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] 0.88378238 0.36972179 0.07176939 0.95750058 0.05950548 0.78023393
##  [7] 0.91358867 0.52847378 0.84638218 0.29880908 0.32159353 0.35077350
## [13] 0.26775541 0.60411849 0.89746416 0.19399546 0.83562078 0.61667994
## [19] 0.06928716 0.49461156
```

```
beta_0 = 3
beta_1 = -2
```

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

```
##  [1] 1.6006477 2.2147082 2.2873566 0.9165754 2.9481029 1.9761075 1.0689102
##  [8] 1.3580338 1.2244187 2.3488318 1.9057780 2.8132407 2.8485919 2.0720249
## [15] 1.4316933 3.2499953 2.1253546 2.1143346 2.9718556 2.2344761
```

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] -1.776447
```

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

```
## [1] 3.0059
```

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
##       3.006       -1.776
```

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

```
## (Intercept)            x
##    3.005900   -1.776447
```

```
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
## 33    65.5  63.2
## 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
## 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
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## 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
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## 78    67.5   64.2
## 79    67.5   64.2
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## 81    67.5   64.2
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## 86    66.5   64.2
## 87    66.5   64.2
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## 90    66.5   64.2
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## 91   65.5  64.2
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## 96   64.5  64.2
## 97   64.5  64.2
## 98   64.5  64.2
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## 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
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## 145    65.5   65.2
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## 147    65.5   65.2
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## 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
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## 405   64.0   67.2
## 406   64.0   67.2
## 407   72.5   68.2
## 408   71.5   68.2
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## 411   70.5   68.2
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## 469    68.5    68.2
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## 529   71.5   69.2
## 530   71.5   69.2
## 531   71.5   69.2
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## 577    69.5   69.2
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## 595    68.5   69.2
## 596    68.5   69.2
## 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
```

```
## 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`.

```r
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
```

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

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

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

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

```r
#The height summaries for the parents column and child column appear very similar.
#The parents column represents the mean of the mother and father's height.
#Both columns have comparable heights for Q1-Q3, median and mean. n is 928 and p is 2.
```

TO-DO

19

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

```
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?

```
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 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
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##  [36] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
##  [43] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
##  [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
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## [113] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
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## [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
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## [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
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## [190] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [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
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## [463] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
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## [498] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
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## [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
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## [568] 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847 68.08847
## [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
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## [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
```

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

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

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

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

```
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.

```
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
## 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
```

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## 141   66.5   65.2
## 142   66.5   65.2
## 143   65.5   65.2
## 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
```

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## 195    68.5    66.2
## 196    68.5    66.2
## 197    68.5    66.2
## 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
```

