Lab 4

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Note: the content of this lab is on the midterm exam (March 5) even though the lab itself is due after the midterm exam.

We now move on to simple linear modeling using the ordinary least squares algorithm.

Let's quickly recreate the sample data set from practice lecture 7:

```
n = 20
x = runif(n)
x
```

```
##  [1] 0.79245830 0.06465941 0.71448487 0.59568844 0.80835272 0.09519201
##  [7] 0.05990573 0.63753841 0.00130387 0.07704847 0.03413300 0.40533060
## [13] 0.67376968 0.87441151 0.95864870 0.35291767 0.44793815 0.40155201
## [19] 0.53442966 0.38499890
```

```
beta_0 = 3
beta_1 = -2

y = beta_0 + beta_1 * x + rnorm(n, mean = 0, sd = 0.33)
y
```

```
##  [1] 1.389507 2.973711 1.725816 2.130435 1.446068 2.764718 2.228478
##  [8] 1.403727 3.484353 2.285520 2.656457 2.368463 1.838116 1.134002
## [15] 1.331938 2.778812 2.123116 2.206528 1.658898 2.078675
```

Solve for the least squares line by computing b_0 and b_1 *without* using the functions `mean`, `cor`, `cov`, `var`, `sd` but instead computing it from the x and y quantities manually using base function such as `sum` and other basic operators. See the class notes.

```
b_1 = (sum(x*y) - n * (sum(x) / n) * (sum(y) / n))  / (sum(x^2) - n*((sum(x) / n)^2))
b_1
```

```
## [1] -1.76669
```

```
b_0 = (sum(y) / n) - (b_1*(sum(x)/n))
b_0
```

```
## [1] 2.887848
```

Verify your computations are correct using the `lm` function in R:

```
lm_mod = lm(y~x)
lm_mod
```

```
##
## Call:
## lm(formula = y ~ x)
##
## Coefficients:
## (Intercept)            x
##       2.888       -1.767
```

```
b_vec = coef(lm_mod)
b_vec
```

```
## (Intercept)           x
##    2.887848   -1.766690
```

```
pacman::p_load(testthat)
expect_equal(b_0, as.numeric(b_vec[1]), tol = 1e-4)
expect_equal(b_1, as.numeric(b_vec[2]), tol = 1e-4)
```

6. We are now going to repeat one of the first linear model building exercises in history — that of Sir Francis Galton in 1886. First load up package `HistData`.

```
pacman::p_load(HistData)
```

In it, there is a dataset called `Galton`. Load it up.

```
Galton
```

```
##     parent child
## 1     70.5  61.7
## 2     68.5  61.7
## 3     65.5  61.7
## 4     64.5  61.7
## 5     64.0  61.7
## 6     67.5  62.2
## 7     67.5  62.2
## 8     67.5  62.2
## 9     66.5  62.2
## 10    66.5  62.2
## 11    66.5  62.2
## 12    64.5  62.2
## 13    70.5  63.2
## 14    69.5  63.2
## 15    68.5  63.2
## 16    68.5  63.2
## 17    68.5  63.2
## 18    68.5  63.2
## 19    68.5  63.2
## 20    68.5  63.2
## 21    68.5  63.2
## 22    67.5  63.2
## 23    67.5  63.2
## 24    67.5  63.2
## 25    67.5  63.2
## 26    67.5  63.2
## 27    66.5  63.2
## 28    66.5  63.2
## 29    66.5  63.2
## 30    65.5  63.2
## 31    65.5  63.2
## 32    65.5  63.2
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## 34    65.5  63.2
## 35    65.5  63.2
## 36    65.5  63.2
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## 37    65.5  63.2
## 38    65.5  63.2
## 39    64.5  63.2
## 40    64.5  63.2
## 41    64.5  63.2
## 42    64.5  63.2
## 43    64.0  63.2
## 44    64.0  63.2
## 45    69.5  64.2
## 46    69.5  64.2
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## 69    68.5  64.2
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## 100   64.0  64.2
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## 104   71.5  65.2
## 105   70.5  65.2
## 106   69.5  65.2
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## 108   69.5  65.2
## 109   69.5  65.2
## 110   68.5  65.2
## 111   68.5  65.2
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## 145   65.5  65.2
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## 151   64.0  65.2
## 152   71.5  66.2
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## 156   69.5  66.2
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## 595   68.5  69.2
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## 597   68.5  69.2
## 598   68.5  69.2
## 599   68.5  69.2
## 600   68.5  69.2
## 601   68.5  69.2
## 602   68.5  69.2
## 603   68.5  69.2
## 604   68.5  69.2
## 605   68.5  69.2
## 606   68.5  69.2
## 607   68.5  69.2
## 608   68.5  69.2
## 609   68.5  69.2
## 610   68.5  69.2
## 611   68.5  69.2
## 612   68.5  69.2
## 613   68.5  69.2
## 614   68.5  69.2
## 615   68.5  69.2
## 616   68.5  69.2
## 617   68.5  69.2
## 618   68.5  69.2
## 619   68.5  69.2
## 620   68.5  69.2
## 621   68.5  69.2
## 622   68.5  69.2
## 623   68.5  69.2
## 624   68.5  69.2
## 625   68.5  69.2
## 626   68.5  69.2
## 627   68.5  69.2
## 628   68.5  69.2
## 629   68.5  69.2
## 630   68.5  69.2
```

```
## 631   68.5  69.2
## 632   68.5  69.2
## 633   67.5  69.2
## 634   67.5  69.2
## 635   67.5  69.2
## 636   67.5  69.2
## 637   67.5  69.2
## 638   67.5  69.2
## 639   67.5  69.2
## 640   67.5  69.2
## 641   67.5  69.2
## 642   67.5  69.2
## 643   67.5  69.2
## 644   67.5  69.2
## 645   67.5  69.2
## 646   67.5  69.2
## 647   67.5  69.2
## 648   67.5  69.2
## 649   67.5  69.2
## 650   67.5  69.2
## 651   67.5  69.2
## 652   67.5  69.2
## 653   67.5  69.2
## 654   67.5  69.2
## 655   67.5  69.2
## 656   67.5  69.2
## 657   67.5  69.2
## 658   67.5  69.2
## 659   67.5  69.2
## 660   67.5  69.2
## 661   67.5  69.2
## 662   67.5  69.2
## 663   67.5  69.2
## 664   67.5  69.2
## 665   67.5  69.2
## 666   67.5  69.2
## 667   67.5  69.2
## 668   67.5  69.2
## 669   67.5  69.2
## 670   67.5  69.2
## 671   66.5  69.2
## 672   66.5  69.2
## 673   66.5  69.2
## 674   66.5  69.2
## 675   66.5  69.2
## 676   66.5  69.2
## 677   66.5  69.2
## 678   66.5  69.2
## 679   66.5  69.2
## 680   66.5  69.2
## 681   66.5  69.2
## 682   66.5  69.2
## 683   66.5  69.2
## 684   65.5  69.2
```

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## 685   65.5  69.2
## 686   65.5  69.2
## 687   65.5  69.2
## 688   65.5  69.2
## 689   65.5  69.2
## 690   65.5  69.2
## 691   64.5  69.2
## 692   64.5  69.2
## 693   64.0  69.2
## 694   72.5  70.2
## 695   71.5  70.2
## 696   71.5  70.2
## 697   71.5  70.2
## 698   71.5  70.2
## 699   71.5  70.2
## 700   71.5  70.2
## 701   71.5  70.2
## 702   71.5  70.2
## 703   71.5  70.2
## 704   71.5  70.2
## 705   70.5  70.2
## 706   70.5  70.2
## 707   70.5  70.2
## 708   70.5  70.2
## 709   70.5  70.2
## 710   70.5  70.2
## 711   70.5  70.2
## 712   70.5  70.2
## 713   70.5  70.2
## 714   70.5  70.2
## 715   70.5  70.2
## 716   70.5  70.2
## 717   70.5  70.2
## 718   70.5  70.2
## 719   69.5  70.2
## 720   69.5  70.2
## 721   69.5  70.2
## 722   69.5  70.2
## 723   69.5  70.2
## 724   69.5  70.2
## 725   69.5  70.2
## 726   69.5  70.2
## 727   69.5  70.2
## 728   69.5  70.2
## 729   69.5  70.2
## 730   69.5  70.2
## 731   69.5  70.2
## 732   69.5  70.2
## 733   69.5  70.2
## 734   69.5  70.2
## 735   69.5  70.2
## 736   69.5  70.2
## 737   69.5  70.2
## 738   69.5  70.2
```

