

PS1_Rmarkdown_Output_Bi610

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```
library(tidyverse)
```

```
## Loading tidyverse: ggplot2
## Loading tidyverse: tibble
## Loading tidyverse: tidyr
## Loading tidyverse: readr
## Loading tidyverse: purrr
## Loading tidyverse: dplyr
```

```
## Conflicts with tidy packages -----
```

```
## filter(): dplyr, stats
## lag():    dplyr, stats
```

```
library(magrittr)
```

```
##
## Attaching package: 'magrittr'
```

```
## The following object is masked from 'package:purrr':
##
##      set_names
```

```
## The following object is masked from 'package:tidyr':
##
##      extract
```

```
library(pander)
```

Problem 1. Download and examine the data set 'SticklebackRNAseq.csv'

List the variables including their characteristics (i.e. categorical, continuous, response, independent)

```

#setwd("/Users/Deweese/Desktop/Advanced_Stats_with_R")
#getwd

# Read in dataset
RNA_data <- read.table("HW_RNAseq.csv", header = TRUE, sep = ",")

# setting categorical (independent) variables
Cat_variable <- data.frame(RNA_data[,1:4])

# setting response variables
response_variable <- data.frame(RNA_data[,5:14])

```

Examine each continuous variable to determine its distribution using histograms, and put these into a single, multi-panel figure.

```

library(ggplot2)
# creating a new orientation of data set that compiles rows to columns
converted_RNA_seq_data <- reshape2::melt(response_variable)

```

```
## No id variables; using all as measure variables
```

```

# plotting each gene column via histogram

# setting value as an representation of gene expression levels
ggplot(data = converted_RNA_seq_data, aes(value)) +

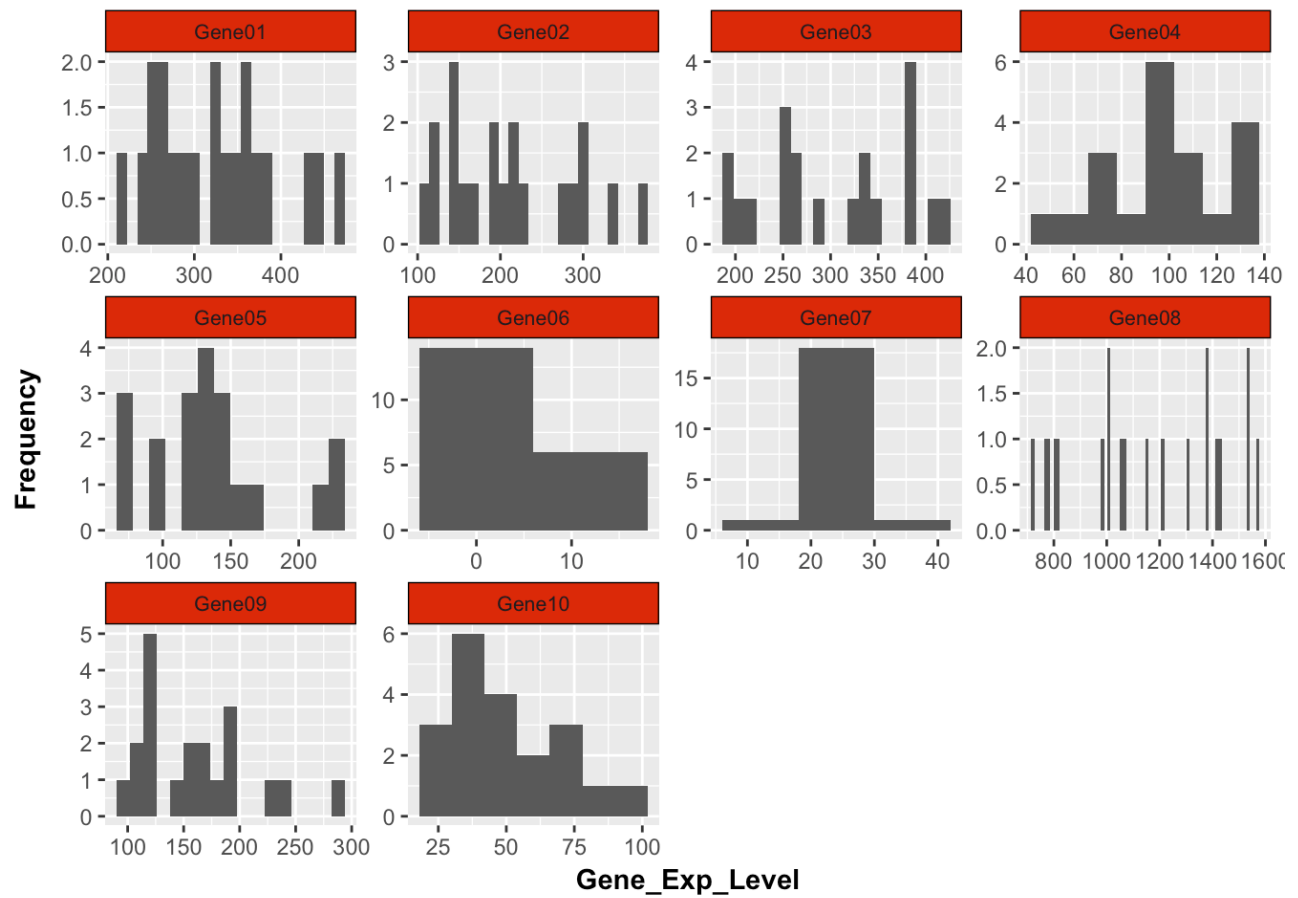
  # Setting variable to be the header title "gene" and its corresponding number
  facet_wrap(~variable, scales = 'free') +