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## 249   66.5   66.2
## 250   66.5   66.2
## 251   65.5   66.2
## 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
## 291   69.5   67.2
## 292   69.5   67.2
## 293   69.5   67.2
## 294   69.5   67.2
## 295   69.5   67.2
## 296   69.5   67.2
## 297   69.5   67.2
## 298   69.5   67.2
## 299   69.5   67.2
## 300   69.5   67.2
## 301   69.5   67.2
## 302   69.5   67.2
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## 303    68.5   67.2
## 304    68.5   67.2
## 305    68.5   67.2
## 306    68.5   67.2
## 307    68.5   67.2
## 308    68.5   67.2
## 309    68.5   67.2
## 310    68.5   67.2
## 311    68.5   67.2
## 312    68.5   67.2
## 313    68.5   67.2
## 314    68.5   67.2
## 315    68.5   67.2
## 316    68.5   67.2
## 317    68.5   67.2
## 318    68.5   67.2
## 319    68.5   67.2
## 320    68.5   67.2
## 321    68.5   67.2
## 322    68.5   67.2
## 323    68.5   67.2
## 324    68.5   67.2
## 325    68.5   67.2
## 326    68.5   67.2
## 327    68.5   67.2
## 328    68.5   67.2
## 329    68.5   67.2
## 330    68.5   67.2
## 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
## 336    67.5   67.2
## 337    67.5   67.2
## 338    67.5   67.2
## 339    67.5   67.2
## 340    67.5   67.2
## 341    67.5   67.2
## 342    67.5   67.2
## 343    67.5   67.2
## 344    67.5   67.2
## 345    67.5   67.2
## 346    67.5   67.2
## 347    67.5   67.2
## 348    67.5   67.2
## 349    67.5   67.2
## 350    67.5   67.2
## 351    67.5   67.2
## 352    67.5   67.2
## 353    67.5   67.2
## 354    67.5   67.2
## 355    67.5   67.2
## 356    67.5   67.2
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## 357    67.5   67.2
## 358    67.5   67.2
## 359    67.5   67.2
## 360    67.5   67.2
## 361    67.5   67.2
## 362    67.5   67.2
## 363    67.5   67.2
## 364    67.5   67.2
## 365    67.5   67.2
## 366    67.5   67.2
## 367    67.5   67.2
## 368    67.5   67.2
## 369    67.5   67.2
## 370    67.5   67.2
## 371    67.5   67.2
## 372    66.5   67.2
## 373    66.5   67.2
## 374    66.5   67.2
## 375    66.5   67.2
## 376    66.5   67.2
## 377    66.5   67.2
## 378    66.5   67.2
## 379    66.5   67.2
## 380    66.5   67.2
## 381    66.5   67.2
## 382    66.5   67.2
## 383    66.5   67.2
## 384    66.5   67.2
## 385    66.5   67.2
## 386    66.5   67.2
## 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
```

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## 411    70.5   68.2
## 412    70.5   68.2
## 413    70.5   68.2
## 414    70.5   68.2
## 415    70.5   68.2
## 416    70.5   68.2
## 417    70.5   68.2
## 418    70.5   68.2
## 419    70.5   68.2
## 420    70.5   68.2
## 421    70.5   68.2
## 422    70.5   68.2
## 423    69.5   68.2
## 424    69.5   68.2
## 425    69.5   68.2
## 426    69.5   68.2
## 427    69.5   68.2
## 428    69.5   68.2
## 429    69.5   68.2
## 430    69.5   68.2
## 431    69.5   68.2
## 432    69.5   68.2
## 433    69.5   68.2
## 434    69.5   68.2
## 435    69.5   68.2
## 436    69.5   68.2
## 437    69.5   68.2
## 438    69.5   68.2
## 439    69.5   68.2
## 440    69.5   68.2
## 441    69.5   68.2
## 442    69.5   68.2
## 443    68.5   68.2
## 444    68.5   68.2
## 445    68.5   68.2
## 446    68.5   68.2
## 447    68.5   68.2
## 448    68.5   68.2
## 449    68.5   68.2
## 450    68.5   68.2
## 451    68.5   68.2
## 452    68.5   68.2
## 453    68.5   68.2
## 454    68.5   68.2
## 455    68.5   68.2
## 456    68.5   68.2
## 457    68.5   68.2
## 458    68.5   68.2
## 459    68.5   68.2
## 460    68.5   68.2
## 461    68.5   68.2
## 462    68.5   68.2
## 463    68.5   68.2
## 464    68.5   68.2
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## 465   68.5   68.2
## 466   68.5   68.2
## 467   68.5   68.2
## 468   68.5   68.2
## 469   68.5   68.2
## 470   68.5   68.2
## 471   68.5   68.2
## 472   68.5   68.2
## 473   68.5   68.2
## 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
## 484   67.5   68.2
## 485   67.5   68.2
## 486   67.5   68.2
## 487   67.5   68.2
## 488   67.5   68.2
## 489   67.5   68.2
## 490   67.5   68.2
## 491   67.5   68.2
## 492   67.5   68.2
## 493   67.5   68.2
## 494   67.5   68.2
## 495   67.5   68.2
## 496   67.5   68.2
## 497   67.5   68.2
## 498   67.5   68.2
## 499   67.5   68.2
## 500   67.5   68.2
## 501   67.5   68.2
## 502   67.5   68.2
## 503   67.5   68.2
## 504   67.5   68.2
## 505   66.5   68.2
## 506   66.5   68.2
## 507   66.5   68.2
## 508   66.5   68.2
## 509   66.5   68.2
## 510   66.5   68.2
## 511   66.5   68.2
## 512   66.5   68.2
## 513   66.5   68.2
## 514   66.5   68.2
## 515   66.5   68.2
## 516   66.5   68.2
## 517   66.5   68.2
## 518   66.5   68.2
```

