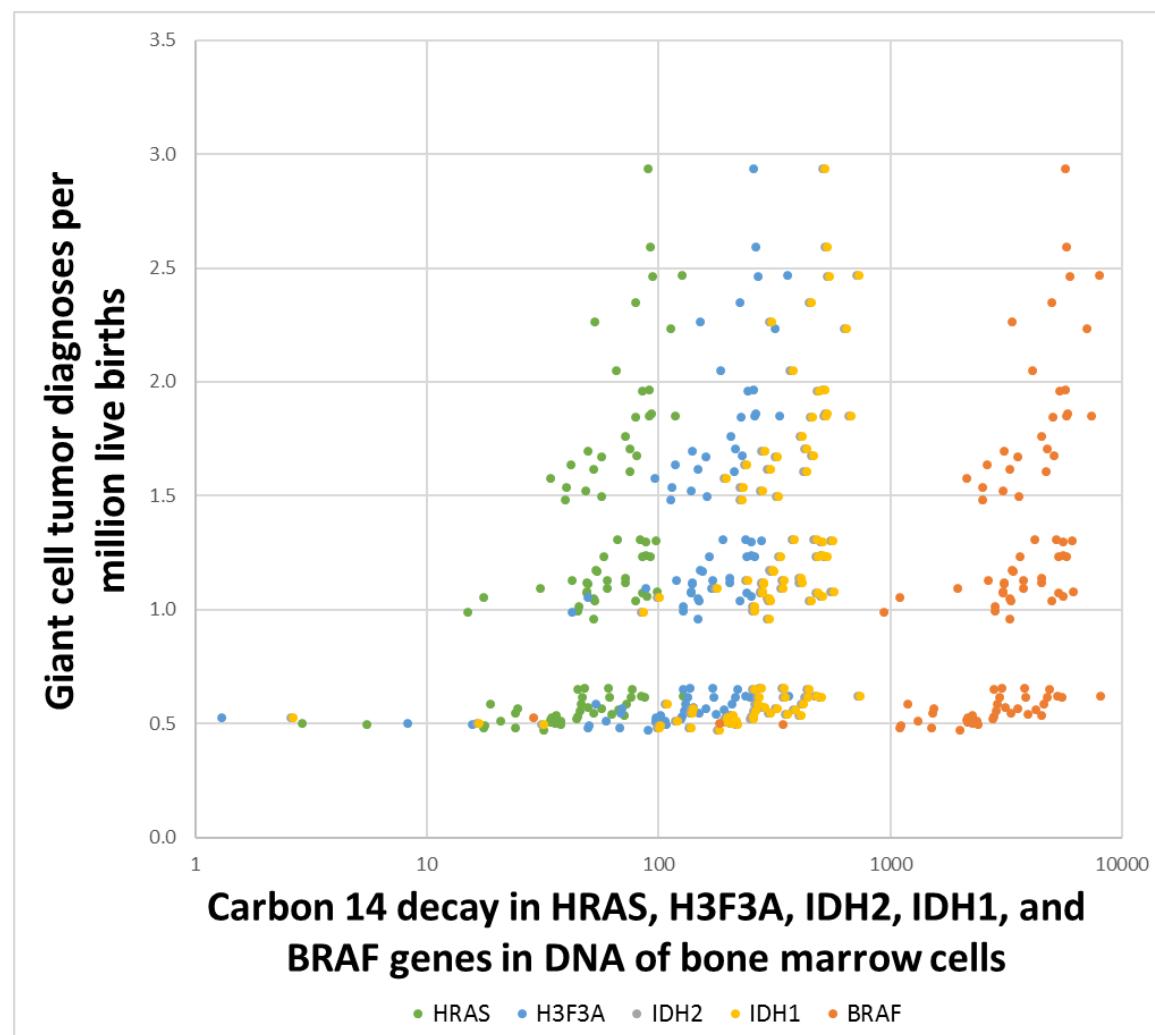






**Extended Data Figure 3: Giant cell tumor diagnoses correlated with carbon-14 decay in DNA of bone marrow cells and point mutations in genes found in bone marrow tumors**

Comparisons of cumulative diagnoses of giant cell tumors between 1973 and 2013: (a) diagnoses correlated with cumulative  $^{14}\text{C}$  decay in HRAS, H3F3A, IDH2, IDH1, and BRAF genes in bone marrow cells.



**Extended Data Table 1: Human fetus growth model from 0 to 38 weeks**

Age (weeks)	Mass (g)	Quantity of Cells	Cumulative Cell- Seconds
0	-	1.00E+00	0.00E+00
1	1.5	6.43E+07	1.94E+13
2	3.2	1.37E+08	8.04E+13
3	4.7	2.01E+08	1.83E+14
4	22.2	9.51E+08	5.31E+14
5	60.9	2.61E+09	1.61E+15
6	123.2	5.28E+09	3.99E+15
7	211.0	9.04E+09	8.33E+15
8	326.7	1.40E+10	1.53E+16
20	472.4	2.02E+10	1.40E+17
22	650.4	2.79E+10	1.69E+17
24	862.8	3.70E+10	2.08E+17
26	1,112.0	4.77E+10	2.59E+17
28	1,400.0	6.00E+10	3.24E+17
30	1,729.0	7.41E+10	4.05E+17
32	2,101.3	9.01E+10	5.05E+17
34	2,519.1	1.08E+11	6.24E+17
36	2,985.0	1.28E+11	7.67E+17
38	3,500.0	1.50E+11	9.35E+17

**Extended Data Table 2: Human fetus growth model for glia and neurons from 0 to 38 weeks**

Age (weeks)	Intracranial Cavity Volume (mL)	Brain Volume (mL)	Brain Mass (g)	Total Glia & Neuron Mass (g)	Quantity of Glia & Neurons	Glia & Neuron Cumulative Cell-Seconds
0	-	-	-	-	0	0.00E+00
1	0.3	0.2	0.2	0.3	1.20E+07	3.64E+12
2	0.6	0.4	0.5	0.6	2.57E+07	1.50E+13
3	0.8	0.5	0.7	0.9	3.77E+07	3.42E+13
4	3.9	2.5	3.5	4.2	1.78E+08	9.95E+13
5	10.6	6.9	9.5	11.4	4.89E+08	3.01E+14
6	21.4	13.9	19.2	23.1	9.89E+08	7.48E+14
7	36.7	23.7	32.8	39.5	1.69E+09	1.56E+15
8	56.8	36.8	50.8	61.2	2.62E+09	2.86E+15
20	82.1	53.1	73.4	88.5	3.79E+09	2.61E+16
22	113.1	73.2	101.1	121.8	5.22E+09	3.16E+16
24	149.6	96.8	133.8	161.2	6.91E+09	3.89E+16
26	189.0	122.3	169.0	204.3	8.76E+09	4.84E+16
28	228.4	147.8	204.2	248.7	1.07E+10	6.01E+16
30	267.8	173.3	239.4	294.4	1.26E+10	7.42E+16
32	307.2	198.8	274.7	341.5	1.46E+10	9.07E+16
34	346.6	224.3	309.9	390.0	1.67E+10	1.10E+17
36	386.0	249.8	345.1	440.1	1.89E+10	1.31E+17
38	425.4	275.3	380.4	491.7	2.11E+10	1.55E+17

### Extended Data Table 3: Interpolated brain and body weight data for males and females

Brain to body weight data with Standard Deviation (SD) and Standard Error of Measurements (SEM) for correction of standard body model glia and neuron tissue abundance for ages 0-85, interpolated from data collected from 2,603 males and 1,848 females. (a) 0-40 and (b) 41-85.

Age	Male						Female					
	Brain Weight (kg)			Body Weight (kg)			Brain Weight (kg)			Body Weight (kg)		
	Mean	SD	SEM	Mean	SD	SEM	Mean	SD	SEM	Mean	SD	SEM
0	0.38	0.09	0.00	2.95	0.47	0.03	0.36	0.08	0.00	2.88	0.46	0.03
(2 mo)	0.47	0.11	0.00	3.93	1.33	0.13	0.43	0.09	0.00	3.56	0.89	0.09
1	0.97	0.16	0.02	9.47	2.37	0.41	0.94	0.12	0.02	8.89	1.97	0.34
2	1.12	0.20	0.02	13.20	3.57	0.49	1.04	0.13	0.02	11.58	2.92	0.50
3	1.27	0.21	0.04	15.55	3.43	0.78	1.09	0.23	0.04	14.10	2.93	0.57
4	1.29	0.12	0.02	17.51	2.32	0.50	1.12	0.15	0.03	16.17	2.48	0.48
5	1.30	0.02	0.00	19.46	1.21	0.22	1.15	0.07	0.01	18.23	2.02	0.39
6	1.32	0.02	0.00	21.20	1.53	0.27	1.18	0.05	0.01	19.76	1.47	0.27
7	1.33	0.01	0.00	22.94	1.85	0.31	1.21	0.03	0.00	21.28	0.92	0.15
8	1.35	0.02	0.00	25.21	1.98	0.37	1.20	0.03	0.00	23.66	1.72	0.39
9	1.37	0.02	0.00	27.48	2.11	0.42	1.18	0.03	0.00	26.04	2.51	0.63
10	1.40	0.02	0.00	32.27	3.47	0.78	1.21	0.03	0.00	31.37	2.75	0.68
11	1.43	0.01	0.00	37.06	4.83	1.15	1.24	0.04	0.01	36.70	3.00	0.73
12	1.44	0.01	0.00	41.64	5.22	1.23	1.26	0.04	0.01	40.27	3.12	0.76
13	1.43	0.01	0.00	46.02	4.63	1.02	1.27	0.04	0.01	42.07	3.11	0.79
14	1.42	0.01	0.00	50.39	4.04	0.81	1.28	0.04	0.01	43.87	3.10	0.82
15	1.42	0.01	0.00	54.91	3.85	0.71	1.29	0.04	0.01	45.63	3.13	0.83
16	1.43	0.02	0.00	59.58	4.04	0.71	1.31	0.04	0.01	47.36	3.18	0.84
17	1.44	0.03	0.00	64.25	4.23	0.71	1.33	0.04	0.01	49.09	3.23	0.84
18	1.44	0.03	0.00	66.91	4.03	0.64	1.34	0.04	0.01	50.14	3.37	0.86
19	1.45	0.03	0.00	67.58	3.43	0.51	1.33	0.05	0.01	50.53	3.59	0.90
20	1.45	0.02	0.00	68.25	2.83	0.38	1.32	0.05	0.01	50.92	3.81	0.93
21	1.45	0.02	0.00	68.52	2.55	0.30	1.31	0.05	0.01	51.41	3.95	0.91
22	1.45	0.02	0.00	68.39	2.60	0.29	1.31	0.04	0.01	52.00	4.00	0.83
23	1.45	0.02	0.00	68.26	2.65	0.28	1.31	0.03	0.01	52.60	4.05	0.75
24	1.44	0.02	0.00	68.14	2.70	0.26	1.30	0.03	0.00	53.19	4.11	0.68
25	1.44	0.02	0.00	68.01	2.75	0.25	1.30	0.02	0.00	53.79	4.16	0.60
26	1.44	0.02	0.00	67.88	2.80	0.24	1.30	0.01	0.00	54.38	4.21	0.52
27	1.44	0.02	0.00	68.04	2.92	0.24	1.30	0.01	0.00	54.82	4.23	0.47
28	1.44	0.02	0.00	68.47	3.12	0.25	1.30	0.01	0.00	55.09	4.21	0.46
29	1.44	0.02	0.00	68.91	3.32	0.26	1.30	0.02	0.00	55.36	4.19	0.44
30	1.44	0.02	0.00	69.34	3.52	0.27	1.30	0.02	0.00	55.64	4.17	0.43
31	1.44	0.02	0.00	69.78	3.72	0.28	1.30	0.02	0.00	55.91	4.15	0.41
32	1.44	0.02	0.00	70.21	3.91	0.29	1.29	0.02	0.00	56.19	4.12	0.40
33	1.44	0.02	0.00	70.65	4.11	0.30	1.29	0.02	0.00	56.46	4.10	0.38
34	1.44	0.02	0.00	71.08	4.31	0.31	1.29	0.03	0.00	56.73	4.08	0.37
35	1.44	0.02	0.00	71.52	4.51	0.32	1.29	0.03	0.00	57.01	4.06	0.35
36	1.44	0.02	0.00	71.95	4.71	0.33	1.29	0.03	0.00	57.28	4.04	0.34
37	1.44	0.02	0.00	72.10	4.48	0.31	1.29	0.03	0.00	57.12	3.89	0.32
38	1.44	0.02	0.00	72.26	4.25	0.29	1.29	0.03	0.00	56.95	3.74	0.30
39	1.44	0.02	0.00	72.41	4.02	0.27	1.29	0.03	0.00	56.79	3.60	0.28
40	1.44	0.02	0.00	72.56	3.79	0.25	1.29	0.03	0.00	56.62	3.45	0.26