```
## 739   69.5  70.2
## 740   69.5  70.2
## 741   69.5  70.2
## 742   69.5  70.2
## 743   69.5  70.2
## 744   68.5  70.2
## 745   68.5  70.2
## 746   68.5  70.2
## 747   68.5  70.2
## 748   68.5  70.2
## 749   68.5  70.2
## 750   68.5  70.2
## 751   68.5  70.2
## 752   68.5  70.2
## 753   68.5  70.2
## 754   68.5  70.2
## 755   68.5  70.2
## 756   68.5  70.2
## 757   68.5  70.2
## 758   68.5  70.2
## 759   68.5  70.2
## 760   68.5  70.2
## 761   68.5  70.2
## 762   68.5  70.2
## 763   68.5  70.2
## 764   68.5  70.2
## 765   67.5  70.2
## 766   67.5  70.2
## 767   67.5  70.2
## 768   67.5  70.2
## 769   67.5  70.2
## 770   67.5  70.2
## 771   67.5  70.2
## 772   67.5  70.2
## 773   67.5  70.2
## 774   67.5  70.2
## 775   67.5  70.2
## 776   67.5  70.2
## 777   67.5  70.2
## 778   67.5  70.2
## 779   67.5  70.2
## 780   67.5  70.2
## 781   67.5  70.2
## 782   67.5  70.2
## 783   67.5  70.2
## 784   66.5  70.2
## 785   66.5  70.2
## 786   66.5  70.2
## 787   66.5  70.2
## 788   65.5  70.2
## 789   65.5  70.2
## 790   65.5  70.2
## 791   65.5  70.2
## 792   65.5  70.2
```

```
## 793   72.5  71.2
## 794   72.5  71.2
## 795   71.5  71.2
## 796   71.5  71.2
## 797   71.5  71.2
## 798   71.5  71.2
## 799   70.5  71.2
## 800   70.5  71.2
## 801   70.5  71.2
## 802   70.5  71.2
## 803   70.5  71.2
## 804   70.5  71.2
## 805   70.5  71.2
## 806   69.5  71.2
## 807   69.5  71.2
## 808   69.5  71.2
## 809   69.5  71.2
## 810   69.5  71.2
## 811   69.5  71.2
## 812   69.5  71.2
## 813   69.5  71.2
## 814   69.5  71.2
## 815   69.5  71.2
## 816   69.5  71.2
## 817   69.5  71.2
## 818   69.5  71.2
## 819   69.5  71.2
## 820   69.5  71.2
## 821   69.5  71.2
## 822   69.5  71.2
## 823   69.5  71.2
## 824   69.5  71.2
## 825   69.5  71.2
## 826   68.5  71.2
## 827   68.5  71.2
## 828   68.5  71.2
## 829   68.5  71.2
## 830   68.5  71.2
## 831   68.5  71.2
## 832   68.5  71.2
## 833   68.5  71.2
## 834   68.5  71.2
## 835   68.5  71.2
## 836   68.5  71.2
## 837   68.5  71.2
## 838   68.5  71.2
## 839   68.5  71.2
## 840   68.5  71.2
## 841   68.5  71.2
## 842   68.5  71.2
## 843   68.5  71.2
## 844   67.5  71.2
## 845   67.5  71.2
## 846   67.5  71.2
```

```
## 847   67.5  71.2
## 848   67.5  71.2
## 849   67.5  71.2
## 850   67.5  71.2
## 851   67.5  71.2
## 852   67.5  71.2
## 853   67.5  71.2
## 854   67.5  71.2
## 855   65.5  71.2
## 856   65.5  71.2
## 857   73.0  72.2
## 858   72.5  72.2
## 859   72.5  72.2
## 860   72.5  72.2
## 861   72.5  72.2
## 862   72.5  72.2
## 863   72.5  72.2
## 864   72.5  72.2
## 865   71.5  72.2
## 866   71.5  72.2
## 867   71.5  72.2
## 868   71.5  72.2
## 869   71.5  72.2
## 870   71.5  72.2
## 871   71.5  72.2
## 872   71.5  72.2
## 873   71.5  72.2
## 874   70.5  72.2
## 875   70.5  72.2
## 876   70.5  72.2
## 877   70.5  72.2
## 878   69.5  72.2
## 879   69.5  72.2
## 880   69.5  72.2
## 881   69.5  72.2
## 882   69.5  72.2
## 883   69.5  72.2
## 884   69.5  72.2
## 885   69.5  72.2
## 886   69.5  72.2
## 887   69.5  72.2
## 888   69.5  72.2
## 889   68.5  72.2
## 890   68.5  72.2
## 891   68.5  72.2
## 892   68.5  72.2
## 893   67.5  72.2
## 894   67.5  72.2
## 895   67.5  72.2
## 896   67.5  72.2
## 897   65.5  72.2
## 898   73.0  73.2
## 899   73.0  73.2
## 900   73.0  73.2
```

```
## 901   72.5  73.2
## 902   72.5  73.2
## 903   71.5  73.2
## 904   71.5  73.2
## 905   70.5  73.2
## 906   70.5  73.2
## 907   70.5  73.2
## 908   69.5  73.2
## 909   69.5  73.2
## 910   69.5  73.2
## 911   69.5  73.2
## 912   68.5  73.2
## 913   68.5  73.2
## 914   68.5  73.2
## 915   72.5  73.7
## 916   72.5  73.7
## 917   72.5  73.7
## 918   72.5  73.7
## 919   71.5  73.7
## 920   71.5  73.7
## 921   70.5  73.7
## 922   70.5  73.7
## 923   70.5  73.7
## 924   69.5  73.7
## 925   69.5  73.7
## 926   69.5  73.7
## 927   69.5  73.7
## 928   69.5  73.7
```

You now should have a data frame in your workspace called `Galton`. Summarize this data frame and write a few sentences about what you see. Make sure you report n, p and a bit about what the columns represent and how the data was measured. See the help file `?Galton`.

```
summary(Galton)
```

```
##      parent          child
##  Min.   :64.00   Min.   :61.70
##  1st Qu.:67.50   1st Qu.:66.20
##  Median :68.50   Median :68.20
##  Mean   :68.31   Mean   :68.09
##  3rd Qu.:69.50   3rd Qu.:70.20
##  Max.   :73.00   Max.   :73.70
```

```
n = nrow(Galton)
n
```

```
## [1] 928
```

```
p = ncol(Galton)
p
```

```
## [1] 2
```

```
#The height summaries for the parents column and child column appear very similar. The parents column r
```

TO-DO

Find the average height (include both parents and children in this computation).

```r
avg_height = ((2*sum(Galton$parent)) + sum(Galton$child)) / (3*n)
avg_height
```

```
## [1] 68.23495
```

If you were to use the null model, what would the RMSE be of this model be?

```r
y_hat = sum(Galton$child) / n
y_hat = rep(y_hat, n)

Galton$child
```

```
##   [1] 61.7 61.7 61.7 61.7 61.7 62.2 62.2 62.2 62.2 62.2 62.2 62.2 63.2 63.2
##  [15] 63.2 63.2 63.2 63.2 63.2 63.2 63.2 63.2 63.2 63.2 63.2 63.2 63.2 63.2
##  [29] 63.2 63.2 63.2 63.2 63.2 63.2 63.2 63.2 63.2 63.2 63.2 63.2 63.2 63.2
##  [43] 63.2 63.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2
##  [57] 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2
##  [71] 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2
##  [85] 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2 64.2
##  [99] 64.2 64.2 64.2 64.2 64.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2
## [113] 65.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2
## [127] 65.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2
## [141] 65.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2 65.2 66.2 66.2 66.2
## [155] 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2
## [169] 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2
## [183] 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2
## [197] 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2
## [211] 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2
## [225] 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2
## [239] 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2
## [253] 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2 66.2
## [267] 66.2 66.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2
## [281] 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2
## [295] 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2
## [309] 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2
## [323] 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2
## [337] 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2
## [351] 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2
## [365] 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2
## [379] 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2
## [393] 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2 67.2
## [407] 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2
## [421] 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2
## [435] 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2
## [449] 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2
## [463] 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2
## [477] 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2
## [491] 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2
## [505] 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2
## [519] 68.2 68.2 68.2 68.2 68.2 68.2 68.2 68.2 69.2 69.2 69.2 69.2 69.2 69.2
## [533] 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2
## [547] 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2
## [561] 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2
## [575] 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2
## [589] 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2
```

