Worksheet on Multiple Regression and Residual Diagnostics

Pace of Life (Adapted from Sleuth3 Exercise 9.14)

We have observations on indicators of pace of life from 36 different metropolitan regions of different sizes throughout the United States:

- `Bank`: bank clerk speed
- `Walk`: pedestrian walking speed
- `Talk`: postal clerk talking speed
- `Heart`: age adjusted death rate due to heart disease

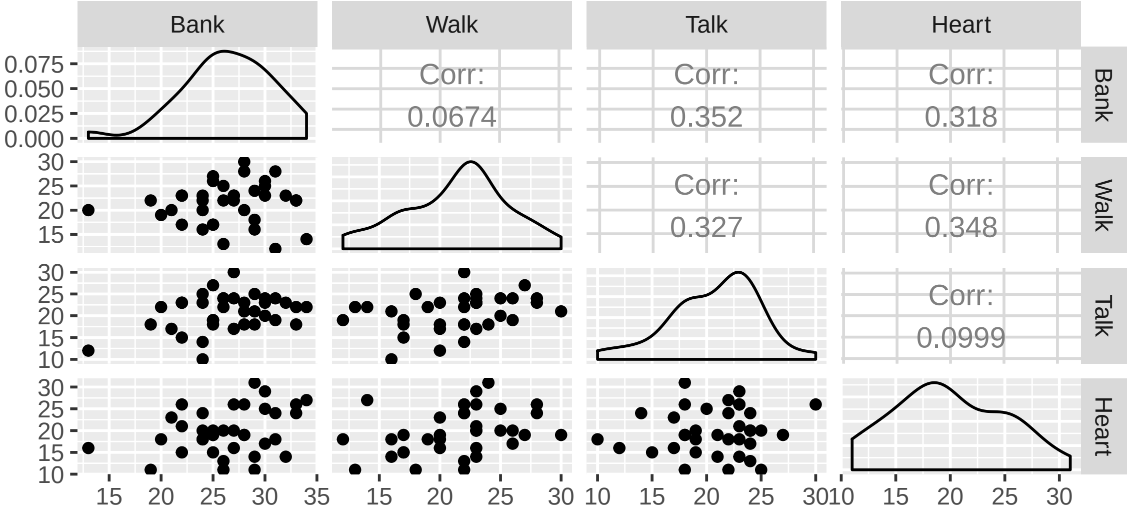
```
pace <- read_csv("http://www.evanlray.com/data/sleuth3/ex0914_pace_of_life.csv")
head(pace)
```

```
## # A tibble: 6 x 4
##    Bank  Walk  Talk Heart
##   <dbl> <dbl> <dbl> <dbl>
## 1    31    28    24    24
## 2    30    23    23    29
## 3    29    24    18    31
## 4    28    28    23    26
## 5    27    22    30    26
## 6    26    25    24    20
```

Let's model the relationship between the death rate due to heart disease (our response variable) and the other indicators of pace of life.

1. Here is a pairs plot of the data.

```
ggpairs(pace)
```



2. Based on the pairs plot, perform an initial check of the conditions of linearity, equal variance, and no outliers/high leverage observations. Do you see any potential causes for concern?

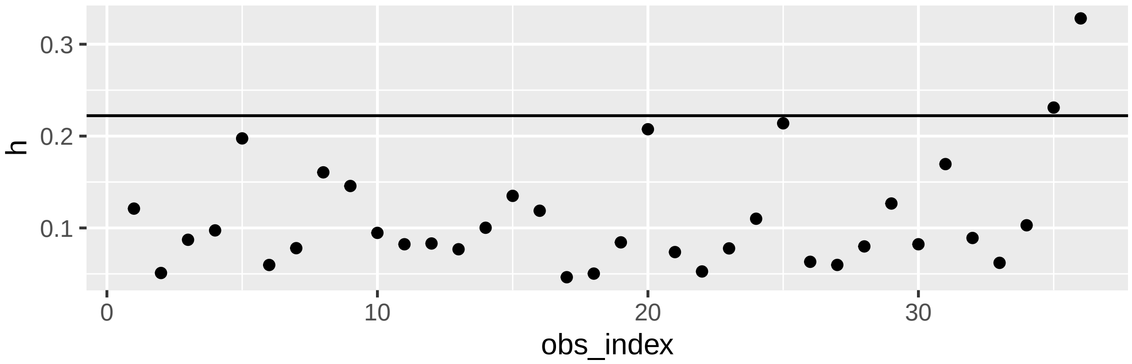
3. Here is a summary of a model that has Heart as the response and the other three variables in the data set as explanatory variables. Is there any indication of associations between the variables in the model and the rate of deaths due to heart disease?

```r
lm_fit <- lm(Heart ~ Bank + Walk + Talk, data = pace)
summary(lm_fit)
```