  # setting width to 12 for each histogram
  geom_histogram(binwidth = 12) +

  # adjusting the theme of each figure by adjusting the text size, colors, etc.
  theme(strip.text.x = element_text(size = 8, angle = 0),
        strip.text.y = element_text(size = 10, face = "bold"),
        strip.background = element_rect(colour = "black", fill = "red")) +

  # adding labels to both X and Y variables
  labs(x=expression(bold("Gene_Exp_Level")), y=expression(bold("Frequency")))

```



Transform all original continuous variables to z-scores and plot the distribution for just two genes.

```
# Transform all original continuous variables to z-scores and plot the distribution for just two genes
```

```
response_variable$gene_1_z_score <- (response_variable$Gene01-mean(response_variable$Gene01)) / sd(response_variable$Gene01)
response_variable$gene_2_z_score <- (response_variable$Gene02-mean(response_variable$Gene02)) / sd(response_variable$Gene02)
response_variable$gene_3_z_score <- (response_variable$Gene03-mean(response_variable$Gene03)) / sd(response_variable$Gene03)
response_variable$gene_4_z_score <- (response_variable$Gene04-mean(response_variable$Gene04)) / sd(response_variable$Gene04)
response_variable$gene_5_z_score <- (response_variable$Gene05-mean(response_variable$Gene05)) / sd(response_variable$Gene05)
response_variable$gene_6_z_score <- (response_variable$Gene06-mean(response_variable$Gene06)) / sd(response_variable$Gene06)
response_variable$gene_7_z_score <- (response_variable$Gene07-mean(response_variable$Gene07)) / sd(response_variable$Gene07)
response_variable$gene_8_z_score <- (response_variable$Gene08-mean(response_variable$Gene08)) / sd(response_variable$Gene08)
response_variable$gene_9_z_score <- (response_variable$Gene09-mean(response_variable$Gene09)) / sd(response_variable$Gene09)
response_variable$gene_10_z_score <- (response_variable$Gene10-mean(response_variable$Gene10)) / sd(response_variable$Gene10)
```

Plot Distribution of Z score for Gene 1/2