```
## [603] 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2
## [617] 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2
## [631] 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2
## [645] 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2
## [659] 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2
## [673] 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2 69.2
## [687] 69.2 69.2 69.2 69.2 69.2 69.2 69.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2
## [701] 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2
## [715] 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2
## [729] 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2
## [743] 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2
## [757] 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2
## [771] 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2
## [785] 70.2 70.2 70.2 70.2 70.2 70.2 70.2 70.2 71.2 71.2 71.2 71.2 71.2 71.2
## [799] 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2
## [813] 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2
## [827] 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2
## [841] 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2 71.2
## [855] 71.2 71.2 72.2 72.2 72.2 72.2 72.2 72.2 72.2 72.2 72.2 72.2 72.2 72.2
## [869] 72.2 72.2 72.2 72.2 72.2 72.2 72.2 72.2 72.2 72.2 72.2 72.2 72.2 72.2
## [883] 72.2 72.2 72.2 72.2 72.2 72.2 72.2 72.2 72.2 72.2 72.2 72.2 72.2 72.2
## [897] 72.2 73.2 73.2 73.2 73.2 73.2 73.2 73.2 73.2 73.2 73.2 73.2 73.2 73.2
## [911] 73.2 73.2 73.2 73.2 73.7 73.7 73.7 73.7 73.7 73.7 73.7 73.7 73.7 73.7
## [925] 73.7 73.7 73.7 73.7
```

```
y_hat
```

```
##   [1] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
##   [8] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
##  [15] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
##  [22] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
##  [29] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
##  [36] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
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##  [50] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
##  [57] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
##  [64] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
##  [71] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
##  [78] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
##  [85] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
##  [92] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
##  [99] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
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## [120] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [127] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [134] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [141] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [148] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [155] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [162] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [169] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [176] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [183] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [190] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
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## [197] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [204] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [211] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [218] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [225] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [232] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [239] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [246] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [253] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [260] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [267] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [274] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [281] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [288] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [295] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [302] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [309] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [316] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [323] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [330] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [337] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [344] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [351] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [358] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
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## [372] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [379] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
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## [393] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [400] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [407] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [414] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [421] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [428] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
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## [449] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [456] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [463] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [470] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [477] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [484] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [491] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [498] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [505] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [512] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [519] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [526] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [533] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [540] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [547] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [554] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [561] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [568] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
```

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## [575] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [582] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [589] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [596] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [603] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [610] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [617] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [624] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [631] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [638] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [645] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [652] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [659] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [666] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [673] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [680] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [687] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [694] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [701] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [708] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [715] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [722] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [729] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [736] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [743] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [750] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [757] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [764] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [771] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [778] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [785] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [792] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [799] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [806] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [813] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [820] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [827] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [834] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [841] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [848] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [855] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [862] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [869] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [876] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [883] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [890] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [897] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [904] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [911] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [918] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [925] 68.08847 68.08847 68.08847 68.08847
```

```r
SSE = sum((Galton$child - y_hat)^2)
SSE
```

```
## [1] 5877.207
```

```r
MSE = (1 / (n-2)) * SSE
MSE
```

```
## [1] 6.346875
```

```r
RMSE = sqrt(MSE)
RMSE
```

```
## [1] 2.519301
```

Note that in Math 241 you learned that the sample average is an estimate of the "mean", the population expected value of height. We will call the average the "mean" going forward since it is probably correct to the nearest tenth of an inch with this amount of data.

Run a linear model attempting to explain the childrens' height using the parents' height. Use `lm` and use the R formula notation. Compute and report b_0, b_1, RMSE and R^2. Use the correct units to report these quantities.

```r
Galton
```

```
##     parent child
## 1     70.5  61.7
## 2     68.5  61.7
## 3     65.5  61.7
## 4     64.5  61.7
## 5     64.0  61.7
## 6     67.5  62.2
## 7     67.5  62.2
## 8     67.5  62.2
## 9     66.5  62.2
## 10    66.5  62.2
## 11    66.5  62.2
## 12    64.5  62.2
## 13    70.5  63.2
## 14    69.5  63.2
## 15    68.5  63.2
## 16    68.5  63.2
## 17    68.5  63.2
## 18    68.5  63.2
## 19    68.5  63.2
## 20    68.5  63.2
## 21    68.5  63.2
## 22    67.5  63.2
## 23    67.5  63.2
## 24    67.5  63.2
## 25    67.5  63.2
## 26    67.5  63.2
## 27    66.5  63.2
## 28    66.5  63.2
## 29    66.5  63.2
## 30    65.5  63.2
## 31    65.5  63.2
## 32    65.5  63.2
## 33    65.5  63.2
## 34    65.5  63.2
## 35    65.5  63.2
```

```
## 36    65.5  63.2
## 37    65.5  63.2
## 38    65.5  63.2
## 39    64.5  63.2
## 40    64.5  63.2
## 41    64.5  63.2
## 42    64.5  63.2
## 43    64.0  63.2
## 44    64.0  63.2
## 45    69.5  64.2
## 46    69.5  64.2
## 47    69.5  64.2
## 48    69.5  64.2
## 49    69.5  64.2
## 50    69.5  64.2
## 51    69.5  64.2
## 52    69.5  64.2
## 53    69.5  64.2
## 54    69.5  64.2
## 55    69.5  64.2
## 56    69.5  64.2
## 57    69.5  64.2
## 58    69.5  64.2
## 59    69.5  64.2
## 60    69.5  64.2
## 61    68.5  64.2
## 62    68.5  64.2
## 63    68.5  64.2
## 64    68.5  64.2
## 65    68.5  64.2
## 66    68.5  64.2
## 67    68.5  64.2
## 68    68.5  64.2
## 69    68.5  64.2
## 70    68.5  64.2
## 71    68.5  64.2
## 72    67.5  64.2
## 73    67.5  64.2
## 74    67.5  64.2
## 75    67.5  64.2
## 76    67.5  64.2
## 77    67.5  64.2
## 78    67.5  64.2
## 79    67.5  64.2
## 80    67.5  64.2
## 81    67.5  64.2
## 82    67.5  64.2
## 83    67.5  64.2
## 84    67.5  64.2
## 85    67.5  64.2
## 86    66.5  64.2
## 87    66.5  64.2
## 88    66.5  64.2
## 89    66.5  64.2
```

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## 90    66.5  64.2
## 91    65.5  64.2
## 92    65.5  64.2
## 93    65.5  64.2
## 94    65.5  64.2
## 95    65.5  64.2
## 96    64.5  64.2
## 97    64.5  64.2
## 98    64.5  64.2
## 99    64.5  64.2
## 100   64.0  64.2
## 101   64.0  64.2
## 102   64.0  64.2
## 103   64.0  64.2
## 104   71.5  65.2
## 105   70.5  65.2
## 106   69.5  65.2
## 107   69.5  65.2
## 108   69.5  65.2
## 109   69.5  65.2
## 110   68.5  65.2
## 111   68.5  65.2
## 112   68.5  65.2
## 113   68.5  65.2
## 114   68.5  65.2
## 115   68.5  65.2
## 116   68.5  65.2
## 117   68.5  65.2
## 118   68.5  65.2
## 119   68.5  65.2
## 120   68.5  65.2
## 121   68.5  65.2
## 122   68.5  65.2
## 123   68.5  65.2
## 124   68.5  65.2
## 125   68.5  65.2
## 126   67.5  65.2
## 127   67.5  65.2
## 128   67.5  65.2
## 129   67.5  65.2
## 130   67.5  65.2
## 131   67.5  65.2
## 132   67.5  65.2
## 133   67.5  65.2
## 134   67.5  65.2
## 135   67.5  65.2
## 136   67.5  65.2
## 137   67.5  65.2
## 138   67.5  65.2
## 139   67.5  65.2
## 140   67.5  65.2
## 141   66.5  65.2
## 142   66.5  65.2
## 143   65.5  65.2
```

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## 144   65.5  65.2
## 145   65.5  65.2
## 146   65.5  65.2
## 147   65.5  65.2
## 148   65.5  65.2
## 149   65.5  65.2
## 150   64.5  65.2
## 151   64.0  65.2
## 152   71.5  66.2
## 153   71.5  66.2
## 154   71.5  66.2
## 155   70.5  66.2
## 156   69.5  66.2
## 157   69.5  66.2
## 158   69.5  66.2
## 159   69.5  66.2
## 160   69.5  66.2
## 161   69.5  66.2
## 162   69.5  66.2
## 163   69.5  66.2
## 164   69.5  66.2
## 165   69.5  66.2
## 166   69.5  66.2
## 167   69.5  66.2
## 168   69.5  66.2
## 169   69.5  66.2
## 170   69.5  66.2
## 171   69.5  66.2
## 172   69.5  66.2
## 173   68.5  66.2
## 174   68.5  66.2
## 175   68.5  66.2
## 176   68.5  66.2
## 177   68.5  66.2
## 178   68.5  66.2
## 179   68.5  66.2
## 180   68.5  66.2
## 181   68.5  66.2
## 182   68.5  66.2
## 183   68.5  66.2
## 184   68.5  66.2
## 185   68.5  66.2
## 186   68.5  66.2
## 187   68.5  66.2
## 188   68.5  66.2
## 189   68.5  66.2
## 190   68.5  66.2
## 191   68.5  66.2
## 192   68.5  66.2
## 193   68.5  66.2
## 194   68.5  66.2
## 195   68.5  66.2
## 196   68.5  66.2
## 197   68.5  66.2
```