Age	Male				Female			
	Brain Weight (kg)		Body Weight (kg)		Brain Weight (kg)		Body Weight (kg)	
41	1.44	0.02	0.00	72.72	3.56	0.23	1.29	0.03
42	1.43	0.02	0.00	72.87	3.33	0.20	1.29	0.02
43	1.43	0.02	0.00	73.02	3.10	0.18	1.29	0.02
44	1.43	0.02	0.00	73.17	2.87	0.16	1.29	0.02
45	1.43	0.02	0.00	73.33	2.64	0.14	1.29	0.02
46	1.43	0.02	0.00	73.48	2.41	0.12	1.29	0.02
47	1.43	0.02	0.00	73.45	2.28	0.12	1.29	0.02
48	1.42	0.02	0.00	73.43	2.16	0.11	1.29	0.02
49	1.42	0.02	0.00	73.40	2.03	0.11	1.29	0.02
50	1.42	0.01	0.00	73.37	1.91	0.11	1.28	0.02
51	1.42	0.01	0.00	73.35	1.78	0.11	1.28	0.02
52	1.41	0.01	0.00	73.32	1.66	0.10	1.28	0.02
53	1.41	0.01	0.00	73.29	1.53	0.10	1.28	0.02
54	1.41	0.01	0.00	73.00	1.50	0.10	1.28	0.02
55	1.40	0.01	0.00	72.45	1.55	0.10	1.27	0.02
56	1.39	0.02	0.00	71.90	1.61	0.11	1.27	0.02
57	1.38	0.02	0.00	71.35	1.66	0.11	1.26	0.02
58	1.37	0.02	0.00	70.80	1.71	0.11	1.25	0.02
59	1.37	0.02	0.00	70.59	1.65	0.10	1.25	0.02
60	1.37	0.02	0.00	70.74	1.48	0.09	1.25	0.02
61	1.37	0.02	0.00	70.88	1.31	0.08	1.25	0.02
62	1.37	0.01	0.00	71.02	1.14	0.07	1.24	0.02
63	1.37	0.01	0.00	71.17	0.97	0.06	1.24	0.02
64	1.37	0.01	0.00	71.33	0.91	0.05	1.24	0.02
65	1.37	0.01	0.00	71.51	0.96	0.06	1.24	0.02
66	1.37	0.01	0.00	71.70	1.01	0.07	1.24	0.02
67	1.36	0.01	0.00	71.88	1.06	0.07	1.24	0.02
68	1.36	0.01	0.00	72.06	1.11	0.08	1.24	0.02
69	1.36	0.01	0.00	71.80	1.21	0.09	1.24	0.02
70	1.36	0.01	0.00	71.11	1.36	0.10	1.24	0.02
71	1.36	0.02	0.00	70.42	1.52	0.12	1.24	0.02
72	1.35	0.02	0.00	69.73	1.68	0.13	1.23	0.02
73	1.35	0.02	0.00	69.04	1.83	0.14	1.23	0.02
74	1.35	0.02	0.00	68.68	1.91	0.15	1.23	0.02
75	1.34	0.02	0.00	68.65	1.92	0.16	1.22	0.02
76	1.34	0.02	0.00	68.63	1.92	0.17	1.21	0.02
77	1.34	0.02	0.00	68.60	1.92	0.18	1.20	0.01
78	1.33	0.02	0.00	68.57	1.93	0.19	1.19	0.01
79	1.33	0.02	0.00	68.41	2.12	0.22	1.19	0.01
80	1.32	0.02	0.00	68.10	2.49	0.28	1.18	0.02
81	1.32	0.02	0.00	67.79	2.86	0.34	1.18	0.02
82	1.32	0.01	0.00	67.48	3.23	0.40	1.18	0.02
83	1.31	0.01	0.00	67.17	3.60	0.46	1.17	0.03
84	1.31	0.02	0.00	66.54	4.58	0.62	1.17	0.04
85	1.30	0.05	0.01	65.61	6.19	0.88	1.16	0.05

**Extended Data Table 4: Northern hemisphere atmospheric abundance of carbon-14 from 1959 to 2013**

Mean and standard deviation (SD) of the Northern hemispheric atmospheric abundance of  $^{14}\text{C}$  ‰ from all referenced sources by year.

Abundance of Carbon-14 ‰		
Year	Mean	SD
1959	242.4	19.9
1960	219.5	9.7
1961	226.8	7.8
1962	374.9	19.4
1963	768.1	77.7
1964	867.6	45.6
1965	767.0	17.7
1966	703.1	16.2
1967	630.2	9.8
1968	567.0	2.4
1969	546.4	1.6
1970	531.8	3.1
1971	505.0	8.9
1972	467.4	2.7
1973	416.7	5.2
1974	402.5	5.6
1975	370.1	4.5
1976	350.2	0.5
1977	334.6	2.4
1978	327.4	5.3
1979	296.4	2.5
1980	267.1	3.0
1981	258.9	3.1
1982	240.3	2.6
1983	226.1	2.2
1984	209.0	4.2
1985	200.2	6.0
1986	187.7	3.6
1987	180.8	3.7
1988	169.4	1.3
1989	161.8	2.8
1990	150.3	2.2
1991	139.5	2.7
1992	134.0	1.9
1993	126.1	1.8
1994	119.4	2.4
1995	113.1	2.3
1996	105.9	2.7
1997	101.0	1.1
1998	99.0	2.4
1999	92.8	3.1
2000	87.2	1.9
2001	80.5	1.5
2002	75.0	2.6
2003	68.6	1.8
2004	63.5	1.8
2005	58.1	0.3
2006	55.8	1.1
2007	51.2	1.8
2008	47.1	1.1
2009	46.7	1.3
2010	40.3	0.4
2011	37.0	2.8
2012	31.4	0.2
2013	28.0	1.1

## Extended Data Table 5: Carbon-14 decay in DNA of nucleated cells by tissue type

Mean and standard deviation (SD) of cumulative Carbon-14 decay in DNA of adipocytes, bone marrow cells, hepatocytes, lymphocytes, neurons & glia, and vascular endothelial cells. Notes: sex 1=male, 2=female; quantitative results for age 0 include 38 weeks of fetal development and two months of age.