```
Gene_1_Z_Hist <- ggplot(data = response_variable, aes(gene_1_z_score)) +
  # adding density layover to histogram and setting color parameters
  geom_histogram(aes(y=..density..), colour="black", fill="white", bins = 8) +
  # adjusting transparency to hist_density
  geom_density(alpha=.3, fill = "darkseagreen2") +
  # adding labels
  labs(x=expression(bold("Z-Score")), y=expression(bold("Frequency")),
  title=expression(bold("Gene-01-Z_score")))

# setting ggplot to a vector so I can call it when plotting in same plane
Gene_2_Z_Hist <- ggplot(data = response_variable, aes(gene_2_z_score)) +
  # adding density layover to histogram and setting color parameters
  geom_histogram(aes(y=..density..), colour="black", fill="white", bins = 8) +
  # adjusting transparency to hist_density
  geom_density(alpha=.3, fill = "darkseagreen2") +
  # adding labels
  labs(x=expression(bold("Z-Score")), y=expression(bold("Frequency")), title=expression(bold("Gene-02-Z_score")))

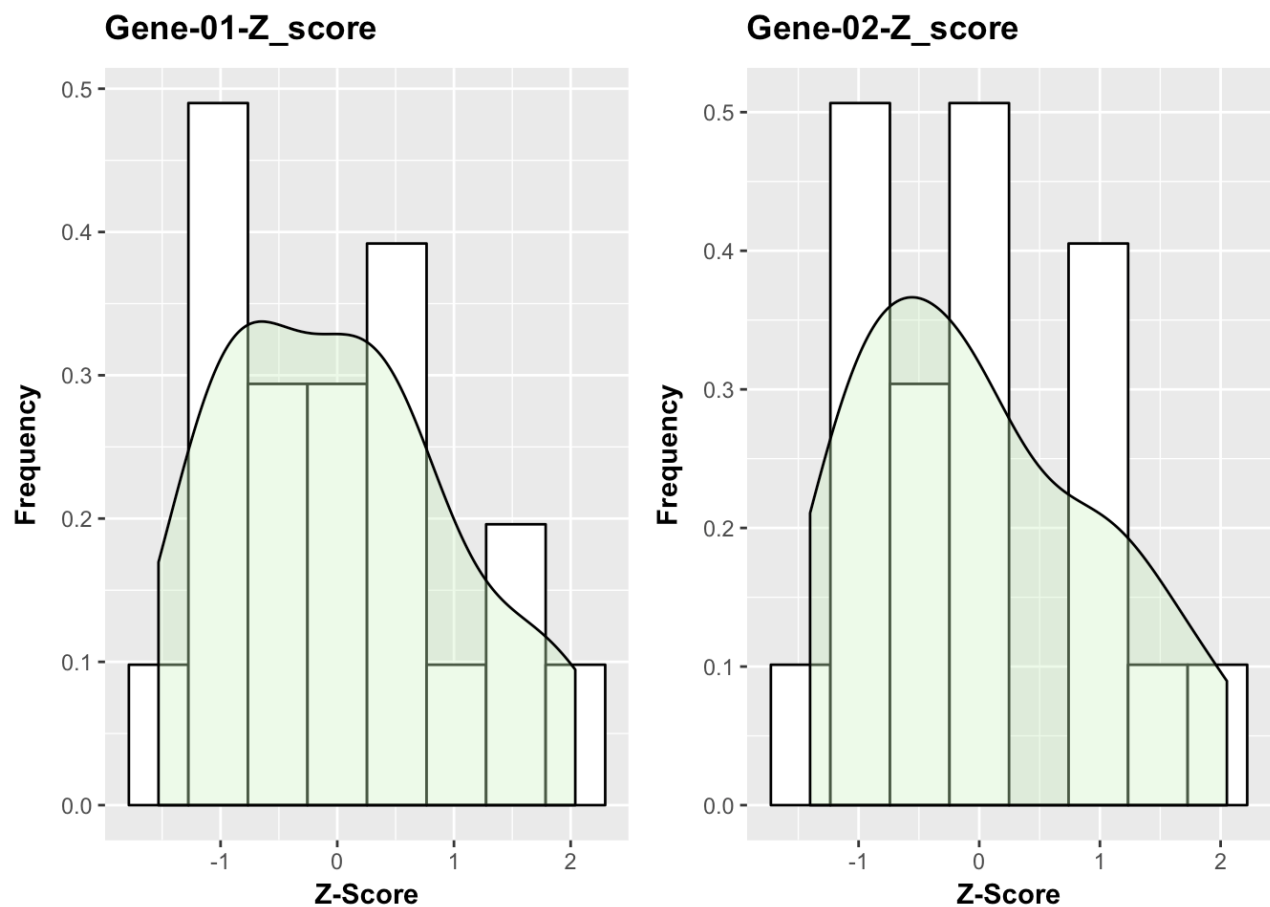
#setting package so I can plot both histograms side by side.
require(gridExtra)
```