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## 198   67.5  66.2
## 199   67.5  66.2
## 200   67.5  66.2
## 201   67.5  66.2
## 202   67.5  66.2
## 203   67.5  66.2
## 204   67.5  66.2
## 205   67.5  66.2
## 206   67.5  66.2
## 207   67.5  66.2
## 208   67.5  66.2
## 209   67.5  66.2
## 210   67.5  66.2
## 211   67.5  66.2
## 212   67.5  66.2
## 213   67.5  66.2
## 214   67.5  66.2
## 215   67.5  66.2
## 216   67.5  66.2
## 217   67.5  66.2
## 218   67.5  66.2
## 219   67.5  66.2
## 220   67.5  66.2
## 221   67.5  66.2
## 222   67.5  66.2
## 223   67.5  66.2
## 224   67.5  66.2
## 225   67.5  66.2
## 226   67.5  66.2
## 227   67.5  66.2
## 228   67.5  66.2
## 229   67.5  66.2
## 230   67.5  66.2
## 231   67.5  66.2
## 232   67.5  66.2
## 233   67.5  66.2
## 234   66.5  66.2
## 235   66.5  66.2
## 236   66.5  66.2
## 237   66.5  66.2
## 238   66.5  66.2
## 239   66.5  66.2
## 240   66.5  66.2
## 241   66.5  66.2
## 242   66.5  66.2
## 243   66.5  66.2
## 244   66.5  66.2
## 245   66.5  66.2
## 246   66.5  66.2
## 247   66.5  66.2
## 248   66.5  66.2
## 249   66.5  66.2
## 250   66.5  66.2
## 251   65.5  66.2
```

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## 252   65.5  66.2
## 253   65.5  66.2
## 254   65.5  66.2
## 255   65.5  66.2
## 256   65.5  66.2
## 257   65.5  66.2
## 258   65.5  66.2
## 259   65.5  66.2
## 260   65.5  66.2
## 261   65.5  66.2
## 262   64.5  66.2
## 263   64.5  66.2
## 264   64.5  66.2
## 265   64.5  66.2
## 266   64.5  66.2
## 267   64.0  66.2
## 268   64.0  66.2
## 269   71.5  67.2
## 270   71.5  67.2
## 271   71.5  67.2
## 272   71.5  67.2
## 273   70.5  67.2
## 274   70.5  67.2
## 275   70.5  67.2
## 276   69.5  67.2
## 277   69.5  67.2
## 278   69.5  67.2
## 279   69.5  67.2
## 280   69.5  67.2
## 281   69.5  67.2
## 282   69.5  67.2
## 283   69.5  67.2
## 284   69.5  67.2
## 285   69.5  67.2
## 286   69.5  67.2
## 287   69.5  67.2
## 288   69.5  67.2
## 289   69.5  67.2
## 290   69.5  67.2
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## 303   68.5  67.2
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## 306   68.5  67.2
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## 331   68.5  67.2
## 332   68.5  67.2
## 333   68.5  67.2
## 334   67.5  67.2
## 335   67.5  67.2
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## 338   67.5  67.2
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## 345   67.5  67.2
## 346   67.5  67.2
## 347   67.5  67.2
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## 360   67.5  67.2
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## 371   67.5  67.2
## 372   66.5  67.2
## 373   66.5  67.2
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## 375   66.5  67.2
## 376   66.5  67.2
## 377   66.5  67.2
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## 387   66.5  67.2
## 388   66.5  67.2
## 389   65.5  67.2
## 390   65.5  67.2
## 391   65.5  67.2
## 392   65.5  67.2
## 393   65.5  67.2
## 394   65.5  67.2
## 395   65.5  67.2
## 396   65.5  67.2
## 397   65.5  67.2
## 398   65.5  67.2
## 399   65.5  67.2
## 400   64.5  67.2
## 401   64.5  67.2
## 402   64.5  67.2
## 403   64.5  67.2
## 404   64.5  67.2
## 405   64.0  67.2
## 406   64.0  67.2
## 407   72.5  68.2
## 408   71.5  68.2
## 409   71.5  68.2
## 410   71.5  68.2
## 411   70.5  68.2
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## 414   70.5  68.2
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## 421   70.5  68.2
## 422   70.5  68.2
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## 468   68.5  68.2
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## 474   68.5  68.2
## 475   68.5  68.2
## 476   68.5  68.2
## 477   67.5  68.2
## 478   67.5  68.2
## 479   67.5  68.2
## 480   67.5  68.2
## 481   67.5  68.2
## 482   67.5  68.2
## 483   67.5  68.2
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## 505   66.5  68.2
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## 522   65.5  68.2
## 523   65.5  68.2
## 524   65.5  68.2
## 525   65.5  68.2
## 526   64.0  68.2
## 527   72.5  69.2
## 528   72.5  69.2
## 529   71.5  69.2
## 530   71.5  69.2
## 531   71.5  69.2
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## 533   71.5  69.2
## 534   70.5  69.2
## 535   70.5  69.2
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## 576   69.5  69.2
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## 582   69.5  69.2
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## 597   68.5  69.2
## 598   68.5  69.2
## 599   68.5  69.2
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## 601   68.5  69.2
## 602   68.5  69.2
## 603   68.5  69.2
## 604   68.5  69.2
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## 630   68.5  69.2
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## 633   67.5  69.2
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## 636   67.5  69.2
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## 640   67.5  69.2
## 641   67.5  69.2
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## 666   67.5  69.2
## 667   67.5  69.2
## 668   67.5  69.2
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## 670   67.5  69.2
## 671   66.5  69.2
## 672   66.5  69.2
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## 674   66.5  69.2
## 675   66.5  69.2
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## 679   66.5  69.2
## 680   66.5  69.2
## 681   66.5  69.2
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## 683   66.5  69.2
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## 684   65.5  69.2
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## 689   65.5  69.2
## 690   65.5  69.2
## 691   64.5  69.2
## 692   64.5  69.2
## 693   64.0  69.2
## 694   72.5  70.2
## 695   71.5  70.2
## 696   71.5  70.2
## 697   71.5  70.2
## 698   71.5  70.2
## 699   71.5  70.2
## 700   71.5  70.2
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## 702   71.5  70.2
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## 710   70.5  70.2
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## 712   70.5  70.2
## 713   70.5  70.2
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## 716   70.5  70.2
## 717   70.5  70.2
## 718   70.5  70.2
## 719   69.5  70.2
## 720   69.5  70.2
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## 737   69.5  70.2
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## 738   69.5  70.2
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## 744   68.5  70.2
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## 747   68.5  70.2
## 748   68.5  70.2
## 749   68.5  70.2
## 750   68.5  70.2
## 751   68.5  70.2
## 752   68.5  70.2
## 753   68.5  70.2
## 754   68.5  70.2
## 755   68.5  70.2
## 756   68.5  70.2
## 757   68.5  70.2
## 758   68.5  70.2
## 759   68.5  70.2
## 760   68.5  70.2
## 761   68.5  70.2
## 762   68.5  70.2
## 763   68.5  70.2
## 764   68.5  70.2
## 765   67.5  70.2
## 766   67.5  70.2
## 767   67.5  70.2
## 768   67.5  70.2
## 769   67.5  70.2
## 770   67.5  70.2
## 771   67.5  70.2
## 772   67.5  70.2
## 773   67.5  70.2
## 774   67.5  70.2
## 775   67.5  70.2
## 776   67.5  70.2
## 777   67.5  70.2
## 778   67.5  70.2
## 779   67.5  70.2
## 780   67.5  70.2
## 781   67.5  70.2
## 782   67.5  70.2
## 783   67.5  70.2
## 784   66.5  70.2
## 785   66.5  70.2
## 786   66.5  70.2
## 787   66.5  70.2
## 788   65.5  70.2
## 789   65.5  70.2
## 790   65.5  70.2
## 791   65.5  70.2
```