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## 519   65.5   68.2
## 520   65.5   68.2
## 521   65.5   68.2
## 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
## 532   71.5   69.2
## 533   71.5   69.2
## 534   70.5   69.2
## 535   70.5   69.2
## 536   70.5   69.2
## 537   70.5   69.2
## 538   70.5   69.2
## 539   70.5   69.2
## 540   70.5   69.2
## 541   70.5   69.2
## 542   70.5   69.2
## 543   70.5   69.2
## 544   70.5   69.2
## 545   70.5   69.2
## 546   70.5   69.2
## 547   70.5   69.2
## 548   70.5   69.2
## 549   70.5   69.2
## 550   70.5   69.2
## 551   70.5   69.2
## 552   69.5   69.2
## 553   69.5   69.2
## 554   69.5   69.2
## 555   69.5   69.2
## 556   69.5   69.2
## 557   69.5   69.2
## 558   69.5   69.2
## 559   69.5   69.2
## 560   69.5   69.2
## 561   69.5   69.2
## 562   69.5   69.2
## 563   69.5   69.2
## 564   69.5   69.2
## 565   69.5   69.2
## 566   69.5   69.2
## 567   69.5   69.2
## 568   69.5   69.2
## 569   69.5   69.2
## 570   69.5   69.2
## 571   69.5   69.2
## 572   69.5   69.2
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## 573   69.5   69.2
## 574   69.5   69.2
## 575   69.5   69.2
## 576   69.5   69.2
## 577   69.5   69.2
## 578   69.5   69.2
## 579   69.5   69.2
## 580   69.5   69.2
## 581   69.5   69.2
## 582   69.5   69.2
## 583   69.5   69.2
## 584   69.5   69.2
## 585   68.5   69.2
## 586   68.5   69.2
## 587   68.5   69.2
## 588   68.5   69.2
## 589   68.5   69.2
## 590   68.5   69.2
## 591   68.5   69.2
## 592   68.5   69.2
## 593   68.5   69.2
## 594   68.5   69.2
## 595   68.5   69.2
## 596   68.5   69.2
## 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
```

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## 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
## 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
```

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## 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
```

```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 88 rows containing missing values (geom_point).
```
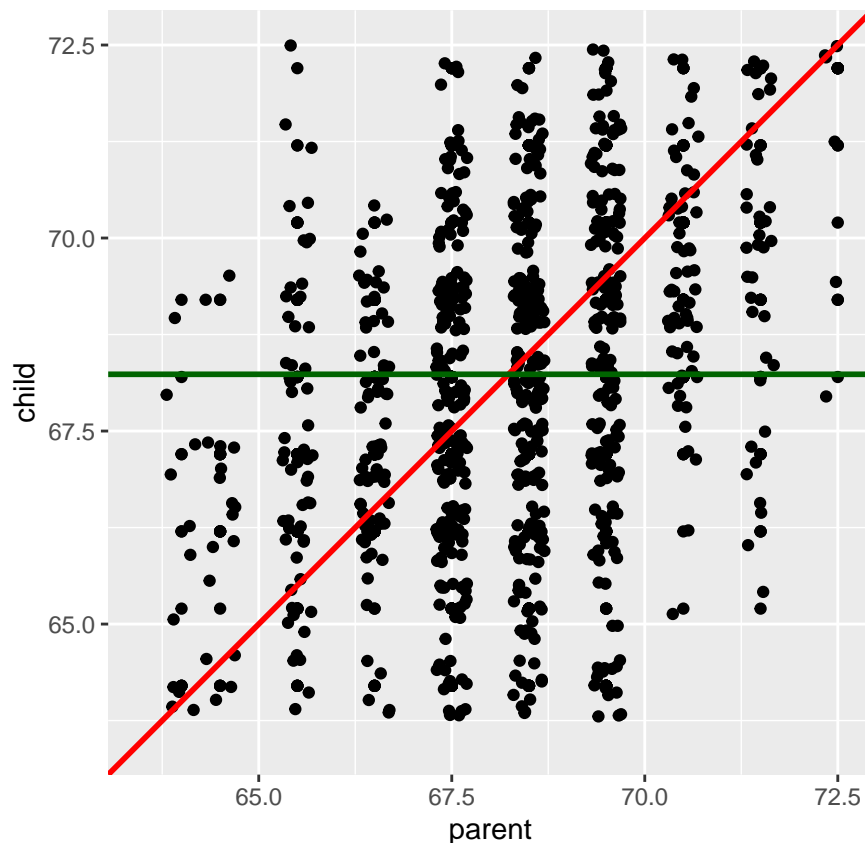
Fill in the following sentence:

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)
```

```
Xy = lm(y~x)
```
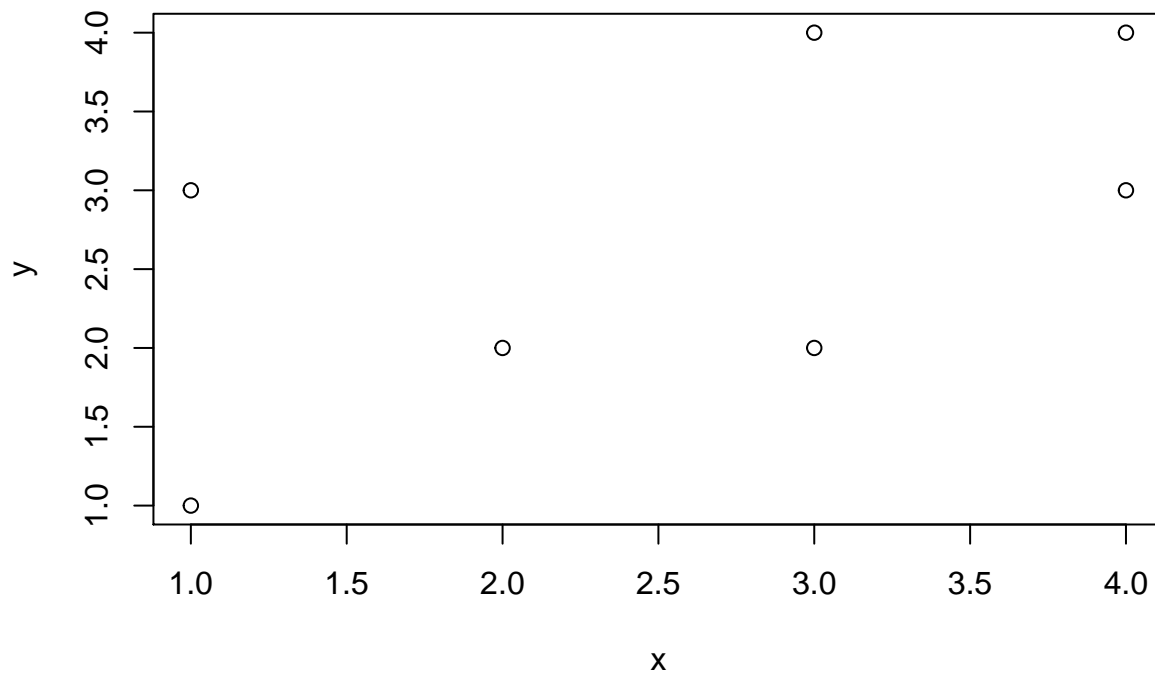
```
summary(Xy)$r.squared #the R^2
```