Birth Year	Sex	Age	Adipocytes		Bone Marrow Cells		Hepatocytes		Lymphocytes		Glia & Neurons		Vascular Endothelial Cells	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1973	1	0	1.63E+4	5.55E+3	2.01E+5	6.81E+4	6.45E+4	2.19E+4	1.21E+5	4.10E+4	3.03E+5	1.03E+5	1.69E+5	5.74E+4
1973	1	1	8.86E+4	2.22E+4	1.09E+6	2.72E+5	3.45E+5	8.63E+4	6.46E+5	1.62E+5	8.72E+5	2.18E+5	9.03E+5	2.26E+5
1973	1	2	2.22E+5	5.99E+4	2.72E+6	7.36E+5	8.60E+5	2.33E+5	1.61E+6	4.36E+5	1.80E+6	4.86E+5	2.25E+6	6.09E+5
1973	1	3	3.84E+5	8.47E+4	4.71E+6	1.04E+6	1.48E+6	3.26E+5	2.77E+6	6.12E+5	2.85E+6	6.28E+5	3.88E+6	8.55E+5
1973	1	4	5.67E+5	7.52E+4	6.97E+6	9.23E+5	2.18E+6	2.89E+5	4.08E+6	5.40E+5	3.98E+6	5.28E+5	5.70E+6	7.56E+5
1973	1	5	7.74E+5	4.81E+4	9.50E+6	5.91E+5	2.96E+6	1.84E+5	5.55E+6	3.45E+5	5.18E+6	3.22E+5	7.76E+6	4.82E+5
1973	1	6	1.00E+6	7.24E+4	1.23E+7	8.88E+5	3.83E+6	2.76E+5	7.17E+6	5.18E+5	6.45E+6	4.65E+5	1.00E+7	7.24E+5
1973	1	7	1.25E+6	1.01E+5	1.54E+7	1.24E+6	4.77E+6	3.85E+5	8.94E+6	7.21E+5	7.77E+6	6.27E+5	1.25E+7	1.01E+6
1973	1	8	1.53E+6	1.20E+5	1.87E+7	1.47E+6	5.79E+6	4.54E+5	1.08E+7	8.51E+5	9.16E+6	7.20E+5	1.52E+7	1.19E+6
1973	1	9	1.83E+6	1.40E+5	2.25E+7	1.72E+6	6.92E+6	5.31E+5	1.30E+7	9.95E+5	1.06E+7	8.17E+5	1.81E+7	1.39E+6
1973	1	10	2.17E+6	2.33E+5	2.66E+7	2.86E+6	8.19E+6	8.80E+5	1.53E+7	1.65E+6	1.22E+7	1.31E+6	2.14E+7	2.31E+6
1973	1	11	2.54E+6	3.31E+5	3.12E+7	4.07E+6	9.58E+6	1.25E+6	1.79E+7	2.34E+6	1.38E+7	1.80E+6	2.51E+7	3.27E+6
1973	1	12	2.96E+6	3.70E+5	3.63E+7	4.55E+6	1.11E+7	1.39E+6	2.09E+7	2.61E+6	1.55E+7	1.95E+6	2.92E+7	3.65E+6
1973	1	13	3.42E+6	3.44E+5	4.20E+7	4.23E+6	1.29E+7	1.30E+6	2.41E+7	2.43E+6	1.73E+7	1.75E+6	3.37E+7	3.40E+6
1973	1	14	3.94E+6	3.16E+5	4.84E+7	3.88E+6	1.48E+7	1.19E+6	2.78E+7	2.23E+6	1.93E+7	1.55E+6	3.89E+7	3.12E+6
1973	1	15	4.51E+6	3.16E+5	5.54E+7	3.88E+6	1.70E+7	1.19E+6	3.18E+7	2.23E+6	2.13E+7	1.49E+6	4.45E+7	3.11E+6
1973	1	16	5.12E+6	3.47E+5	6.29E+7	4.26E+6	1.93E+7	1.31E+6	3.61E+7	2.45E+6	2.34E+7	1.59E+6	5.05E+7	3.43E+6
1973	1	17	5.77E+6	3.80E+5	7.08E+7	4.67E+6	2.17E+7	1.43E+6	4.07E+7	2.68E+6	2.56E+7	1.68E+6	5.69E+7	3.75E+6
1973	1	18	6.44E+6	3.88E+5	7.91E+7	4.76E+6	2.43E+7	1.46E+6	4.54E+7	2.74E+6	2.78E+7	1.67E+6	6.36E+7	3.83E+6
1973	1	19	7.13E+6	3.62E+5	8.76E+7	4.44E+6	2.69E+7	1.36E+6	5.03E+7	2.55E+6	3.00E+7	1.52E+6	7.03E+7	3.57E+6
1973	1	20	7.81E+6	3.24E+5	9.59E+7	3.98E+6	2.94E+7	1.22E+6	5.51E+7	2.29E+6	3.22E+7	1.34E+6	7.71E+7	3.20E+6
1973	1	21	8.50E+6	3.17E+5	1.04E+8	3.89E+6	3.20E+7	1.19E+6	5.99E+7	2.23E+6	3.45E+7	1.29E+6	8.38E+7	3.12E+6
1973	1	22	9.19E+6	3.50E+5	1.13E+8	4.29E+6	3.46E+7	1.32E+6	6.48E+7	2.47E+6	3.68E+7	1.40E+6	9.06E+7	3.45E+6
1973	1	23	9.88E+6	3.84E+5	1.21E+8	4.71E+6	3.72E+7	1.44E+6	6.97E+7	2.70E+6	3.90E+7	1.52E+6	9.74E+7	3.78E+6
1973	1	24	1.06E+7	4.19E+5	1.30E+8	5.15E+6	3.98E+7	1.58E+6	7.46E+7	2.95E+6	4.13E+7	1.64E+6	1.04E+8	4.13E+6
1973	1	25	1.13E+7	4.56E+5	1.39E+8	5.60E+6	4.24E+7	1.71E+6	7.95E+7	3.21E+6	4.37E+7	1.76E+6	1.11E+8	4.49E+6
1973	1	26	1.20E+7	4.93E+5	1.47E+8	6.06E+6	4.51E+7	1.86E+6	8.44E+7	3.48E+6	4.60E+7	1.90E+6	1.18E+8	4.86E+6
1973	1	27	1.27E+7	5.44E+5	1.56E+8	6.68E+6	4.77E+7	2.05E+6	8.94E+7	3.83E+6	4.84E+7	2.08E+6	1.25E+8	5.36E+6
1973	1	28	1.34E+7	6.09E+5	1.64E+8	7.48E+6	5.03E+7	2.29E+6	9.43E+7	4.29E+6	5.07E+7	2.31E+6	1.32E+8	6.01E+6
1973	1	29	1.41E+7	6.78E+5	1.73E+8	8.32E+6	5.30E+7	2.55E+6	9.92E+7	4.78E+6	5.31E+7	2.56E+6	1.39E+8	6.68E+6
1973	1	30	1.48E+7	7.50E+5	1.81E+8	9.20E+6	5.56E+7	2.82E+6	1.04E+8	5.28E+6	5.55E+7	2.81E+6	1.46E+8	7.39E+6
1973	1	31	1.55E+7	8.24E+5	1.90E+8	1.01E+7	5.82E+7	3.10E+6	1.09E+8	5.81E+6	5.78E+7	3.08E+6	1.53E+8	8.12E+6
1973	1	32	1.62E+7	9.02E+5	1.99E+8	1.11E+7	6.09E+7	3.39E+6	1.14E+8	6.36E+6	6.02E+7	3.36E+6	1.59E+8	8.89E+6
1973	1	33	1.69E+7	9.83E+5	2.07E+8	1.21E+7	6.35E+7	3.70E+6	1.19E+8	6.93E+6	6.26E+7	3.64E+6	1.66E+8	9.68E+6
1973	1	34	1.76E+7	1.07E+6	2.16E+8	1.31E+7	6.61E+7	4.01E+6	1.24E+8	7.52E+6	6.50E+7	3.94E+6	1.73E+8	1.05E+7
1973	1	35	1.83E+7	1.15E+6	2.24E+8	1.42E+7	6.88E+7	4.34E+6	1.29E+8	8.13E+6	6.74E+7	4.25E+6	1.80E+8	1.14E+7
1973	1	36	1.90E+7	1.24E+6	2.33E+8	1.52E+7	7.14E+7	4.67E+6	1.34E+8	8.75E+6	6.97E+7	4.57E+6	1.87E+8	1.22E+7
1973	1	37	1.97E+7	1.22E+6	2.41E+8	1.50E+7	7.40E+7	4.60E+6	1.39E+8	8.62E+6	7.21E+7	4.48E+6	1.94E+8	1.20E+7
1973	1	38	2.03E+7	1.20E+6	2.50E+8	1.47E+7	7.66E+7	4.51E+6	1.44E+8	8.44E+6	7.45E+7	4.38E+6	2.01E+8	1.18E+7
1973	1	39	2.10E+7	1.17E+6	2.58E+8	1.43E+7	7.92E+7	4.40E+6	1.48E+8	8.24E+6	7.69E+7	4.27E+6	2.08E+8	1.15E+7
1973	1	40	2.17E+7	1.13E+6	2.67E+8	1.39E+7	8.18E+7	4.27E+6	1.53E+8	8.01E+6	7.93E+7	4.14E+6	2.14E+8	1.12E+7
1974	1	0	1.58E+4	5.36E+3	1.94E+5	6.58E+4	6.22E+4	2.11E+4	1.17E+5	3.96E+4	2.93E+5	9.95E+4	1.63E+5	5.54E+4
1974	1	1	8.67E+4	2.17E+4	1.06E+6	2.66E+5	3.41E+5	8.53E+4	6.38E+5	1.60E+5	8.49E+5	2.12E+5	8.92E+5	2.23E+5
1974	1	2	2.17E+5	5.86E+4	2.66E+6	7.20E+5	8.44E+5	2.28E+5	1.58E+6	4.28E+5	1.75E+6	4.74E+5	2.21E+6	5.98E+5
1974	1	3	3.76E+5	8.28E+4	4.61E+6	1.02E+6	1.45E+6	3.21E+5	2.72E+6	6.01E+5	2.78E+6	6.12E+5	3.81E+6	8.40E+5
1974	1	4	5.55E+5	7.36E+4	6.82E+6	9.04E+5	2.14E+6	2.84E+5	4.01E+6	5.32E+5	3.89E+6	5.15E+5	5.61E+6	7.44E+5
1974	1	5	7.58E+5	4.71E+4	9.31E+6	5.79E+5	2.92E+6	1.82E+5	5.47E+6	3.40E+5	5.06E+6	3.14E+5	7.65E+6	4.76E+5
1974	1	6	9.83E+5	7.09E+4	1.21E+7	8.71E+5	3.77E+6	2.72E+5	7.06E+6	5.10E+5	6.29E+6	4.54E+5	9.87E+6	7.13E+5
1974	1	7	1.23E+6	9.92E+4	1.51E+7	1.22E+6	4.70E+6	3.79E+5	8.80E+6	7.09E+5	7.59E+6	6.12E+5	1.23E+7	9.92E+5
1974	1	8	1.50E+6	1.18E+5	1.84E+7	1.45E+6	5.71E+6	4.48E+5	1.07E+7	8.39E+5	8.96E+6	7.04E+5	1.49E+7	1.17E+6
1974	1	9	1.80E+6	1.38E+5	2.21E+7	1.69E+6	6.82E+6	5.24E+5	1.28E+7	9.82E+5	1.04E+7	7.99E+5	1.79E+7	1.37E+6
1974	1	10	2.13E+6	2.29E+5	2.62E+7	2.82E+6	8.08E+6	8.69E+5	1.51E+7	1.63E+6	1.19E+7	1.28E+6	2.12E+7	2.28E+6
1974	1	11	2.50E+6	3.26E+5	3.07E+7	4.00E+6	9.47E+6	1.23E+6	1.77E+7	2.31E+6	1.35E+7	1.77E+6	2.48E+7	3.23E+6