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## 792   65.5  70.2
## 793   72.5  71.2
## 794   72.5  71.2
## 795   71.5  71.2
## 796   71.5  71.2
## 797   71.5  71.2
## 798   71.5  71.2
## 799   70.5  71.2
## 800   70.5  71.2
## 801   70.5  71.2
## 802   70.5  71.2
## 803   70.5  71.2
## 804   70.5  71.2
## 805   70.5  71.2
## 806   69.5  71.2
## 807   69.5  71.2
## 808   69.5  71.2
## 809   69.5  71.2
## 810   69.5  71.2
## 811   69.5  71.2
## 812   69.5  71.2
## 813   69.5  71.2
## 814   69.5  71.2
## 815   69.5  71.2
## 816   69.5  71.2
## 817   69.5  71.2
## 818   69.5  71.2
## 819   69.5  71.2
## 820   69.5  71.2
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## 822   69.5  71.2
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## 827   68.5  71.2
## 828   68.5  71.2
## 829   68.5  71.2
## 830   68.5  71.2
## 831   68.5  71.2
## 832   68.5  71.2
## 833   68.5  71.2
## 834   68.5  71.2
## 835   68.5  71.2
## 836   68.5  71.2
## 837   68.5  71.2
## 838   68.5  71.2
## 839   68.5  71.2
## 840   68.5  71.2
## 841   68.5  71.2
## 842   68.5  71.2
## 843   68.5  71.2
## 844   67.5  71.2
## 845   67.5  71.2
```

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## 846   67.5  71.2
## 847   67.5  71.2
## 848   67.5  71.2
## 849   67.5  71.2
## 850   67.5  71.2
## 851   67.5  71.2
## 852   67.5  71.2
## 853   67.5  71.2
## 854   67.5  71.2
## 855   65.5  71.2
## 856   65.5  71.2
## 857   73.0  72.2
## 858   72.5  72.2
## 859   72.5  72.2
## 860   72.5  72.2
## 861   72.5  72.2
## 862   72.5  72.2
## 863   72.5  72.2
## 864   72.5  72.2
## 865   71.5  72.2
## 866   71.5  72.2
## 867   71.5  72.2
## 868   71.5  72.2
## 869   71.5  72.2
## 870   71.5  72.2
## 871   71.5  72.2
## 872   71.5  72.2
## 873   71.5  72.2
## 874   70.5  72.2
## 875   70.5  72.2
## 876   70.5  72.2
## 877   70.5  72.2
## 878   69.5  72.2
## 879   69.5  72.2
## 880   69.5  72.2
## 881   69.5  72.2
## 882   69.5  72.2
## 883   69.5  72.2
## 884   69.5  72.2
## 885   69.5  72.2
## 886   69.5  72.2
## 887   69.5  72.2
## 888   69.5  72.2
## 889   68.5  72.2
## 890   68.5  72.2
## 891   68.5  72.2
## 892   68.5  72.2
## 893   67.5  72.2
## 894   67.5  72.2
## 895   67.5  72.2
## 896   67.5  72.2
## 897   65.5  72.2
## 898   73.0  73.2
## 899   73.0  73.2
```

```
## 900   73.0  73.2
## 901   72.5  73.2
## 902   72.5  73.2
## 903   71.5  73.2
## 904   71.5  73.2
## 905   70.5  73.2
## 906   70.5  73.2
## 907   70.5  73.2
## 908   69.5  73.2
## 909   69.5  73.2
## 910   69.5  73.2
## 911   69.5  73.2
## 912   68.5  73.2
## 913   68.5  73.2
## 914   68.5  73.2
## 915   72.5  73.7
## 916   72.5  73.7
## 917   72.5  73.7
## 918   72.5  73.7
## 919   71.5  73.7
## 920   71.5  73.7
## 921   70.5  73.7
## 922   70.5  73.7
## 923   70.5  73.7
## 924   69.5  73.7
## 925   69.5  73.7
## 926   69.5  73.7
## 927   69.5  73.7
## 928   69.5  73.7
```

```r
y = Galton$child
x = Galton$parent
galt = lm(y~x)
galt #b_0 and b_1
```

```
##
## Call:
## lm(formula = y ~ x)
##
## Coefficients:
## (Intercept)            x
##     23.9415       0.6463
```

```r
summary(galt)$r.squared #the R^2
```

```
## [1] 0.2104629
```

```r
summary(galt)$sigma #the RMSE
```

```
## [1] 2.238547
```

```r
#b_0 is 23.9415 inches, b_1 is 0.6463 inches, RMSE is 2.238547 inches, and R^2 is 0.2104629
```

Interpret all four quantities: b_0, b_1, RMSE and R^2.

b_0 (23.9415 inches) isn't very significant because the intercept is far from any of the data points, b_1 indicates that our model predicts a 0.6463 inch height increase in the child for every 1.0 inch increase in parent height, RMSE (2.238547 inches) indicates that, on average, our model predicts a 2.238547 inch error from actual child height, and the R^2 (0.2104629) indicates that our linear model is not much better than the null model.

How good is this model? How well does it predict? Discuss.

This model is not very good. The RMSE of 2.238547 is significant, and the R^2 value indicates the model is not much better than the null model.

It is reasonable to assume that parents and their children have the same height? Explain why this is reasonable using basic biology and common sense.

It is reasonable to assume parents and their children will be similar in height, because height is mainly determined by genetics. However, the gender of the child is also a significant variable, because males are taller than females on average, and that is not considered in this model.

If they were to have the same height and any differences were just random noise with expectation 0, what would the values of β_0 and β_1 be?

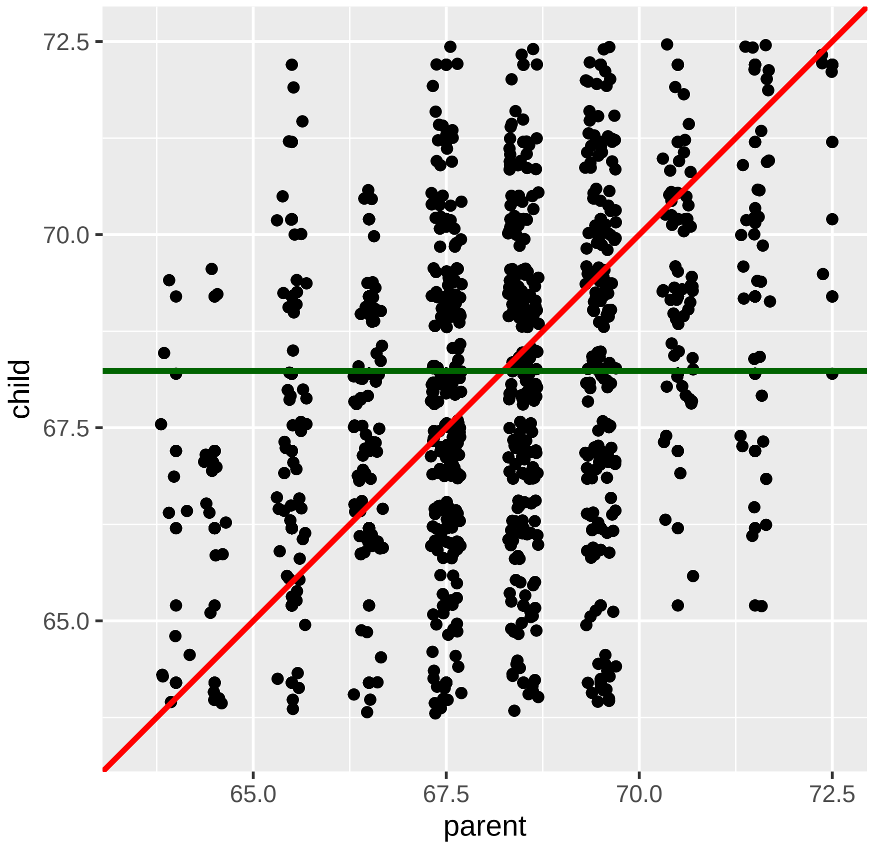
beta_1 would be 1, and beta_0 would be 0.