```
## Loading required package: gridExtra
```

```
##  
## Attaching package: 'gridExtra'
```

```
## The following object is masked from 'package:dplyr':  
##  
##      combine
```

```
grid.arrange(Gene_1_Z_Hist, Gene_2_Z_Hist, ncol=2)
```



Create boxplots of the original data and the z-scores for these two genes, split by population, treatment and sex. Use colors in your figures. Again, make a single, multi-panel figure.

```

RNA_data$gene1_zscore <- response_variable$gene_1_z_score

RNA_data$gene2_zscore <- response_variable$gene_2_z_score

# using interaction to categorize and filter through all possible combination of sex and treatment levels
RNA_data$sex_treatment_combination <- interaction(RNA_data$Sex, RNA_data$Treatment)

Gene_1_boxplot_Z <- ggplot(data = RNA_data, aes(y = gene1_zscore, x = sex_treatment_combination, fill=Population)) + geom_boxplot() + scale_fill_manual(values=c("slateblue1", "olivedrab1")) + theme(axis.text.x = element_text(angle = 40, vjust = 0.3, size = 6)) +
  labs(x=expression(bold("Sex/Treatment")), y=expression(bold("Gene1_Z-Score")),
  , title=expression(bold("Gene1_Z-score_to_Sex/Treatment"))))