1974	1	12	2.91E+6	3.65E+5	3.58E+7	4.48E+6	1.10E+7	1.38E+6	2.06E+7	2.58E+6	1.52E+7	1.91E+6	2.88E+7	3.61E+6
1974	1	13	3.37E+6	3.39E+5	4.14E+7	4.17E+6	1.27E+7	1.28E+6	2.39E+7	2.40E+6	1.70E+7	1.71E+6	3.34E+7	3.36E+6
1974	1	14	3.89E+6	3.12E+5	4.77E+7	3.83E+6	1.47E+7	1.18E+6	2.75E+7	2.21E+6	1.89E+7	1.52E+6	3.85E+7	3.09E+6
1974	1	15	4.45E+6	3.12E+5	5.46E+7	3.83E+6	1.68E+7	1.18E+6	3.15E+7	2.20E+6	2.09E+7	1.46E+6	4.40E+7	3.08E+6
1974	1	16	5.05E+6	3.43E+5	6.20E+7	4.21E+6	1.91E+7	1.29E+6	3.58E+7	2.43E+6	2.29E+7	1.56E+6	5.00E+7	3.39E+6
1974	1	17	5.69E+6	3.75E+5	6.99E+7	4.60E+6	2.15E+7	1.42E+6	4.03E+7	2.65E+6	2.51E+7	1.65E+6	5.63E+7	3.71E+6
1974	1	18	6.36E+6	3.83E+5	7.80E+7	4.70E+6	2.40E+7	1.45E+6	4.50E+7	2.71E+6	2.72E+7	1.64E+6	6.29E+7	3.79E+6
1974	1	19	7.04E+6	3.57E+5	8.64E+7	4.38E+6	2.66E+7	1.35E+6	4.98E+7	2.53E+6	2.94E+7	1.49E+6	6.96E+7	3.53E+6
1974	1	20	7.71E+6	3.20E+5	9.47E+7	3.93E+6	2.91E+7	1.21E+6	5.45E+7	2.26E+6	3.16E+7	1.31E+6	7.63E+7	3.16E+6
1974	1	21	8.39E+6	3.13E+5	1.03E+8	3.84E+6	3.17E+7	1.18E+6	5.93E+7	2.21E+6	3.38E+7	1.26E+6	8.30E+7	3.09E+6
1974	1	22	9.07E+6	3.45E+5	1.11E+8	4.24E+6	3.42E+7	1.30E+6	6.41E+7	2.44E+6	3.60E+7	1.37E+6	8.97E+7	3.41E+6
1974	1	23	9.76E+6	3.79E+5	1.20E+8	4.65E+6	3.68E+7	1.43E+6	6.90E+7	2.68E+6	3.83E+7	1.49E+6	9.65E+7	3.75E+6
1974	1	24	1.04E+7	4.14E+5	1.28E+8	5.08E+6	3.94E+7	1.56E+6	7.38E+7	2.92E+6	4.05E+7	1.61E+6	1.03E+8	4.09E+6
1974	1	25	1.11E+7	4.50E+5	1.37E+8	5.53E+6	4.20E+7	1.70E+6	7.87E+7	3.18E+6	4.28E+7	1.73E+6	1.10E+8	4.45E+6
1974	1	26	1.18E+7	4.88E+5	1.45E+8	5.99E+6	4.47E+7	1.84E+6	8.36E+7	3.44E+6	4.51E+7	1.86E+6	1.17E+8	4.82E+6
1974	1	27	1.25E+7	5.38E+5	1.54E+8	6.60E+6	4.73E+7	2.03E+6	8.85E+7	3.80E+6	4.74E+7	2.04E+6	1.24E+8	5.31E+6
1974	1	28	1.32E+7	6.02E+5	1.62E+8	7.39E+6	4.99E+7	2.27E+6	9.34E+7	4.26E+6	4.98E+7	2.27E+6	1.31E+8	5.95E+6
1974	1	29	1.39E+7	6.70E+5	1.71E+8	8.23E+6	5.25E+7	2.53E+6	9.83E+7	4.73E+6	5.21E+7	2.51E+6	1.38E+8	6.62E+6
1974	1	30	1.46E+7	7.41E+5	1.79E+8	9.10E+6	5.51E+7	2.79E+6	1.03E+8	5.24E+6	5.44E+7	2.76E+6	1.44E+8	7.32E+6
1974	1	31	1.53E+7	8.15E+5	1.88E+8	1.00E+7	5.77E+7	3.07E+6	1.08E+8	5.76E+6	5.67E+7	3.02E+6	1.51E+8	8.05E+6
1974	1	32	1.60E+7	8.92E+5	1.96E+8	1.09E+7	6.03E+7	3.36E+6	1.13E+8	6.30E+6	5.91E+7	3.29E+6	1.58E+8	8.81E+6
1974	1	33	1.67E+7	9.72E+5	2.05E+8	1.19E+7	6.30E+7	3.67E+6	1.18E+8	6.87E+6	6.14E+7	3.58E+6	1.65E+8	9.60E+6
1974	1	34	1.74E+7	1.05E+6	2.13E+8	1.29E+7	6.56E+7	3.98E+6	1.23E+8	7.45E+6	6.38E+7	3.87E+6	1.72E+8	1.04E+7
1974	1	35	1.81E+7	1.14E+6	2.22E+8	1.40E+7	6.82E+7	4.30E+6	1.28E+8	8.06E+6	6.61E+7	4.17E+6	1.79E+8	1.13E+7
1974	1	36	1.88E+7	1.23E+6	2.30E+8	1.51E+7	7.08E+7	4.64E+6	1.33E+8	8.68E+6	6.84E+7	4.48E+6	1.85E+8	1.21E+7
1974	1	37	1.95E+7	1.21E+6	2.39E+8	1.48E+7	7.34E+7	4.56E+6	1.38E+8	8.54E+6	7.08E+7	4.40E+6	1.92E+8	1.19E+7
1974	1	38	2.01E+7	1.18E+6	2.47E+8	1.45E+7	7.60E+7	4.47E+6	1.42E+8	8.37E+6	7.31E+7	4.30E+6	1.99E+8	1.17E+7
1974	1	39	2.08E+7	1.16E+6	2.56E+8	1.42E+7	7.86E+7	4.36E+6	1.47E+8	8.17E+6	7.55E+7	4.19E+6	2.06E+8	1.14E+7
1975	1	0	1.56E+4	5.30E+3	1.92E+5	6.51E+4	6.16E+4	2.09E+4	1.15E+5	3.92E+4	2.90E+5	9.85E+4	1.61E+5	5.48E+4
1975	1	1	8.55E+4	2.14E+4	1.05E+6	2.63E+5	3.34E+5	8.37E+4	6.26E+5	1.57E+5	8.39E+5	2.10E+5	8.76E+5	2.19E+5
1975	1	2	2.14E+5	5.78E+4	2.62E+6	7.09E+5	8.31E+5	2.25E+5	1.56E+6	4.21E+5	1.73E+6	4.68E+5	2.18E+6	5.89E+5
1975	1	3	3.70E+5	8.15E+4	4.54E+6	1.00E+6	1.43E+6	3.16E+5	2.68E+6	5.92E+5	2.74E+6	6.03E+5	3.75E+6	8.28E+5
1975	1	4	5.47E+5	7.25E+4	6.71E+6	8.90E+5	2.12E+6	2.80E+5	3.96E+6	5.25E+5	3.83E+6	5.07E+5	5.54E+6	7.35E+5
1975	1	5	7.46E+5	4.64E+4	9.16E+6	5.69E+5	2.87E+6	1.79E+5	5.38E+6	3.35E+5	4.98E+6	3.10E+5	7.53E+6	4.68E+5
1975	1	6	9.67E+5	6.98E+4	1.19E+7	8.57E+5	3.70E+6	2.67E+5	6.94E+6	5.01E+5	6.20E+6	4.47E+5	9.71E+6	7.00E+5
1975	1	7	1.21E+6	9.77E+4	1.49E+7	1.20E+6	4.63E+6	3.73E+5	8.67E+6	6.99E+5	7.48E+6	6.04E+5	1.21E+7	9.78E+5
1975	1	8	1.48E+6	1.16E+5	1.82E+7	1.43E+6	5.63E+6	4.42E+5	1.05E+7	8.28E+5	8.83E+6	6.94E+5	1.47E+7	1.16E+6
1975	1	9	1.77E+6	1.36E+5	2.18E+7	1.67E+6	6.74E+6	5.17E+5	1.26E+7	9.69E+5	1.03E+7	7.88E+5	1.77E+7	1.36E+6
1975	1	10	2.10E+6	2.26E+5	2.58E+7	2.78E+6	7.98E+6	8.58E+5	1.49E+7	1.61E+6	1.18E+7	1.27E+6	2.09E+7	2.25E+6
1975	1	11	2.47E+6	3.22E+5	3.04E+7	3.96E+6	9.36E+6	1.22E+6	1.75E+7	2.29E+6	1.34E+7	1.74E+6	2.45E+7	3.20E+6
1975	1	12	2.88E+6	3.61E+5	3.53E+7	4.43E+6	1.09E+7	1.37E+6	2.04E+7	2.56E+6	1.50E+7	1.88E+6	2.85E+7	3.58E+6
1975	1	13	3.33E+6	3.35E+5	4.09E+7	4.12E+6	1.26E+7	1.27E+6	2.36E+7	2.38E+6	1.68E+7	1.69E+6	3.30E+7	3.33E+6
1975	1	14	3.84E+6	3.08E+5	4.72E+7	3.78E+6	1.45E+7	1.17E+6	2.72E+7	2.19E+6	1.86E+7	1.50E+6	3.81E+7	3.06E+6
1975	1	15	4.40E+6	3.08E+5	5.40E+7	3.78E+6	1.66E+7	1.17E+6	3.12E+7	2.18E+6	2.06E+7	1.44E+6	4.36E+7	3.06E+6
1975	1	16	5.00E+6	3.39E+5	6.14E+7	4.16E+6	1.89E+7	1.28E+6	3.54E+7	2.40E+6	2.26E+7	1.54E+6	4.96E+7	3.36E+6
1975	1	17	5.63E+6	3.71E+5	6.91E+7	4.55E+6	2.13E+7	1.40E+6	3.99E+7	2.63E+6	2.47E+7	1.63E+6	5.58E+7	3.68E+6
1975	1	18	6.28E+6	3.78E+5	7.71E+7	4.64E+6	2.38E+7	1.43E+6	4.45E+7	2.68E+6	2.69E+7	1.62E+6	6.23E+7	3.75E+6
1975	1	19	6.95E+6	3.53E+5	8.54E+7	4.33E+6	2.63E+7	1.34E+6	4.93E+7	2.50E+6	2.90E+7	1.47E+6	6.89E+7	3.50E+6
1975	1	20	7.62E+6	3.16E+5	9.36E+7	3.88E+6	2.88E+7	1.20E+6	5.40E+7	2.24E+6	3.12E+7	1.29E+6	7.55E+7	3.13E+6
1975	1	21	8.29E+6	3.09E+5	1.02E+8	3.80E+6	3.14E+7	1.17E+6	5.87E+7	2.19E+6	3.33E+7	1.24E+6	8.22E+7	3.06E+6
1975	1	22	8.97E+6	3.41E+5	1.10E+8	4.19E+6	3.39E+7	1.29E+6	6.35E+7	2.42E+6	3.55E+7	1.35E+6	8.88E+7	3.38E+6
1975	1	23	9.65E+6	3.75E+5	1.18E+8	4.60E+6	3.65E+7	1.42E+6	6.83E+7	2.65E+6	3.78E+7	1.47E+6	9.56E+7	3.71E+6
1975	1	24	1.03E+7	4.09E+5	1.27E+8	5.03E+6	3.91E+7	1.55E+6	7.32E+7	2.90E+6	4.00E+7	1.58E+6	1.02E+8	4.05E+6
1975	1	25	1.10E+7	4.45E+5	1.35E+8	5.47E+6	4.17E+7	1.68E+6	7.80E+7	3.15E+6	4.23E+7	1.71E+6	1.09E+8	4.41E+6
1975	1	26	1.17E+7	4.82E+5	1.44E+8	5.92E+6	4.43E+7	1.82E+6	8.29E+7	3.41E+6	4.45E+7	1.83E+6	1.16E+8	4.78E+6
1975	1	27	1.24E+7	5.32E+5	1.52E+8	6.53E+6	4.69E+7	2.01E+6	8.78E+7	3.77E+6	4.68E+7	2.01E+6	1.23E+8	5.27E+6
1975	1	28	1.31E+7	5.96E+5	1.61E+8	7.32E+6	4.95E+7	2.25E+6	9.26E+7	4.22E+6	4.91E+7	2.24E+6	1.30E+8	5.90E+6
1975	1	29	1.38E+7	6.63E+5	1.69E+8	8.14E+6	5.20E+7	2.51E+6	9.75E+7	4.69E+6	5.14E+7	2.47E+6	1.36E+8	6.56E+6
1975	1	30	1.45E+7	7.33E+5	1.78E+8	9.00E+6	5.46E+7	2.77E+6	1.02E+8	5.19E+6	5.37E+7	2.72E+6	1.43E+8	7.26E+6
1975	1	31	1.51E+7	8.06E+5	1.86E+8	9.90E+6	5.72E+7	3.05E+6	1.07E+8	5.71E+6	5.60E+7	2.98E+6	1.50E+8	7.98E+6
1975	1	32	1.58E+7	8.83E+5	1.94E+8	1.08E+7	5.98E+7	3.34E+6	1.12E+8	6.25E+6	5.83E+7	3.25E+6	1.57E+8	8.74E+6
1975	1	33	1.65E+7	9.62E+5	2.03E+8	1.18E+7	6.24E+7	3.63E+6	1.17E+8	6.81E+6	6.06E+7	3.53E+6	1.64E+8	9.52E+6
1975	1	34	1.72E+7	1.04E+6	2.11E+8	1.28E+7	6.50E+7	3.95E+6	1.22E+8	7.39E+6	6.29E+7	3.81E+6	1.70E+8	1.03E+7
1975	1	35	1.79E+7	1.13E+6	2.20E+8	1.39E+7	6.76E+7	4.27E+6	1.27E+8	7.99E+6	6.52E+7	4.11E+6	1.77E+8	1.12E+7
1975	1	36	1.86E+7	1.22E+6	2.28E+8	1.49E+7	7.02E+7	4.60E+6	1.32E+8	8.61E+6	6.75E+			

