Step 1: Load the appropriate R package.

You will need two libraries: nlme and lme4.

Step 2: Fit a separate mixed model for each independence claim in the basis set.

For instance, in Table 2 the first basis set is $(X_1,X_3)|\{X_2\}$, meaning that we must obtain the null probability that the Julian date of bud burst (X_3, called "Date" in the data set) is independent of latitude (X_1, called "lat"), after controlling for the number of degree days (X_2, called "DD" in the data set). Since X_3 is normally distributed we could use either the lmer() function of the lme4 package or the lme() function of the nlme package. Since the nlme() function prints out degrees of freedom but the lmer() function does not, we and will use the nlme() function. The data are in the data frame "out" and we allow only the intercepts to vary (this could be extended to slopes if desired); I have indicated the variable whose partial slope must be tested by bold type.

Independence claim: (Date,lat)|{DD}

fit1<-lme(Date~DD+**lat**,data=Shipley,random=~1|site/tree,na.action=na.omit)

To obtain the probability of independence between Date and lat, conditional on DD, we must test the null hypothesis that the partial slope of lat is zero. To do this, we use the summary() function: summary(fit1). Here is the output:

```
> summary(fit1)
Linear mixed-effects model fit by REML
 Data: Shipley
```

```
       AIC      BIC    logLik
  4706.589 4738.173 -2347.295

Random effects:
 Formula: ~1 | site
        (Intercept)
StdDev:    3.803355

 Formula: ~1 | tree %in% site
        (Intercept) Residual
StdDev:    4.816661 1.014405

Fixed effects: Date ~ lat + DD
                Value Std.Error   DF    t-value p-value
(Intercept) 198.91522  7.337100 1330   27.11088  0.0000
lat          -0.00905  0.113477   18   -0.07976  0.9373
DD           -0.49766  0.004937 1330 -100.80609  0.0000
 Correlation:
    (Intr) lat
lat -0.986
DD  -0.132  0.036

Standardized Within-Group Residuals:
        Min          Q1         Med          Q3         Max
```

```
-4.03862871 -0.60616453 -0.01426884  0.62856908  2.80922832

Number of Observations: 1431
Number of Groups:
          site tree %in% site
            20            100
```

We see that the partial slope associated with “lat” is -0.00905 with a t-value of -0.080 having 18 degrees of freedom (since there were 20 sites and latitude only varies between sites, not between trees or years). The null probability of observing a t-value at least as extreme as this (2-sided test) is 0.9373. Note that the degrees of freedom must be calculated by hand if using the lmer() function since these are not given directly.

We would do the same thing two of the other independence claims in Table 2 whose dependent variables are normally distributed:

Independence claim: (Growth,lat)|{Date}

fit2<-lme(Growth~Date+**lat**,data=Shipley,random=~1|site/tree,na.action=na.omit)

Independence claim: (Growth,DD)|{Date,lat}

fit3<-lme(Growth~Date+lat+**DD**,data=Shipley,random=~1|site/tree,na.action=na.omit)

The final three independence claims have “Live” as the dependent variable and this is a binary variable (1=alive, 0=dead). We must therefore use a binomial error

distribution with a logit link and this requires the lmer() function. The first such independence claim is (Live,lat)|{Growth} and so we fit:

fit4<-lmer(Live~Growth+**lat**+(1|site)+(1|tree),data=Shipley, na.action=na.omit, family=binomial(link="logit")). Using the summary() function we get:

```
> summary(fit4)
Generalized linear mixed model fit using Laplace
Formula: Live ~ Growth + lat + (1 | site) + (1 | tree)
   Data: out
 Family: binomial(logit link)
 AIC   BIC logLik deviance
 262 288.3 -126.0    252.0
Random effects:
 Groups Name        Variance Std.Dev.
 tree   (Intercept) 0.807468 0.89859
 site   (Intercept) 0.052827 0.22984
number of obs: 1431, groups: tree, 100; site, 20

Estimated scale (compare to  1 )  0.7281885

Fixed effects:
             Estimate Std. Error z value Pr(>|z|)
(Intercept) -14.42861    2.65184  -5.441 5.30e-08 ***
Growth        0.35521    0.04552   7.803 6.05e-15 ***
lat           0.03042    0.02817   1.080     0.28
```

```
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '
' 1

Correlation of Fixed Effects:
       (Intr) Growth
Growth -0.744
lat    -0.684  0.029
Correlation of Fixed Effects:
       (Intr) Growth
Growth -0.538
lat    -0.815 -0.037
```

We see that the partial slope associated with “lat” is 0.03042 with a z-value of 1.08. The null probability of observing a z-value at least as extreme as this (2-sided test) is 0.28. We do this for the other 2 independence claims in the basis set of Table 2 in which “Live” is the dependent variable:

(Live,DD)|{Growth,lat}

fit5<-lmer(Live~Growth+lat+**DD**+(1|site)+(1|tree),data=Shipley,na.action=na.omit, family=binomial(link=”logit”))

(Live,Date)|{DD,Growth}

fit6<-lmer(Live~Growth +DD+**Date**+(1|site)+(1|tree),data=Shipley,na.action=na.omit, family=binomial(link=”logit”))