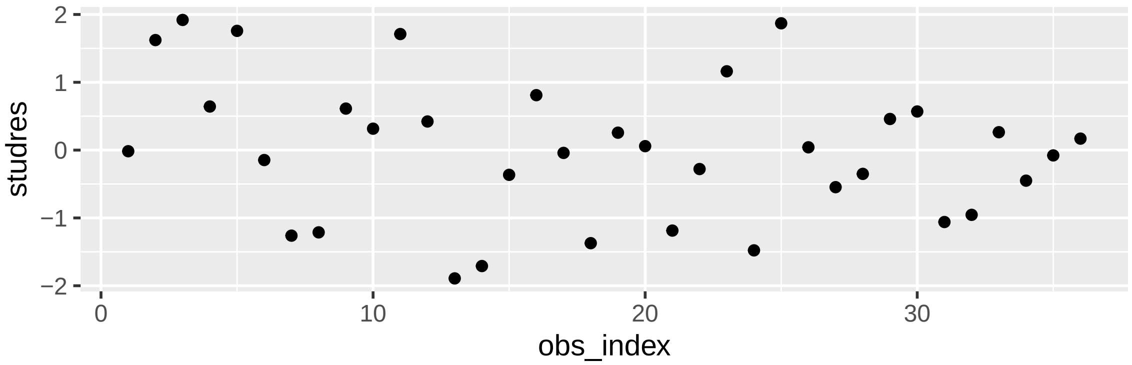
```
##
## Call:
## lm(formula = Heart ~ Bank + Walk + Talk, data = pace)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -8.4014 -3.0263  0.0602  2.6748  8.4646
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   3.1787     6.3369   0.502   0.6194
## Bank          0.4052     0.1971   2.056   0.0480 *
## Walk          0.4516     0.2009   2.248   0.0316 *
## Talk         -0.1796     0.2222  -0.808   0.4249
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.805 on 32 degrees of freedom
## Multiple R-squared:  0.2236, Adjusted R-squared:  0.1509
## F-statistic: 3.073 on 3 and 32 DF,  p-value: 0.04162
```

4. Here are plots showing the leverage, studentized residual, and Cook's distance for each observation. Do these diagnostics suggest that any observations are worth investigating further?

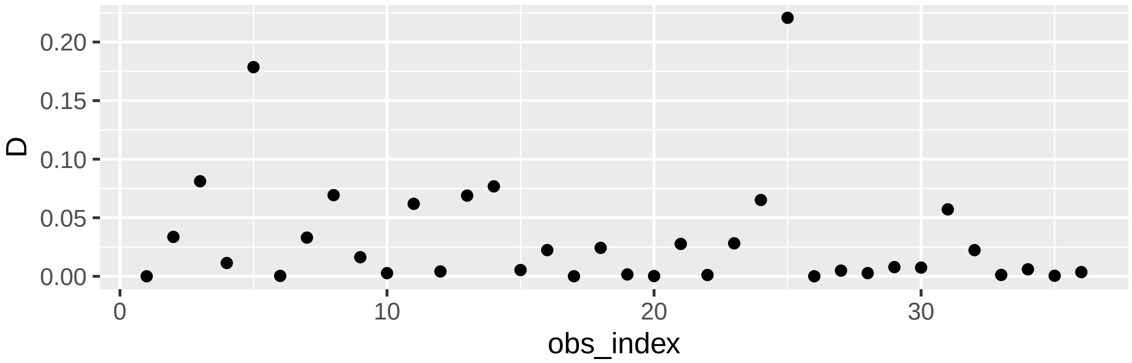
```
pace <- pace %>%
  mutate(
    obs_index = row_number(),
    h = hatvalues(lm_fit),
    studres = rstudent(lm_fit),
    D = cooks.distance(lm_fit)
  )

ggplot(data = pace, mapping = aes(x = obs_index, y = h)) +
  geom_hline(yintercept = 2*4/ nrow(pace))+
  geom_point()
```



```
ggplot(data = pace, mapping = aes(x = obs_index, y = studres)) +
  geom_point()
```

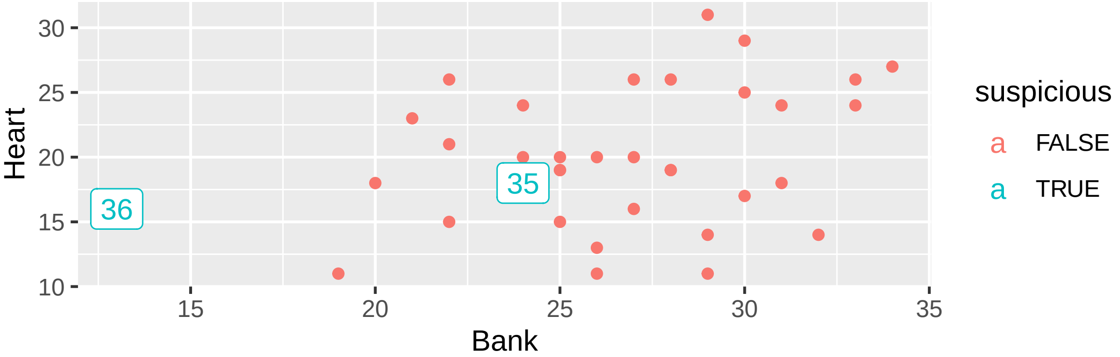


```
ggplot(data = pace, mapping = aes(x = obs_index, y = D)) +
  geom_point()
```