1976	1	0	1.53E+4	5.18E+3	1.87E+5	6.36E+4	6.02E+4	2.04E+4	1.13E+5	3.83E+4	2.83E+5	9.62E+4	1.58E+5	5.35E+4
1976	1	1	8.41E+4	2.10E+4	1.03E+6	2.58E+5	3.30E+5	8.26E+4	6.18E+5	1.55E+5	8.23E+5	2.06E+5	8.64E+5	2.16E+5
1976	1	2	2.10E+5	5.68E+4	2.58E+6	6.98E+5	8.21E+5	2.22E+5	1.54E+6	4.16E+5	1.70E+6	4.59E+5	2.15E+6	5.82E+5
1976	1	3	3.64E+5	8.02E+4	4.47E+6	9.85E+5	1.42E+6	3.13E+5	2.66E+6	5.86E+5	2.68E+6	5.92E+5	3.72E+6	8.19E+5
1976	1	4	5.38E+5	7.13E+4	6.61E+6	8.75E+5	2.09E+6	2.76E+5	3.91E+6	5.18E+5	3.76E+6	4.98E+5	5.46E+6	7.24E+5
1976	1	5	7.33E+5	4.56E+4	9.00E+6	5.60E+5	2.82E+6	1.76E+5	5.29E+6	3.29E+5	4.89E+6	3.04E+5	7.39E+6	4.60E+5
1976	1	6	9.51E+5	6.86E+4	1.17E+7	8.43E+5	3.65E+6	2.63E+5	6.84E+6	4.93E+5	6.08E+6	4.39E+5	9.56E+6	6.90E+5
1976	1	7	1.19E+6	9.62E+4	1.46E+7	1.18E+6	4.56E+6	3.68E+5	8.55E+6	6.89E+5	7.35E+6	5.93E+5	1.20E+7	9.64E+5
1976	1	8	1.46E+6	1.14E+5	1.79E+7	1.40E+6	5.56E+6	4.36E+5	1.04E+7	8.18E+5	8.68E+6	6.82E+5	1.46E+7	1.14E+6
1976	1	9	1.75E+6	1.34E+5	2.15E+7	1.65E+6	6.65E+6	5.11E+5	1.25E+7	9.57E+5	1.01E+7	7.75E+5	1.74E+7	1.34E+6
1976	1	10	2.08E+6	2.23E+5	2.55E+7	2.74E+6	7.89E+6	8.49E+5	1.48E+7	1.59E+6	1.16E+7	1.25E+6	2.07E+7	2.22E+6
1976	1	11	2.44E+6	3.18E+5	3.00E+7	3.91E+6	9.27E+6	1.21E+6	1.74E+7	2.26E+6	1.32E+7	1.72E+6	2.43E+7	3.17E+6
1976	1	12	2.84E+6	3.56E+5	3.49E+7	4.38E+6	1.08E+7	1.35E+6	2.02E+7	2.53E+6	1.48E+7	1.85E+6	2.83E+7	3.54E+6
1976	1	13	3.29E+6	3.31E+5	4.04E+7	4.07E+6	1.25E+7	1.26E+6	2.34E+7	2.36E+6	1.65E+7	1.66E+6	3.27E+7	3.29E+6
1976	1	14	3.80E+6	3.05E+5	4.66E+7	3.74E+6	1.44E+7	1.16E+6	2.70E+7	2.17E+6	1.84E+7	1.47E+6	3.77E+7	3.03E+6
1976	1	15	4.35E+6	3.05E+5	5.34E+7	3.74E+6	1.65E+7	1.16E+6	3.09E+7	2.16E+6	2.03E+7	1.42E+6	4.32E+7	3.03E+6
1976	1	16	4.94E+6	3.35E+5	6.07E+7	4.11E+6	1.88E+7	1.27E+6	3.51E+7	2.38E+6	2.23E+7	1.51E+6	4.91E+7	3.33E+6
1976	1	17	5.56E+6	3.67E+5	6.83E+7	4.50E+6	2.11E+7	1.39E+6	3.95E+7	2.61E+6	2.44E+7	1.61E+6	5.53E+7	3.64E+6
1976	1	18	6.21E+6	3.74E+5	7.62E+7	4.59E+6	2.35E+7	1.42E+6	4.41E+7	2.66E+6	2.64E+7	1.59E+6	6.17E+7	3.72E+6
1976	1	19	6.87E+6	3.49E+5	8.44E+7	4.28E+6	2.61E+7	1.32E+6	4.88E+7	2.48E+6	2.86E+7	1.45E+6	6.83E+7	3.46E+6
1976	1	20	7.53E+6	3.12E+5	9.25E+7	3.83E+6	2.86E+7	1.18E+6	5.35E+7	2.22E+6	3.07E+7	1.27E+6	7.48E+7	3.10E+6
1976	1	21	8.20E+6	3.06E+5	1.01E+8	3.75E+6	3.11E+7	1.16E+6	5.82E+7	2.17E+6	3.28E+7	1.22E+6	8.14E+7	3.03E+6
1976	1	22	8.87E+6	3.37E+5	1.09E+8	4.14E+6	3.36E+7	1.28E+6	6.30E+7	2.40E+6	3.50E+7	1.33E+6	8.80E+7	3.35E+6
1976	1	23	9.54E+6	3.71E+5	1.17E+8	4.55E+6	3.62E+7	1.40E+6	6.77E+7	2.63E+6	3.72E+7	1.44E+6	9.47E+7	3.68E+6
1976	1	24	1.02E+7	4.05E+5	1.25E+8	4.97E+6	3.87E+7	1.53E+6	7.25E+7	2.87E+6	3.94E+7	1.56E+6	1.01E+8	4.02E+6
1976	1	25	1.09E+7	4.40E+5	1.34E+8	5.41E+6	4.13E+7	1.67E+6	7.74E+7	3.13E+6	4.16E+7	1.68E+6	1.08E+8	4.37E+6
1976	1	26	1.16E+7	4.77E+5	1.42E+8	5.86E+6	4.39E+7	1.81E+6	8.22E+7	3.39E+6	4.38E+7	1.81E+6	1.15E+8	4.74E+6
1976	1	27	1.23E+7	5.26E+5	1.51E+8	6.46E+6	4.65E+7	1.99E+6	8.70E+7	3.73E+6	4.61E+7	1.98E+6	1.22E+8	5.22E+6
1976	1	28	1.29E+7	5.90E+5	1.59E+8	7.24E+6	4.90E+7	2.23E+6	9.19E+7	4.18E+6	4.83E+7	2.20E+6	1.28E+8	5.85E+6
1976	1	29	1.36E+7	6.56E+5	1.67E+8	8.06E+6	5.16E+7	2.48E+6	9.67E+7	4.65E+6	5.06E+7	2.44E+6	1.35E+8	6.51E+6
1976	1	30	1.43E+7	7.26E+5	1.76E+8	8.91E+6	5.42E+7	2.75E+6	1.02E+8	5.15E+6	5.29E+7	2.68E+6	1.42E+8	7.20E+6
1976	1	31	1.50E+7	7.98E+5	1.84E+8	9.80E+6	5.68E+7	3.02E+6	1.06E+8	5.66E+6	5.51E+7	2.93E+6	1.49E+8	7.92E+6
1976	1	32	1.57E+7	8.74E+5	1.92E+8	1.07E+7	5.94E+7	3.31E+6	1.11E+8	6.20E+6	5.74E+7	3.20E+6	1.55E+8	8.67E+6
1976	1	33	1.64E+7	9.52E+5	2.01E+8	1.17E+7	6.19E+7	3.61E+6	1.16E+8	6.75E+6	5.97E+7	3.47E+6	1.62E+8	9.45E+6
1976	1	34	1.70E+7	1.03E+6	2.09E+8	1.27E+7	6.45E+7	3.91E+6	1.21E+8	7.33E+6	6.19E+7	3.76E+6	1.69E+8	1.03E+7
1976	1	35	1.77E+7	1.12E+6	2.18E+8	1.37E+7	6.71E+7	4.23E+6	1.26E+8	7.93E+6	6.42E+7	4.05E+6	1.76E+8	1.11E+7
1976	1	36	1.84E+7	1.20E+6	2.26E+8	1.48E+7	6.97E+7	4.56E+6	1.31E+8	8.55E+6	6.65E+7	4.35E+6	1.83E+8	1.20E+7
1976	1	37	1.91E+7	1.19E+6	2.34E+8	1.46E+7	7.23E+7	4.49E+6	1.35E+8	8.41E+6	6.88E+7	4.27E+6	1.89E+8	1.18E+7
1977	1	0	1.50E+4	5.11E+3	1.85E+5	6.27E+4	5.93E+4	2.01E+4	1.11E+5	3.77E+4	2.79E+5	9.48E+4	1.55E+5	5.28E+4
1977	1	1	8.32E+4	2.08E+4	1.02E+6	2.56E+5	3.27E+5	8.18E+4	6.12E+5	1.53E+5	8.13E+5	2.03E+5	8.56E+5	2.14E+5
1977	1	2	2.08E+5	5.63E+4	2.55E+6	6.91E+5	8.15E+5	2.21E+5	1.53E+6	4.13E+5	1.68E+6	4.54E+5	2.14E+6	5.78E+5
1977	1	3	3.59E+5	7.92E+4	4.41E+6	9.73E+5	1.40E+6	3.08E+5	2.62E+6	5.77E+5	2.65E+6	5.84E+5	3.66E+6	8.08E+5
1977	1	4	5.31E+5	7.03E+4	6.51E+6	8.63E+5	2.05E+6	2.72E+5	3.84E+6	5.09E+5	3.71E+6	4.91E+5	5.37E+6	7.11E+5
1977	1	5	7.22E+5	4.49E+4	8.87E+6	5.52E+5	2.78E+6	1.73E+5	5.21E+6	3.24E+5	4.82E+6	2.99E+5	7.28E+6	4.53E+5
1977	1	6	9.38E+5	6.77E+4	1.15E+7	8.31E+5	3.60E+6	2.59E+5	6.74E+6	4.86E+5	6.00E+6	4.33E+5	9.42E+6	6.80E+5
1977	1	7	1.18E+6	9.49E+4	1.45E+7	1.17E+6	4.50E+6	3.63E+5	8.43E+6	6.80E+5	7.25E+6	5.85E+5	1.18E+7	9.51E+5
1977	1	8	1.44E+6	1.13E+5	1.77E+7	1.39E+6	5.49E+6	4.31E+5	1.03E+7	8.07E+5	8.57E+6	6.73E+5	1.44E+7	1.13E+6
1977	1	9	1.73E+6	1.33E+5	2.12E+7	1.63E+6	6.58E+6	5.05E+5	1.23E+7	9.46E+5	9.97E+6	7.65E+5	1.72E+7	1.32E+6
1977	1	10	2.05E+6	2.21E+5	2.52E+7	2.71E+6	7.81E+6	8.39E+5	1.46E+7	1.57E+6	1.15E+7	1.23E+6	2.04E+7	2.20E+6
1977	1	11	2.42E+6	3.15E+5	2.97E+7	3.87E+6	9.19E+6	1.20E+6	1.72E+7	2.24E+6	1.30E+7	1.70E+6	2.41E+7	3.14E+6
1977	1	12	2.82E+6	3.53E+5	3.46E+7	4.33E+6	1.07E+7	1.34E+6	2.00E+7	2.51E+6	1.46E+7	1.83E+6	2.80E+7	3.51E+6
1977	1	13	3.26E+6	3.28E+5	4.00E+7	4.03E+6	1.24E+7	1.25E+6	2.32E+7	2.34E+6	1.63E+7	1.64E+6	3.25E+7	3.27E+6
1977	1	14	3.76E+6	3.01E+5	4.61E+7	3.70E+6	1.43E+7	1.15E+6	2.68E+7	2.15E+6	1.82E+7	1.46E+6	3.74E+7	3.00E+6
1977	1	15	4.30E+6	3.02E+5	5.28E+7	3.70E+6	1.64E+7	1.15E+6	3.06E+7	2.15E+6	2.01E+7	1.41E+6	4.28E+7	3.00E+6
1977	1	16	4.89E+6	3.32E+5	6.01E+7	4.07E+6	1.86E+7	1.26E+6	3.48E+7	2.36E+6	2.21E+7	1.50E+6	4.87E+7	3.30E+6
1977	1	17	5.51E+6	3.63E+5	6.76E+7	4.46E+6	2.09E+7	1.38E+6	3.92E+7	2.58E+6	2.41E+7	1.59E+6	5.48E+7	3.61E+6
1977	1	18	6.14E+6	3.70E+5	7.54E+7	4.54E+6	2.33E+7	1.41E+6	4.37E+7	2.63E+6	2.61E+7	1.57E+6	6.11E+7	3.68E+6
1977	1	19	6.80E+6	3.45E+5	8.35E+7	4.24E+6	2.58E+7	1.31E+6	4.84E+7	2.45E+6	2.82E+7	1.43E+6	6.76E+7	3.43E+6
1977	1	20	7.45E+6	3.09E+5	9.15E+7	3.79E+6	2.83E+7	1.17E+6	5.30E+7	2.20E+6	3.03E+7	1.26E+6	7.41E+7	3.07E+6
1977	1	21	8.11E+6	3.02E+5	9.96E+7	3.71E+6	3.08E+7	1.15E+6	5.77E+7	2.15E+6	3.24E+7	1.21E+6	8.07E+7	3.01E+6
1977	1	22	8.78E+6	3.34E+5	1.08E+8	4.10E+6	3.33E+7	1.27E+6	6.24E+7	2.38E+6	3.46E+7	1.31E+6	8.73E+7	3.32E+6
1977	1	23	9.44E+6	3.67E+5	1.16E+8	4.50E+6	3.59E+7	1.39E+6	6.72E+7	2.61E+6	3.67E+7	1.43E+6	9.39E+7	3.65E+6
1977	1	24	1.01E+7	4.01E+5	1.24E+8	4.92E+6	3.84E+7	1.52E+6	7.20E+7	2.85E+6	3.89E+7	1.54E+6	1.01E+8	3.99E+6
1977	1	25	1.08E+7	4.36E+5	1.32E+8	5.35E+6	4.10E+7	1.66E+6	7.67E+7	3.10E+6	4.11E+7	1.66E+6	1.07E+8	4.34E+6
1977	1	26	1.15E+7	4.72E+5	1.41E+8	5.80E+6	4.35E+7	1.79E+6	8.15E+7	3.36E+6	4.33E+7	1.78E		