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

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

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

```
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.

```
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)
```

```
Xy = lm(y~x)
```
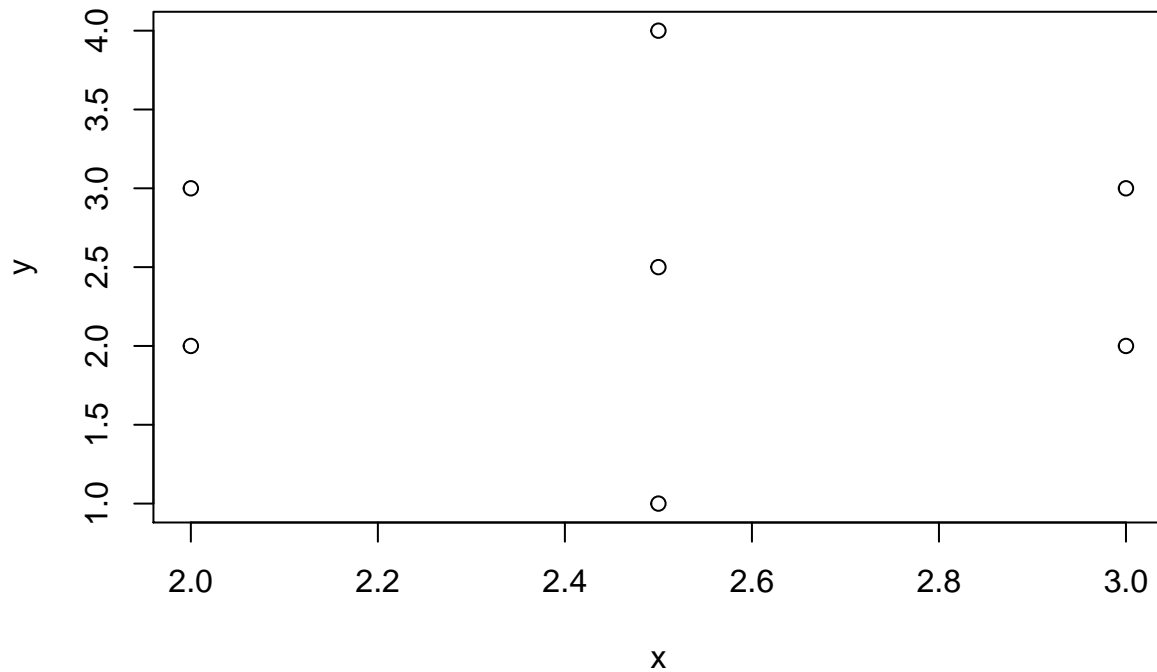
```
summary(Xy)$r.squared #the R^2
```

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

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

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

```
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
```

```
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.

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

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

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

```
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.

```
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
```

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

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

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

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