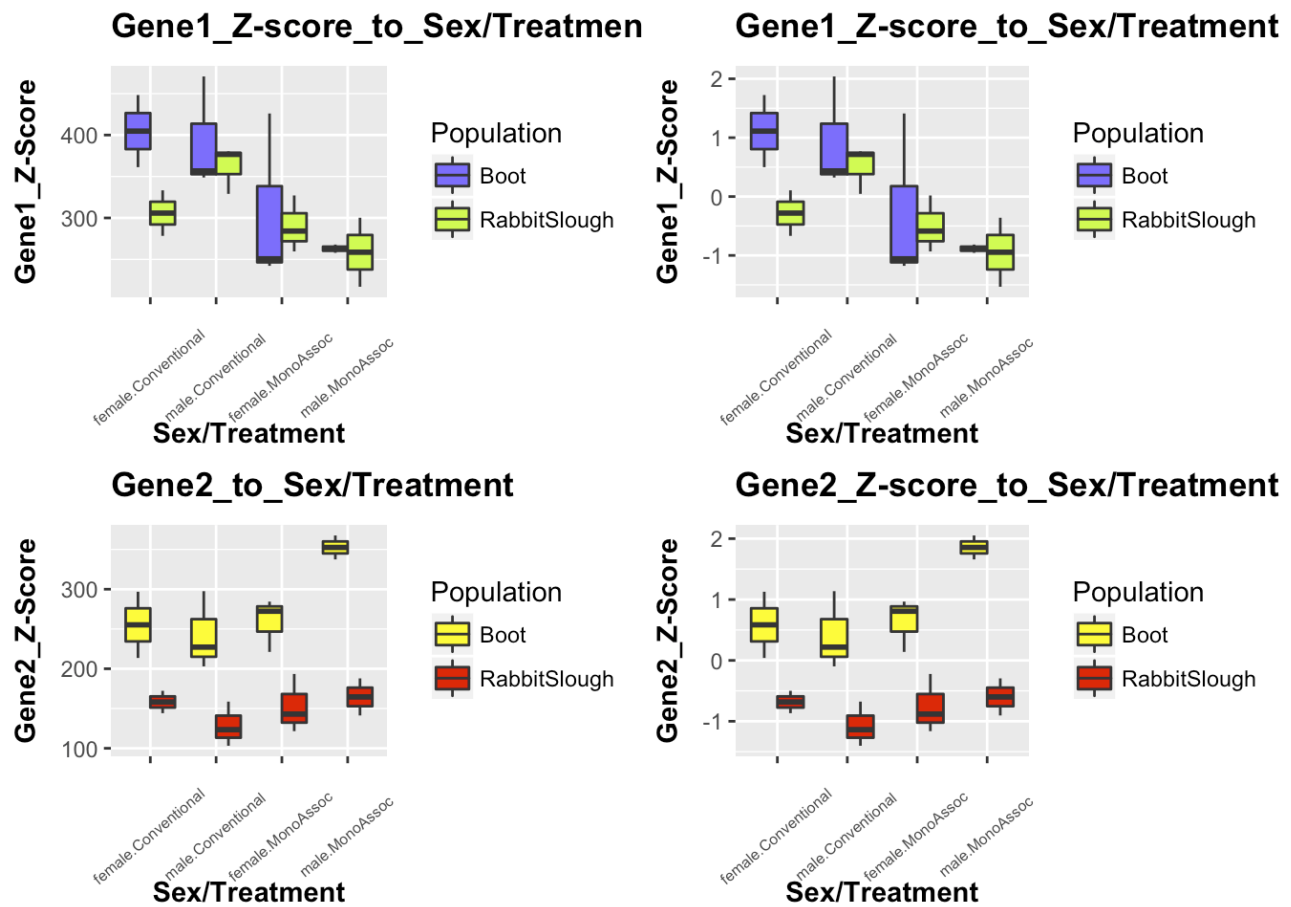
Gene_2_boxplot_Z <- ggplot(data = RNA_data, aes(y = gene2_zscore, x = sex_treatment_combination, fill=Population)) + geom_boxplot() + scale_fill_manual(values=c("yellow1", "red1")) + theme(axis.text.x = element_text(angle = 40, vjust = 0.3, size = 6)) +
  labs(x=expression(bold("Sex/Treatment")), y=expression(bold("Gene2_Z-Score")),
  , title=expression(bold("Gene2_Z-score_to_Sex/Treatment"))))

Gene_1_boxplot <- ggplot(data = RNA_data, aes(y = Gene01, x = sex_treatment_combination, fill=Population)) + geom_boxplot() + scale_fill_manual(values=c("slateblue1", "olivedrab1")) + theme(axis.text.x = element_text(angle = 40, vjust = 0.3, size = 6)) +
  labs(x=expression(bold("Sex/Treatment")), y=expression(bold("Gene1_Z-Score")),
  , title=expression(bold("Gene1_Z-score_to_Sex/Treatment"))))

Gene_2_boxplot <- ggplot(data = RNA_data, aes(y = Gene02, x = sex_treatment_combination, fill=Population)) + geom_boxplot() + scale_fill_manual(values=c("yellow1", "red1")) + theme(axis.text.x = element_text(angle = 40, vjust = 0.3, size = 6)) +
  labs(x=expression(bold("Sex/Treatment")), y=expression(bold("Gene2_Z-Score")),
  , title=expression(bold("Gene2_to_Sex/Treatment"))))

require(gridExtra)
grid.arrange(Gene_1_boxplot, Gene_1_boxplot_Z, Gene_2_boxplot, Gene_2_boxplot_Z)

```



Calculate descriptive statistics (mean, variance, standard deviation) for each population for each variable, for each treatment for each variable, and for each sex for each variable. Compile these into a table.