1979	1	23	9.30E+6	3.61E+5	1.14E+8	4.44E+6	3.55E+7	1.38E+6	6.64E+7	2.58E+6	3.60E+7	1.40E+6	9.29E+7	3.61E+6
1979	1	24	9.97E+6	3.95E+5	1.22E+8	4.85E+6	3.80E+7	1.50E+6	7.12E+7	2.82E+6	3.82E+7	1.51E+6	9.95E+7	3.94E+6
1979	1	25	1.06E+7	4.30E+5	1.31E+8	5.27E+6	4.05E+7	1.64E+6	7.59E+7	3.07E+6	4.03E+7	1.63E+6	1.06E+8	4.29E+6
1979	1	26	1.13E+7	4.66E+5	1.39E+8	5.72E+6	4.31E+7	1.77E+6	8.06E+7	3.32E+6	4.25E+7	1.75E+6	1.13E+8	4.65E+6
1979	1	27	1.20E+7	5.14E+5	1.47E+8	6.31E+6	4.56E+7	1.96E+6	8.54E+7	3.66E+6	4.46E+7	1.92E+6	1.19E+8	5.12E+6
1979	1	28	1.26E+7	5.76E+5	1.55E+8	7.07E+6	4.81E+7	2.19E+6	9.02E+7	4.11E+6	4.68E+7	2.13E+6	1.26E+8	5.74E+6
1979	1	29	1.33E+7	6.41E+5	1.63E+8	7.87E+6	5.07E+7	2.44E+6	9.49E+7	4.57E+6	4.90E+7	2.36E+6	1.33E+8	6.39E+6
1979	1	30	1.40E+7	7.09E+5	1.72E+8	8.70E+6	5.32E+7	2.70E+6	9.97E+7	5.05E+6	5.12E+7	2.60E+6	1.39E+8	7.07E+6
1979	1	31	1.46E+7	7.80E+5	1.80E+8	9.57E+6	5.58E+7	2.97E+6	1.04E+8	5.56E+6	5.34E+7	2.84E+6	1.46E+8	7.78E+6
1979	1	32	1.53E+7	8.54E+5	1.88E+8	1.05E+7	5.83E+7	3.25E+6	1.09E+8	6.09E+6	5.56E+7	3.10E+6	1.53E+8	8.52E+6
1979	1	33	1.60E+7	9.31E+5	1.96E+8	1.14E+7	6.09E+7	3.54E+6	1.14E+8	6.64E+6	5.78E+7	3.36E+6	1.59E+8	9.28E+6
1979	1	34	1.67E+7	1.01E+6	2.05E+8	1.24E+7	6.34E+7	3.85E+6	1.19E+8	7.21E+6	6.00E+7	3.64E+6	1.66E+8	1.01E+7
1980	1	0	1.44E+4	4.90E+3	1.77E+5	6.02E+4	5.70E+4	1.93E+4	1.07E+5	3.62E+4	2.68E+5	9.10E+4	1.49E+5	5.07E+4
1980	1	1	8.01E+4	2.00E+4	9.83E+5	2.46E+5	3.13E+5	7.84E+4	5.87E+5	1.47E+5	7.83E+5	1.96E+5	8.20E+5	2.05E+5
1980	1	2	2.00E+5	5.40E+4	2.45E+6	6.63E+5	7.79E+5	2.11E+5	1.46E+6	3.95E+5	1.61E+6	4.36E+5	2.04E+6	5.52E+5
1980	1	3	3.44E+5	7.59E+4	4.22E+6	9.31E+5	1.34E+6	2.95E+5	2.50E+6	5.52E+5	2.54E+6	5.61E+5	3.50E+6	7.72E+5
1980	1	4	5.08E+5	6.73E+4	6.24E+6	8.26E+5	1.97E+6	2.61E+5	3.68E+6	4.88E+5	3.55E+6	4.71E+5	5.15E+6	6.83E+5
1980	1	5	6.91E+5	4.30E+4	8.49E+6	5.28E+5	2.67E+6	1.66E+5	5.00E+6	3.11E+5	4.61E+6	2.87E+5	6.99E+6	4.35E+5
1980	1	6	8.99E+5	6.49E+4	1.10E+7	7.96E+5	3.46E+6	2.50E+5	6.48E+6	4.68E+5	5.74E+6	4.15E+5	9.07E+6	6.54E+5
1980	1	7	1.13E+6	9.12E+4	1.39E+7	1.12E+6	4.34E+6	3.50E+5	8.14E+6	6.56E+5	6.96E+6	5.61E+5	1.14E+7	9.18E+5
1980	1	8	1.39E+6	1.09E+5	1.70E+7	1.34E+6	5.32E+6	4.18E+5	9.97E+6	7.83E+5	8.24E+6	6.47E+5	1.39E+7	1.10E+6
1980	1	9	1.67E+6	1.28E+5	2.05E+7	1.57E+6	6.40E+6	4.92E+5	1.20E+7	9.21E+5	9.60E+6	7.37E+5	1.68E+7	1.29E+6
1980	1	10	1.99E+6	2.14E+5	2.44E+7	2.63E+6	7.62E+6	8.20E+5	1.43E+7	1.54E+6	1.11E+7	1.19E+6	2.00E+7	2.15E+6
1980	1	11	2.35E+6	3.06E+5	2.88E+7	3.76E+6	8.99E+6	1.17E+6	1.68E+7	2.19E+6	1.26E+7	1.64E+6	2.35E+7	3.07E+6
1980	1	12	2.74E+6	3.43E+5	3.37E+7	4.22E+6	1.05E+7	1.31E+6	1.97E+7	2.46E+6	1.42E+7	1.77E+6	2.75E+7	3.44E+6
1980	1	13	3.18E+6	3.20E+5	3.90E+7	3.93E+6	1.22E+7	1.22E+6	2.28E+7	2.29E+6	1.58E+7	1.59E+6	3.19E+7	3.21E+6
1980	1	14	3.67E+6	2.95E+5	4.51E+7	3.62E+6	1.40E+7	1.13E+6	2.63E+7	2.11E+6	1.76E+7	1.41E+6	3.68E+7	2.95E+6
1980	1	15	4.21E+6	2.95E+5	5.17E+7	3.62E+6	1.61E+7	1.13E+6	3.02E+7	2.12E+6	1.95E+7	1.36E+6	4.22E+7	2.96E+6
1980	1	16	4.80E+6	3.25E+5	5.89E+7	3.99E+6	1.83E+7	1.24E+6	3.44E+7	2.33E+6	2.14E+7	1.45E+6	4.81E+7	3.26E+6
1980	1	17	5.40E+6	3.56E+5	6.63E+7	4.37E+6	2.07E+7	1.36E+6	3.87E+7	2.55E+6	2.34E+7	1.54E+6	5.41E+7	3.57E+6
1980	1	18	6.02E+6	3.63E+5	7.39E+7	4.45E+6	2.30E+7	1.39E+6	4.31E+7	2.60E+6	2.54E+7	1.53E+6	6.03E+7	3.63E+6
1980	1	19	6.66E+6	3.38E+5	8.18E+7	4.15E+6	2.55E+7	1.29E+6	4.77E+7	2.42E+6	2.74E+7	1.39E+6	6.67E+7	3.39E+6
1980	1	20	7.30E+6	3.03E+5	8.96E+7	3.72E+6	2.79E+7	1.16E+6	5.23E+7	2.17E+6	2.94E+7	1.22E+6	7.31E+7	3.03E+6
1980	1	21	7.95E+6	2.96E+5	9.76E+7	3.64E+6	3.04E+7	1.13E+6	5.69E+7	2.12E+6	3.14E+7	1.17E+6	7.96E+7	2.97E+6
1980	1	22	8.60E+6	3.27E+5	1.06E+8	4.02E+6	3.29E+7	1.25E+6	6.16E+7	2.34E+6	3.35E+7	1.28E+6	8.61E+7	3.28E+6
1980	1	23	9.26E+6	3.59E+5	1.14E+8	4.41E+6	3.54E+7	1.37E+6	6.63E+7	2.57E+6	3.56E+7	1.38E+6	9.27E+7	3.60E+6
1980	1	24	9.92E+6	3.93E+5	1.22E+8	4.82E+6	3.79E+7	1.50E+6	7.10E+7	2.81E+6	3.77E+7	1.49E+6	9.92E+7	3.93E+6
1980	1	25	1.06E+7	4.28E+5	1.30E+8	5.25E+6	4.04E+7	1.63E+6	7.57E+7	3.06E+6	3.98E+7	1.61E+6	1.06E+8	4.28E+6
1980	1	26	1.12E+7	4.63E+5	1.38E+8	5.69E+6	4.29E+7	1.77E+6	8.04E+7	3.31E+6	4.20E+7	1.73E+6	1.12E+8	4.63E+6
1980	1	27	1.19E+7	5.11E+5	1.46E+8	6.28E+6	4.55E+7	1.95E+6	8.52E+7	3.65E+6	4.41E+7	1.89E+6	1.19E+8	5.11E+6
1980	1	28	1.26E+7	5.73E+5	1.54E+8	7.03E+6	4.80E+7	2.19E+6	8.99E+7	4.10E+6	4.63E+7	2.11E+6	1.26E+8	5.73E+6
1980	1	29	1.32E+7	6.38E+5	1.63E+8	7.83E+6	5.05E+7	2.43E+6	9.47E+7	4.56E+6	4.84E+7	2.33E+6	1.32E+8	6.37E+6
1980	1	30	1.39E+7	7.06E+5	1.71E+8	8.66E+6	5.31E+7	2.69E+6	9.94E+7	5.04E+6	5.06E+7	2.57E+6	1.39E+8	7.05E+6
1980	1	31	1.46E+7	7.76E+5	1.79E+8	9.53E+6	5.56E+7	2.96E+6	1.04E+8	5.55E+6	5.28E+7	2.81E+6	1.46E+8	7.76E+6
1980	1	32	1.53E+7	8.50E+5	1.87E+8	1.04E+7	5.82E+7	3.24E+6	1.09E+8	6.08E+6	5.50E+7	3.06E+6	1.52E+8	8.50E+6
1980	1	33	1.59E+7	9.27E+5	1.95E+8	1.14E+7	6.07E+7	3.54E+6	1.14E+8	6.62E+6	5.71E+7	3.33E+6	1.59E+8	9.26E+6
1981	1	0	1.41E+4	4.79E+3	1.73E+5	5.88E+4	5.57E+4	1.89E+4	1.04E+5	3.54E+4	2.62E+5	8.90E+4	1.46E+5	4.95E+4
1981	1	1	7.90E+4	1.98E+4	9.70E+5	2.43E+5	3.11E+5	7.78E+4	5.82E+5	1.46E+5	7.70E+5	1.93E+5	8.15E+5	2.04E+5
1981	1	2	1.97E+5	5.33E+4	2.42E+6	6.55E+5	7.71E+5	2.09E+5	1.44E+6	3.91E+5	1.59E+6	4.30E+5	2.02E+6	5.47E+5
1981	1	3	3.40E+5	7.49E+4	4.17E+6	9.20E+5	1.32E+6	2.92E+5	2.48E+6	5.47E+5	2.51E+6	5.53E+5	3.47E+6	7.65E+5
1981	1	4	5.02E+5	6.65E+4	6.16E+6	8.16E+5	1.95E+6	2.58E+5	3.64E+6	4.83E+5	3.50E+6	4.64E+5	5.10E+6	6.75E+5
1981	1	5	6.83E+5	4.25E+4	8.38E+6	5.21E+5	2.64E+6	1.64E+5	4.95E+6	3.08E+5	4.55E+6	2.83E+5	6.92E+6	4.30E+5
1981	1	6	8.88E+5	6.41E+4	1.09E+7	7.87E+5	3.43E+6	2.47E+5	6.42E+6	4.63E+5	5.66E+6	4.09E+5	8.98E+6	6.48E+5
1981	1	7	1.12E+6	9.02E+4	1.37E+7	1.11E+6	4.31E+6	3.47E+5	8.07E+6	6.51E+5	6.86E+6	5.54E+5	1.13E+7	9.10E+5
1981	1	8	1.37E+6	1.08E+5	1.69E+7	1.32E+6	5.28E+6	4.15E+5	9.90E+6	7.77E+5	8.14E+6	6.39E+5	1.38E+7	1.09E+6
1981	1	9	1.66E+6	1.27E+5	2.03E+7	1.56E+6	6.37E+6	4.89E+5	1.19E+7	9.16E+5	9.49E+6	7.29E+5	1.67E+7	1.28E+6
1981	1	10	1.97E+6	2.12E+5	2.42E+7	2.61E+6	7.58E+6	8.15E+5	1.42E+7	1.53E+6	1.09E+7	1.18E+6	1.99E+7	2.14E+6
1981	1	11	2.33E+6	3.04E+5	2.86E+7	3.73E+6	8.94E+6	1.16E+6	1.67E+7	2.18E+6	1.24E+7	1.62E+6	2.34E+7	3.05E+6
1981	1	12	2.72E+6	3.41E+5	3.34E+7	4.19E+6	1.04E+7	1.31E+6	1.96E+7	2.45E+6	1.40E+7	1.75E+6	2.74E+7	3.43E+6
1981	1	13	3.16E+6	3.18E+5	3.88E+7	3.90E+6	1.21E+7	1.22E+6	2.27E+7	2.28E+6	1.57E+7	1.58E+6	3.17E+7	3.19E+6
1981	1	14	3.65E+6	2.93E+5	4.48E+7	3.60E+6	1.40E+7	1.12E+6	2.62E+7	2.10E+6	1.74E+7	1.40E+6	3.67E+7	2.94E+6
1981	1	15	4.20E+6	2.94E+5	5.15E+7	3.61E+6	1.61E+7	1.13E+6	3.01E+7	2.11E+6	1.93E+7	1.35E+6	4.21E+7	2.95E+6
1981	1	16	4.78E+6	3.24E+5	5.86E+7	3.98E+6	1.83E+7	1.24E+6	3.43E+7	2.33E+6	2.12E+7	1.44E+6	4.80E+7	3.25E+6
1981	1	17	5.38E+6	3.54E+5	6.60E+7	4.35E+6	2.06E+7	1.36E+6	3.86E+7	2.54E+6	2.32E+7	1.53E+6	5.40E+7	3.56E+6
1981	1	18	6.00E+6	3.61E+5	7.36E+7	4.44E+6	2.30E+7	1.38E+6	4.31E+7	2.59E+6	2.51E+7	1.51		











