Let's plot (a) the data in $\mathbb{D}$ as black dots, (b) your least squares line defined by b_0 and b_1 in blue, (c) the theoretical line β_0 and β_1 if the parent-child height equality held in red and (d) the mean height in green.

```
pacman::p_load(ggplot2)
ggplot(Galton, aes(x = parent, y = child)) +
  geom_point() +
  geom_jitter() +
  geom_abline(intercept = b_0, slope = b_1, color = "blue", size = 1) +
  geom_abline(intercept = 0, slope = 1, color = "red", size = 1) +
  geom_abline(intercept = avg_height, slope = 0, color = "darkgreen", size = 1) +
  xlim(63.5, 72.5) +
  ylim(63.5, 72.5) +
  coord_equal(ratio = 1)
```

```
## Warning: Removed 76 rows containing missing values (geom_point).

## Warning: Removed 90 rows containing missing values (geom_point).
```



Fill in the following sentence:

Children of short parents became shorter on average and children of tall parents became taller on average.

Why did Galton call it "Regression towards mediocrity in hereditary stature" which was later shortened to "regression to the mean"?

"... he found that the heights of the children tended to be more moderate than the heights of their parents. For example, if parents were very tall the children tended to be tall but shorter than their parents. If parents were very short the children tended to be short but taller than their parents were. This discovery he called"regression to the mean," with the word "regression" meaning to come back to." source: http://www.biostat.jhsph.edu/courses/bio653/misc/JMPer%20Cable%20Summer%2098%20Why%20is%20it%20called%20Regression.htm

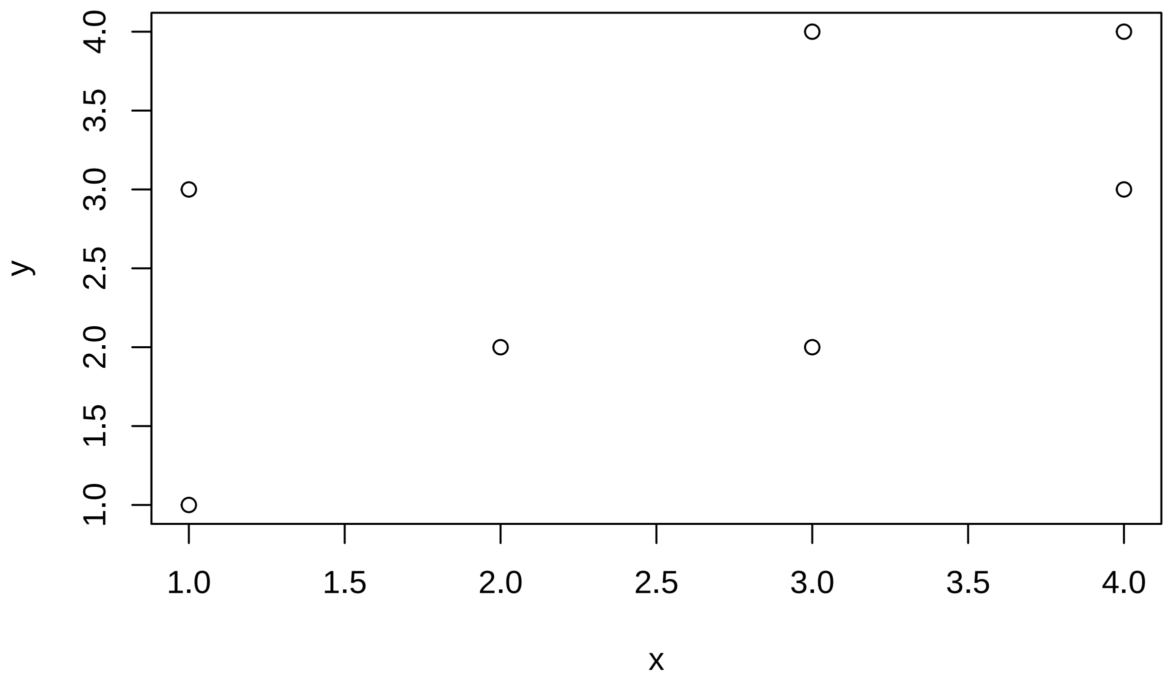
Why should this effect be real?

There are multiple other variables that contribute to adult height that are unaccounted for. You now have unlocked the mystery. Why is it that when modeling with y continuous, everyone calls it "regression"? Write a better, more descriptive and appropriate name for building predictive models with y continuous.

"regression" is a term that is historically derived from Galton's research on parental-child height, that has stuck even today. A better name for predictive models with y continuous is "least predictive error equation line".

Create a dataset $\mathbb{D}$ which we call `Xy` such that the linear model as R^2 about 50% and RMSE approximately 1.

```
x = c(1,1,2,3,3,4,4)
y = c(1,3,2,2,4,3,4)
plot(x,y)
```




```r
Xy = lm(y~x)

summary(Xy)$r.squared #the R^2
```

```
## [1] 0.3665158
```

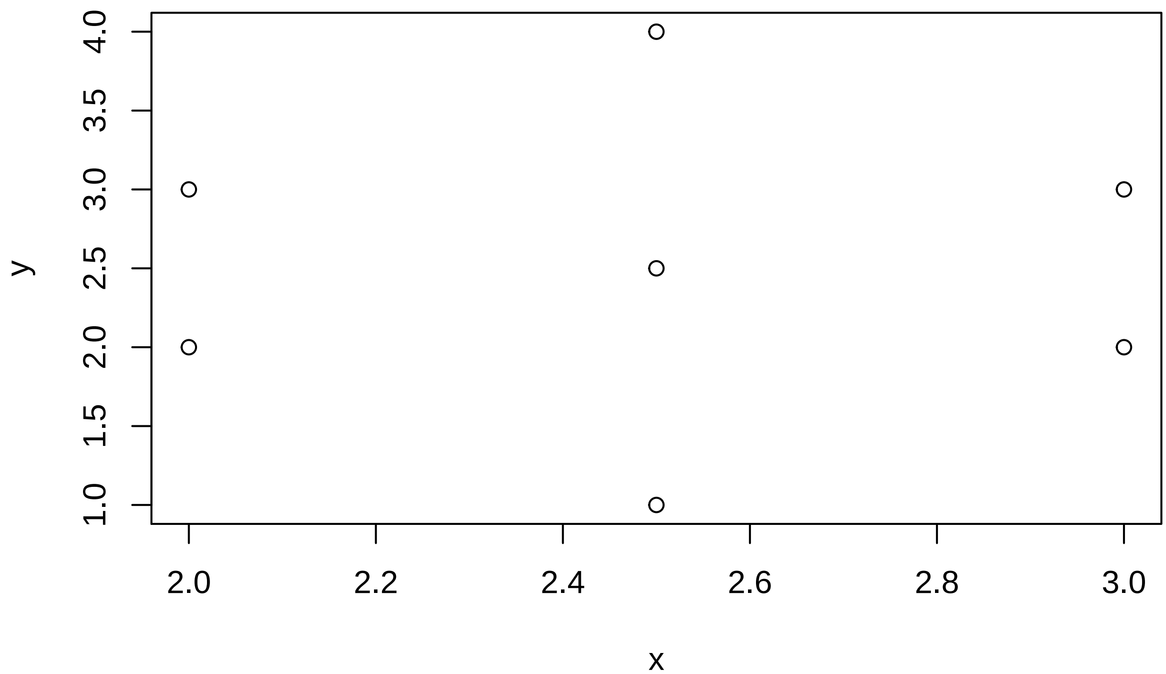
```r
summary(Xy)$sigma #the RMSE
```

```
## [1] 0.9701425
```

```r
Xy = data.frame(x = x, y = y)
```

Create a dataset $\mathbb{D}$ which we call `Xy` such that the linear model as R^2 about 0% but x, y are clearly associated.

```r
x = c(2,2,2.5,2.5,2.5,3,3)
y = c(2,3,1,2.5,4,2,3)
plot(x,y)
```




```r
Xy = lm(y~x)

summary(Xy)$r.squared #the R^2
```

```
## [1] 2.151439e-31
```

```r
Xy = data.frame(x = x, y = y)
```