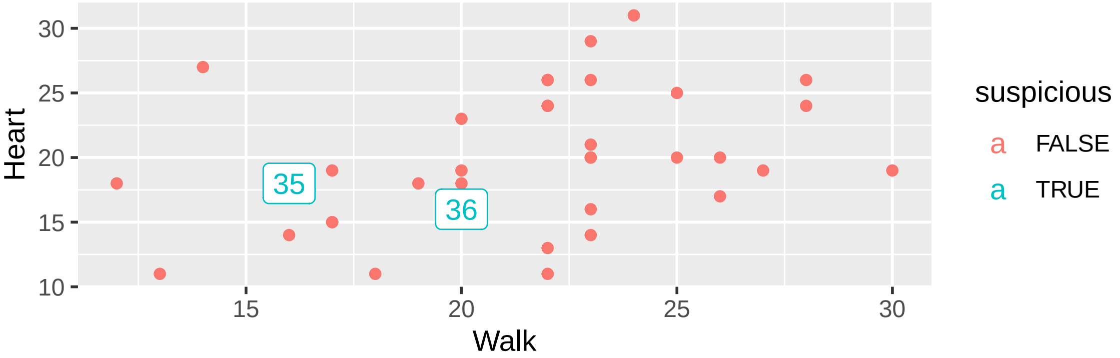


Here are scatter plots of each quantitative explanatory variable vs. the response, highlighting observation numbers 35 and 36 (these are the two I identified as being worth further attention from the diagnostic plots above).

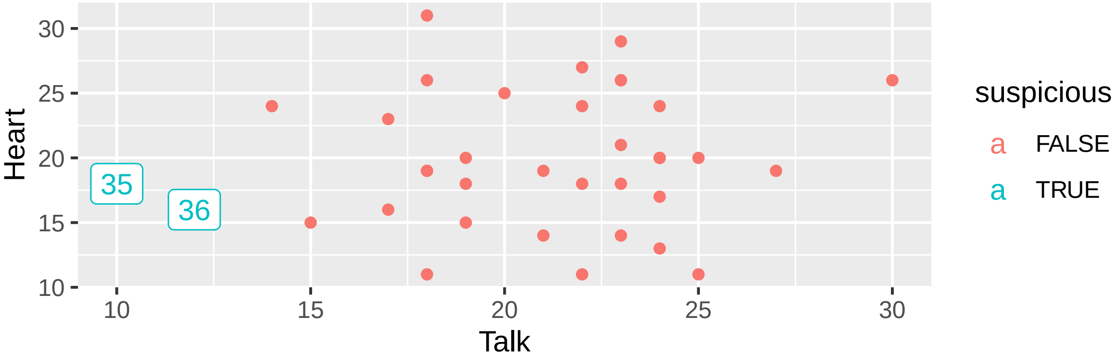
```
obs_to_investigate <- c(35, 36)

pace <- pace %>%
  mutate(
    suspicious = row_number() %in% obs_to_investigate
  )

ggplot(data = pace, mapping = aes(x = Bank, y = Heart, color = suspicious)) +
  geom_point() +
  geom_label(data = pace %>% filter(suspicious), mapping = aes(label = obs_index))
```



```
ggplot(data = pace, mapping = aes(x = Walk, y = Heart, color = suspicious)) +
  geom_point() +
  geom_label(data = pace %>% filter(suspicious), mapping = aes(label = obs_index))
```



```
ggplot(data = pace, mapping = aes(x = Talk, y = Heart, color = suspicious)) +
  geom_point() +
  geom_label(data = pace %>% filter(suspicious), mapping = aes(label = obs_index))
```



Here is a model fit to a version of the data set that does not include the two suspect observations.

```
pace2 <- pace %>%
  filter(
    !suspicious
  )

lm_fit2 <- lm(Heart ~ Bank + Walk + Talk, data = pace2)
summary(lm_fit2)
```

```
##
## Call:
## lm(formula = Heart ~ Bank + Walk + Talk, data = pace2)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -8.4811 -3.9503  0.0251  2.7203  8.4580
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   2.6861     8.1503   0.330   0.7440
## Bank          0.4219     0.2276   1.854   0.0736 .
## Walk          0.4492     0.2082   2.158   0.0391 *
## Talk         -0.1755     0.2628  -0.668   0.5095
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.96 on 30 degrees of freedom
## Multiple R-squared:  0.2089, Adjusted R-squared:  0.1298
## F-statistic:  2.64 on 3 and 30 DF,  p-value: 0.06749
```

5. What is the interpretation of the coefficient estimate for "Walk" in the model fit without the suspicious observations?

6. How would you sum up what you have learned about the associations between each of the explanatory variables and the response based on this analysis?