**Extended Data Table 6: Most common gene mutations by tissue and histology with relative pathogenic sensitivity**

Most common gene mutations by tissue and histology listed by frequency from review of full genome and targeted screens with relative pathogenic sensitivity (RPS) calculation results. (a) adipocytes, bone marrow cells, and hepatocytes; (b) lymphocytes; (c) neurons & glia, and vascular endothelial cells.

Tissue	Histology	Gene	Mutation Found	Quantity of Tests	Percent w/ Mutations	RSP
Adipocytes	Liposarcoma	TERT	54	169	32.0%	7.53E-06
		PIK3CA	22	200	11.0%	1.20E-06
		TP53	20	212	9.4%	4.93E-06
		HRAS	4	101	4.0%	1.19E-05
		FGFR3	1	28	3.6%	2.29E-06
		CDKN2A	2	78	2.6%	9.40E-07
		KRAS	2	91	2.2%	4.65E-07
		CTNNB1	4	186	2.2%	5.25E-07
		KIT	3	157	1.9%	2.31E-07
		NF1	2	107	1.9%	6.61E-08
		BRAF	1	54	1.9%	9.01E-08
Bone Marrow Cells	Chondroblastoma	H3F3B	74	87	85.1%	2.43E-04
		H3F3A	5	86	5.8%	6.25E-06
		IDH1	315	693	45.5%	2.40E-05
		COL2A1	31	126	24.6%	7.40E-06
		TP53	26	177	14.7%	7.67E-06
	Chondrosarcoma	TTN	8	76	10.5%	3.74E-07
		MUC16	6	76	7.9%	4.89E-07
		MUC17	6	76	7.9%	2.04E-06
		RYR2	6	76	7.9%	9.97E-08
		IDH2	27	425	6.4%	3.42E-06
Giant Cell Tumor	Giant Cell Tumor	CDKN2A	14	278	5.0%	1.85E-06
		PTCH1	5	116	4.3%	5.83E-07
		H3F3A	107	133	80.5%	8.65E-05
		HRAS	1	2	50.0%	1.50E-04
		BRAF	1	17	5.9%	2.86E-07
	Osteosarcoma	IDH1	1	60	1.7%	8.81E-07
		IDH2	1	60	1.7%	8.97E-07
		H3F3B	2	132	1.5%	4.33E-06
		TP53	75	291	25.8%	1.35E-05
		MUC16	18	107	16.8%	1.04E-06
Hepatocytes	Hepatocellular Carcinoma	MUC4	12	107	11.2%	1.72E-06
		ATRX	13	139	9.4%	3.32E-07
		CDKN2A	28	365	7.7%	2.81E-06
		RB1	16	210	7.6%	4.28E-07
		APOB	8	107	7.5%	1.75E-06
		TTN	8	107	7.5%	2.66E-07
		TTN	305	1,021	29.9%	1.06E-06
		TP53	1,234	4,236	29.1%	1.52E-05
		TERT	593	2,265	26.2%	6.17E-06
		CTNNB1	1,177	5,429	21.7%	5.29E-06
		MUC16	201	984	20.4%	1.26E-06
		OBSCN	130	982	13.2%	7.63E-07
		AXIN1	200	1,628	12.3%	1.81E-06
		ARID1A	142	1,183	12.0%	1.39E-06