Load up the famous iris dataset and drop the data for Species "virginica".

```r
iris
```

```
##     Sepal.Length Sepal.Width Petal.Length Petal.Width    Species
## 1            5.1         3.5          1.4         0.2     setosa
## 2            4.9         3.0          1.4         0.2     setosa
## 3            4.7         3.2          1.3         0.2     setosa
## 4            4.6         3.1          1.5         0.2     setosa
## 5            5.0         3.6          1.4         0.2     setosa
## 6            5.4         3.9          1.7         0.4     setosa
## 7            4.6         3.4          1.4         0.3     setosa
## 8            5.0         3.4          1.5         0.2     setosa
## 9            4.4         2.9          1.4         0.2     setosa
## 10           4.9         3.1          1.5         0.1     setosa
## 11           5.4         3.7          1.5         0.2     setosa
## 12           4.8         3.4          1.6         0.2     setosa
## 13           4.8         3.0          1.4         0.1     setosa
## 14           4.3         3.0          1.1         0.1     setosa
## 15           5.8         4.0          1.2         0.2     setosa
## 16           5.7         4.4          1.5         0.4     setosa
## 17           5.4         3.9          1.3         0.4     setosa
## 18           5.1         3.5          1.4         0.3     setosa
## 19           5.7         3.8          1.7         0.3     setosa
## 20           5.1         3.8          1.5         0.3     setosa
## 21           5.4         3.4          1.7         0.2     setosa
```

```
## 22          5.1         3.7          1.5         0.4     setosa
## 23          4.6         3.6          1.0         0.2     setosa
## 24          5.1         3.3          1.7         0.5     setosa
## 25          4.8         3.4          1.9         0.2     setosa
## 26          5.0         3.0          1.6         0.2     setosa
## 27          5.0         3.4          1.6         0.4     setosa
## 28          5.2         3.5          1.5         0.2     setosa
## 29          5.2         3.4          1.4         0.2     setosa
## 30          4.7         3.2          1.6         0.2     setosa
## 31          4.8         3.1          1.6         0.2     setosa
## 32          5.4         3.4          1.5         0.4     setosa
## 33          5.2         4.1          1.5         0.1     setosa
## 34          5.5         4.2          1.4         0.2     setosa
## 35          4.9         3.1          1.5         0.2     setosa
## 36          5.0         3.2          1.2         0.2     setosa
## 37          5.5         3.5          1.3         0.2     setosa
## 38          4.9         3.6          1.4         0.1     setosa
## 39          4.4         3.0          1.3         0.2     setosa
## 40          5.1         3.4          1.5         0.2     setosa
## 41          5.0         3.5          1.3         0.3     setosa
## 42          4.5         2.3          1.3         0.3     setosa
## 43          4.4         3.2          1.3         0.2     setosa
## 44          5.0         3.5          1.6         0.6     setosa
## 45          5.1         3.8          1.9         0.4     setosa
## 46          4.8         3.0          1.4         0.3     setosa
## 47          5.1         3.8          1.6         0.2     setosa
## 48          4.6         3.2          1.4         0.2     setosa
## 49          5.3         3.7          1.5         0.2     setosa
## 50          5.0         3.3          1.4         0.2     setosa
## 51          7.0         3.2          4.7         1.4 versicolor
## 52          6.4         3.2          4.5         1.5 versicolor
## 53          6.9         3.1          4.9         1.5 versicolor
## 54          5.5         2.3          4.0         1.3 versicolor
## 55          6.5         2.8          4.6         1.5 versicolor
## 56          5.7         2.8          4.5         1.3 versicolor
## 57          6.3         3.3          4.7         1.6 versicolor
## 58          4.9         2.4          3.3         1.0 versicolor
## 59          6.6         2.9          4.6         1.3 versicolor
## 60          5.2         2.7          3.9         1.4 versicolor
## 61          5.0         2.0          3.5         1.0 versicolor
## 62          5.9         3.0          4.2         1.5 versicolor
## 63          6.0         2.2          4.0         1.0 versicolor
## 64          6.1         2.9          4.7         1.4 versicolor
## 65          5.6         2.9          3.6         1.3 versicolor
## 66          6.7         3.1          4.4         1.4 versicolor
## 67          5.6         3.0          4.5         1.5 versicolor
## 68          5.8         2.7          4.1         1.0 versicolor
## 69          6.2         2.2          4.5         1.5 versicolor
## 70          5.6         2.5          3.9         1.1 versicolor
## 71          5.9         3.2          4.8         1.8 versicolor
## 72          6.1         2.8          4.0         1.3 versicolor
## 73          6.3         2.5          4.9         1.5 versicolor
## 74          6.1         2.8          4.7         1.2 versicolor
## 75          6.4         2.9          4.3         1.3 versicolor
```

```
## 76           6.6         3.0          4.4         1.4 versicolor
## 77           6.8         2.8          4.8         1.4 versicolor
## 78           6.7         3.0          5.0         1.7 versicolor
## 79           6.0         2.9          4.5         1.5 versicolor
## 80           5.7         2.6          3.5         1.0 versicolor
## 81           5.5         2.4          3.8         1.1 versicolor
## 82           5.5         2.4          3.7         1.0 versicolor
## 83           5.8         2.7          3.9         1.2 versicolor
## 84           6.0         2.7          5.1         1.6 versicolor
## 85           5.4         3.0          4.5         1.5 versicolor
## 86           6.0         3.4          4.5         1.6 versicolor
## 87           6.7         3.1          4.7         1.5 versicolor
## 88           6.3         2.3          4.4         1.3 versicolor
## 89           5.6         3.0          4.1         1.3 versicolor
## 90           5.5         2.5          4.0         1.3 versicolor
## 91           5.5         2.6          4.4         1.2 versicolor
## 92           6.1         3.0          4.6         1.4 versicolor
## 93           5.8         2.6          4.0         1.2 versicolor
## 94           5.0         2.3          3.3         1.0 versicolor
## 95           5.6         2.7          4.2         1.3 versicolor
## 96           5.7         3.0          4.2         1.2 versicolor
## 97           5.7         2.9          4.2         1.3 versicolor
## 98           6.2         2.9          4.3         1.3 versicolor
## 99           5.1         2.5          3.0         1.1 versicolor
## 100          5.7         2.8          4.1         1.3 versicolor
## 101          6.3         3.3          6.0         2.5  virginica
## 102          5.8         2.7          5.1         1.9  virginica
## 103          7.1         3.0          5.9         2.1  virginica
## 104          6.3         2.9          5.6         1.8  virginica
## 105          6.5         3.0          5.8         2.2  virginica
## 106          7.6         3.0          6.6         2.1  virginica
## 107          4.9         2.5          4.5         1.7  virginica
## 108          7.3         2.9          6.3         1.8  virginica
## 109          6.7         2.5          5.8         1.8  virginica
## 110          7.2         3.6          6.1         2.5  virginica
## 111          6.5         3.2          5.1         2.0  virginica
## 112          6.4         2.7          5.3         1.9  virginica
## 113          6.8         3.0          5.5         2.1  virginica
## 114          5.7         2.5          5.0         2.0  virginica
## 115          5.8         2.8          5.1         2.4  virginica
## 116          6.4         3.2          5.3         2.3  virginica
## 117          6.5         3.0          5.5         1.8  virginica
## 118          7.7         3.8          6.7         2.2  virginica
## 119          7.7         2.6          6.9         2.3  virginica
## 120          6.0         2.2          5.0         1.5  virginica
## 121          6.9         3.2          5.7         2.3  virginica
## 122          5.6         2.8          4.9         2.0  virginica
## 123          7.7         2.8          6.7         2.0  virginica
## 124          6.3         2.7          4.9         1.8  virginica
## 125          6.7         3.3          5.7         2.1  virginica
## 126          7.2         3.2          6.0         1.8  virginica
## 127          6.2         2.8          4.8         1.8  virginica
## 128          6.1         3.0          4.9         1.8  virginica
## 129          6.4         2.8          5.6         2.1  virginica
```

```