Tissue	Histology	Gene	Mutation Found	Quantity of Tests	Percent w/ Mutations	RSP
Lymphocytes	Hodgkin's Lymphoma	SOCS1	11	24	45.8%	2.60E-04
		TNFAIP3	24	74	32.4%	1.91E-05
		NFKBIE	2	12	16.7%	2.19E-05
		NRAS	6	40	15.0%	1.21E-05
		TP53	3	26	11.5%	6.03E-06
		MYC	26	56	46.4%	8.65E-05
		ID3	17	53	32.1%	1.72E-04
		TP53	70	338	20.7%	1.08E-05
		FBXO11	8	53	15.1%	1.53E-06
		GNA13	6	53	11.3%	2.38E-06
		SMARCA4	6	53	11.3%	1.12E-06
		ARID1A	8	82	9.8%	1.13E-06
		DDX3X	5	53	9.4%	3.03E-06
		PTEN	9	108	8.3%	7.68E-07
		RHOA	10	131	7.6%	1.44E-06
Mature B-Cell Lymphoma	Mature B-Cell Lymphoma	BCL2	89	286	31.1%	1.58E-06
		KMT2D	103	335	30.7%	7.34E-06
		TP53	180	866	20.8%	1.09E-05
		CREBBP	83	436	19.0%	1.22E-06
		PIM1	44	269	16.4%	3.10E-05
		MYD88	262	1,712	15.3%	3.37E-05
		SOCS1	55	371	14.8%	8.39E-05
		B2M	40	283	14.1%	2.12E-05
		EZH2	136	1,034	13.2%	1.70E-06
		GNA13	34	268	12.7%	2.67E-06
		SGK1	33	273	12.1%	8.12E-07
		TNFAIP3	84	876	9.6%	5.64E-06
Precursor Cell Lymphoblastic Lymphoma	Precursor Cell Lymphoblastic Lymphoma	TET2	1	1	100.0%	7.47E-06
		NOTCH1	111	193	57.5%	1.12E-05
		NRAS	1	4	25.0%	2.01E-05
		FBXW7	28	181	15.5%	7.20E-07
		CTNNB1	1	9	11.1%	2.71E-06
		WT1	1	14	7.1%	1.50E-06
T & NK-Cell Lymphoma	T & NK-Cell Lymphoma	DDX3X	3	6	50.0%	1.60E-05
		TP53	114	280	40.7%	2.13E-05
		JAK3	25	71	35.2%	1.51E-05
		BCOR	7	31	22.6%	1.79E-06
		CTNNB1	35	155	22.6%	5.51E-06
		KIT	29	158	18.4%	2.22E-06
		KMT2C	5	31	16.1%	5.35E-07
		AMER1	4	31	12.9%	6.26E-06
		RHOA	3	26	11.5%	2.18E-06
		STAT3	10	89	11.2%	1.49E-06

Tissue	Histology	Gene	Mutation Found	Quantity of Tests	Percent w/ Mutations	RSP
Neurons & Glia	Glioma	TP53	3,419	7,632	44.8%	2.34E-05
		TERT	3,252	7,425	43.8%	1.03E-05
		TTN	591	1,621	36.5%	1.30E-06
		IDH1	6,930	19,128	36.2%	1.92E-05
		ATRX	539	2,287	23.6%	8.38E-07
		MUC16	246	1,349	18.2%	1.13E-06
		H3F3A	532	3,146	16.9%	1.82E-05
		CDKN2A	812	5,136	15.8%	5.79E-06
		PTEN	783	5,022	15.6%	1.44E-06
		CIC	247	2,034	12.1%	4.45E-06
		EGFR	406	3,348	12.1%	6.44E-07
		PIK3CA	316	2,961	10.7%	1.16E-06
	Meningioma	NF2	508	1,518	33.5%	3.52E-06
		TRAF7	107	378	28.3%	1.26E-05
		KLF4	60	373	16.1%	3.30E-05
		AKT1	111	1,429	7.8%	2.94E-06
		TTN	5	65	7.7%	2.73E-07
		CDKN2A	18	255	7.1%	2.59E-06
		TERT	22	475	4.6%	1.09E-06
Nerve Sheath Tumors	Tumors	SMO	15	431	3.5%	1.41E-06
		SMARCB1	7	279	2.5%	5.27E-07
		TP53	5	226	2.2%	1.16E-06
		NF2	285	664	42.9%	4.52E-06
		NF1	244	650	37.5%	1.33E-06
		CDKN2A	27	201	13.4%	4.92E-06
		TP53	33	316	10.4%	5.45E-06
		TERT	5	108	4.6%	1.09E-06
	Neuroblastoma	SMARCB1	2	47	4.3%	8.94E-07
		PDGFRA	2	99	2.0%	2.92E-07
Vascular Endothelial Cells	Angiosarcoma	BRAF	2	214	0.9%	4.55E-08
		ALK	364	4,473	8.1%	1.12E-07
		MUC16	27	387	7.0%	4.32E-07
		TTN	23	387	5.9%	2.11E-07
		FLG	11	387	2.8%	1.23E-06
		LRP1B	10	387	2.6%	1.36E-08
		RYR1	10	387	2.6%	1.68E-07
		AHNAK	9	387	2.3%	2.05E-07
		AHNAK2	9	387	2.3%	5.66E-07
		HMCN1	9	387	2.3%	5.10E-08
		MUC17	9	387	2.3%	6.00E-07
		MUC4	9	387	2.3%	3.57E-07
		ARID1A	9	472	1.9%	2.22E-07
		TP53	28	111	25.2%	1.32E-05
		PTPRB	10	43	23.3%	1.93E-06

## Extended Data Table 7: Point mutation pathogenesis observations from review of full genome and targeted sequence data by tissue and histology

Tissue	Histology	Point Mutation Pathogenesis Observations
Adipocytes	Liposarcoma	From review of full genome sequence data, at least two genes were damaged in each sample suggesting a partial point mutation pathogenesis as follows: ((TERT or PIK3CA or TP53 or HRAS or CTNNB1 or other) and (other)) where "other" is one or more other genes.
	Chondroblastoma	From review of full genome sequence data, two or more genes were mutated in each sample, suggesting an incomplete point mutation pathogenesis as follows: ((H3F3B or H3F3A or (other)) and (other)) where "other" is one or more other genes.
Bone Marrow Cells	Chondrosarcoma	From review of full genome sequence data, two samples were found with only IDH1 mutations, suggesting an incomplete point mutation pathogenesis as follows: (IDH1 or (other)) where "other" is one or more other genes.
	Giant Cell Tumor	Without full genome sequence data, insufficient data exists to suggest a partial point mutation pathogenesis.
	Osteosarcoma	From review of full genome sequence data, at least two genes were mutated in each sample suggesting an incomplete point mutation pathogenesis as follows: ((TP53 or MUC16 or MUC4 or ATRX or CDKN2A or RB1 or other) and (other)) where "other" is one or more other genes.
Hepatocytes	Hepatocellular Carcinoma	From review of full genome sequence data, at least two genes were mutated in each sample suggesting a partial point mutation pathogenesis as follows: ((CTNNB1 and (TP53 or TERT or AXIN1 or (PCLO and ARID1A))) or (other)) where "other" is one or more other genes.
	Hodgkin's Lymphoma	The lack of genome sequencing precludes certainty, but the gene mutations available suggests an incomplete point mutation pathogenesis as follows: (SOCS1 or TNFAIP3 or ((other))) where "other" is one or more other genes.
Lymphocytes	Malignant Lymphoma	From review of full genome sequence data, Burkitt lymphoma were diagnosed with as few as one mutated gene including CCT6B, ID3, NOD1, MYC, and ZNRF4, suggesting an incomplete point mutation pathogenesis as follows: (CCT6B or ID3 or NOD1 or MYC or ZNRF4 or ((other))) where "other" is one or more other genes.
	Mature B-Cell Lymphoma	From review of full genome sequence data, diffuse large B-Cell lymphoma were diagnosed with as few as one mutated gene including ABCA7, CARD11, CD79B, EZH2, FAS, HIST1H2AG, IRF4, and MYD88 suggesting an incomplete point mutation pathogenesis as follows: (ABCA7 or CARD11 or CD79B or EZH2 or FAS or HIST1H2AG or IRF4 or MYD88 or ((other))) where "other" is one or more other genes.
	Precursor Cell Lymphoblastic Lymphoma	Without full genome sequence data, insufficient data exists to suggest a partial point mutation pathogenesis.
Neurons & Glia	T & NK-Cell Lymphoma	From review of six samples of full genome sequence data, multiple genes were damaged in each sample without suggesting a specific point mutation pathogenesis.
	Glioma	From review of full genome sequence data, at least two genes were mutated in each sample suggesting an incomplete point mutation pathogenesis as follows: (IDH1 and ((TERT or (TP53 and (PTEN or ATRX)) or (other)) or ((other)))) where "other" is one or more other genes.
Vascular Endothelial Cells	Meningioma	From review of full genome sequence data, one sample was found with a single mutation in TRAF7, while all other samples had multiple gene mutations suggesting an incomplete point mutation pathogenesis as follows: (TRAF7 or ((other))) where "other" is one or more other genes.
	Nerve Sheath Tumors	From review of full genome sequence data, neurofibromas were diagnosed with only one or more mutations to NF1, suggesting an incomplete point mutation pathogenesis as follows: (NF1 or ((other) and (other))). Including targeted screens, 221 of 226 neurofibroma samples had NF1 mutations. Similarly, 285 of 290 schwannoma samples from the targeted screens contained NF2 mutations suggesting an incomplete point mutation pathogenesis as follows: (NF2 or ((other))) where "other" is one or more other genes.
	Neuroblastoma	From review of full genome sequence data, one sample was found with a single mutation in NRAS, while all other samples had multiple gene mutations suggesting an incomplete point mutation pathogenesis as follows: (NRAS or (ALK and (other)) or ((other))) where "other" is one or more other genes.
Vascular Endothelial Cells	Angiosarcoma	From review of full genome sequence data, at least two genes were mutated in each sample suggesting a point mutation pathogenesis as follows: ((TP53 or KRAS or PTPRB or PLCG1 or KDR or other) and (other)) where "other" is one or more other genes.