## 130          7.2         3.0          5.8         1.6  virginica
## 131          7.4         2.8          6.1         1.9  virginica
## 132          7.9         3.8          6.4         2.0  virginica
## 133          6.4         2.8          5.6         2.2  virginica
## 134          6.3         2.8          5.1         1.5  virginica
## 135          6.1         2.6          5.6         1.4  virginica
## 136          7.7         3.0          6.1         2.3  virginica
## 137          6.3         3.4          5.6         2.4  virginica
## 138          6.4         3.1          5.5         1.8  virginica
## 139          6.0         3.0          4.8         1.8  virginica
## 140          6.9         3.1          5.4         2.1  virginica
## 141          6.7         3.1          5.6         2.4  virginica
## 142          6.9         3.1          5.1         2.3  virginica
## 143          5.8         2.7          5.1         1.9  virginica
## 144          6.8         3.2          5.9         2.3  virginica
## 145          6.7         3.3          5.7         2.5  virginica
## 146          6.7         3.0          5.2         2.3  virginica
## 147          6.3         2.5          5.0         1.9  virginica
## 148          6.5         3.0          5.2         2.0  virginica
## 149          6.2         3.4          5.4         2.3  virginica
## 150          5.9         3.0          5.1         1.8  virginica
```

```r
iris2 = iris[iris$Species != "virginica", ]
iris2
```

```
##     Sepal.Length Sepal.Width Petal.Length Petal.Width    Species
## 1            5.1         3.5          1.4         0.2     setosa
## 2            4.9         3.0          1.4         0.2     setosa
## 3            4.7         3.2          1.3         0.2     setosa
## 4            4.6         3.1          1.5         0.2     setosa
## 5            5.0         3.6          1.4         0.2     setosa
## 6            5.4         3.9          1.7         0.4     setosa
## 7            4.6         3.4          1.4         0.3     setosa
## 8            5.0         3.4          1.5         0.2     setosa
## 9            4.4         2.9          1.4         0.2     setosa
## 10           4.9         3.1          1.5         0.1     setosa
## 11           5.4         3.7          1.5         0.2     setosa
## 12           4.8         3.4          1.6         0.2     setosa
## 13           4.8         3.0          1.4         0.1     setosa
## 14           4.3         3.0          1.1         0.1     setosa
## 15           5.8         4.0          1.2         0.2     setosa
## 16           5.7         4.4          1.5         0.4     setosa
## 17           5.4         3.9          1.3         0.4     setosa
## 18           5.1         3.5          1.4         0.3     setosa
## 19           5.7         3.8          1.7         0.3     setosa
## 20           5.1         3.8          1.5         0.3     setosa
## 21           5.4         3.4          1.7         0.2     setosa
## 22           5.1         3.7          1.5         0.4     setosa
## 23           4.6         3.6          1.0         0.2     setosa
## 24           5.1         3.3          1.7         0.5     setosa
## 25           4.8         3.4          1.9         0.2     setosa
## 26           5.0         3.0          1.6         0.2     setosa
## 27           5.0         3.4          1.6         0.4     setosa
## 28           5.2         3.5          1.5         0.2     setosa
## 29           5.2         3.4          1.4         0.2     setosa
```

```
## 30          4.7         3.2          1.6         0.2     setosa
## 31          4.8         3.1          1.6         0.2     setosa
## 32          5.4         3.4          1.5         0.4     setosa
## 33          5.2         4.1          1.5         0.1     setosa
## 34          5.5         4.2          1.4         0.2     setosa
## 35          4.9         3.1          1.5         0.2     setosa
## 36          5.0         3.2          1.2         0.2     setosa
## 37          5.5         3.5          1.3         0.2     setosa
## 38          4.9         3.6          1.4         0.1     setosa
## 39          4.4         3.0          1.3         0.2     setosa
## 40          5.1         3.4          1.5         0.2     setosa
## 41          5.0         3.5          1.3         0.3     setosa
## 42          4.5         2.3          1.3         0.3     setosa
## 43          4.4         3.2          1.3         0.2     setosa
## 44          5.0         3.5          1.6         0.6     setosa
## 45          5.1         3.8          1.9         0.4     setosa
## 46          4.8         3.0          1.4         0.3     setosa
## 47          5.1         3.8          1.6         0.2     setosa
## 48          4.6         3.2          1.4         0.2     setosa
## 49          5.3         3.7          1.5         0.2     setosa
## 50          5.0         3.3          1.4         0.2     setosa
## 51          7.0         3.2          4.7         1.4 versicolor
## 52          6.4         3.2          4.5         1.5 versicolor
## 53          6.9         3.1          4.9         1.5 versicolor
## 54          5.5         2.3          4.0         1.3 versicolor
## 55          6.5         2.8          4.6         1.5 versicolor
## 56          5.7         2.8          4.5         1.3 versicolor
## 57          6.3         3.3          4.7         1.6 versicolor
## 58          4.9         2.4          3.3         1.0 versicolor
## 59          6.6         2.9          4.6         1.3 versicolor
## 60          5.2         2.7          3.9         1.4 versicolor
## 61          5.0         2.0          3.5         1.0 versicolor
## 62          5.9         3.0          4.2         1.5 versicolor
## 63          6.0         2.2          4.0         1.0 versicolor
## 64          6.1         2.9          4.7         1.4 versicolor
## 65          5.6         2.9          3.6         1.3 versicolor
## 66          6.7         3.1          4.4         1.4 versicolor
## 67          5.6         3.0          4.5         1.5 versicolor
## 68          5.8         2.7          4.1         1.0 versicolor
## 69          6.2         2.2          4.5         1.5 versicolor
## 70          5.6         2.5          3.9         1.1 versicolor
## 71          5.9         3.2          4.8         1.8 versicolor
## 72          6.1         2.8          4.0         1.3 versicolor
## 73          6.3         2.5          4.9         1.5 versicolor
## 74          6.1         2.8          4.7         1.2 versicolor
## 75          6.4         2.9          4.3         1.3 versicolor
## 76          6.6         3.0          4.4         1.4 versicolor
## 77          6.8         2.8          4.8         1.4 versicolor
## 78          6.7         3.0          5.0         1.7 versicolor
## 79          6.0         2.9          4.5         1.5 versicolor
## 80          5.7         2.6          3.5         1.0 versicolor
## 81          5.5         2.4          3.8         1.1 versicolor
## 82          5.5         2.4          3.7         1.0 versicolor
## 83          5.8         2.7          3.9         1.2 versicolor
```

```
## 84           6.0         2.7         5.1         1.6 versicolor
## 85           5.4         3.0         4.5         1.5 versicolor
## 86           6.0         3.4         4.5         1.6 versicolor
## 87           6.7         3.1         4.7         1.5 versicolor
## 88           6.3         2.3         4.4         1.3 versicolor
## 89           5.6         3.0         4.1         1.3 versicolor
## 90           5.5         2.5         4.0         1.3 versicolor
## 91           5.5         2.6         4.4         1.2 versicolor
## 92           6.1         3.0         4.6         1.4 versicolor
## 93           5.8         2.6         4.0         1.2 versicolor
## 94           5.0         2.3         3.3         1.0 versicolor
## 95           5.6         2.7         4.2         1.3 versicolor
## 96           5.7         3.0         4.2         1.2 versicolor
## 97           5.7         2.9         4.2         1.3 versicolor
## 98           6.2         2.9         4.3         1.3 versicolor
## 99           5.1         2.5         3.0         1.1 versicolor
## 100          5.7         2.8         4.1         1.3 versicolor
```

If the only input x is Species and you are trying to predict y which is Petal.Length, what would a reasonable, naive prediction be under both Species? Hint: it's what we did in class.

```r
#Find the mean of the petal lengths of both species

setosa = iris[iris$Species == "setosa", ]
mean(setosa$Petal.Length)
```

```
## [1] 1.462
```

```r
versicolor = iris[iris$Species == "versicolor", ]
mean(versicolor$Petal.Length)
```

```
## [1] 4.26
```

Prove that this is the OLS model by fitting an appropriate `lm` and then using the predict function to verify you get the same answers as you wrote previously.

```r
iris_lm = lm(Petal.Length ~ Species, data = iris2)
iris_lm
```

```
##
## Call:
## lm(formula = Petal.Length ~ Species, data = iris2)
##
## Coefficients:
##       (Intercept)  Speciesversicolor
##             1.462              2.798
```

```r
predict(iris_lm, data.frame(Species = "setosa"))
```

```
##     1
## 1.462
```

```r
predict(iris_lm, data.frame(Species = "versicolor"))
```

```
##    1
## 4.26
```