```
Gene1_summary <- group_by(RNA_data, Sex, Treatment, Population) %>%
  summarise_at("Gene01", .funs = c(Variance = "var", Mean="mean", SD="sd")) %>%
  write.csv('Gene_1_Summary_Stats.csv', row.names = F)

# setting table for mean, variance, and SD for the categorical vairables
Gene2_summary <- group_by(RNA_data, Sex, Treatment, Population) %>%
  summarise_at("Gene02", .funs = c(Variance = "var", Mean="mean", SD="sd")) %>%
  write.csv('Gene_2_Summary_Stats.csv', row.names = F)

# setting table for mean, variance, and SD for the categorical vairables
Gene3_summary <- group_by(RNA_data, Sex, Treatment, Population) %>%
  summarise_at("Gene03", .funs = c(Variance = "var", Mean="mean", SD="sd")) %>%
  write.csv('Gene_3_Summary_Stats.csv', row.names = F)

# setting table for mean, variance, and SD for the categorical vairables
Gene4_summary <- group_by(RNA_data, Sex, Treatment, Population) %>%
  summarise_at("Gene04", .funs = c(Variance = "var", Mean="mean", SD="sd")) %>%
  write.csv('Gene_4_Summary_Stats.csv', row.names = F)

# setting table for mean, variance, and SD for the categorical vairables
Gene5_summary <- group_by(RNA_data, Sex, Treatment, Population) %>%
  summarise_at("Gene05", .funs = c(Variance = "var", Mean="mean", SD="sd")) %>%
  write.csv('Gene_5_Summary_Stats.csv', row.names = F)

# setting table for mean, variance, and SD for the categorical vairables
Gene6_summary <- group_by(RNA_data, Sex, Treatment, Population) %>%
  summarise_at("Gene06", .funs = c(Variance = "var", Mean="mean", SD="sd")) %>%
  write.csv('Gene_6_Summary_Stats.csv', row.names = F)

# setting table for mean, variance, and SD for the categorical vairables
Gene7_summary <- group_by(RNA_data, Sex, Treatment, Population) %>%
  summarise_at("Gene07", .funs = c(Variance = "var", Mean="mean", SD="sd")) %>%
  write.csv('Gene_7_Summary_Stats.csv', row.names = F)

# setting table for mean, variance, and SD for the categorical vairables
Gene8_summary <- group_by(RNA_data, Sex, Treatment, Population) %>%
  summarise_at("Gene08", .funs = c(Variance = "var", Mean="mean", SD="sd")) %>%
  write.csv('Gene_8_Summary_Stats.csv', row.names = F)

# setting table for mean, variance, and SD for the categorical vairables
Gene9_summary <- group_by(RNA_data, Sex, Treatment, Population) %>%
  summarise_at("Gene09", .funs = c(Variance = "var", Mean="mean", SD="sd")) %>%
  write.csv('Gene_9_Summary_Stats.csv', row.names = F)

# setting table for mean, variance, and SD for the categorical vairables
Gene10_summary <- group_by(RNA_data, Sex, Treatment, Population) %>%
  summarise_at("Gene10", .funs = c(Variance = "var", Mean="mean", SD="sd")) %>%
  write.csv('Gene_10_Summary_Stats.csv', row.names = F)
```


Problem 2. Write an R script to calculate the Standard Error (SE) and 95% confidence interval (CI) of the mean for each gene from above using both the parametric approach as well as the resampling approach that you learned in class. Assemble your results for all genes in a single table. Comment on whether the two approaches give you approximately the same result, and interpret your observation. In addition, modify the resampling approach to calculate the SE of the variance for all 10 genes, and add those to the table as well.

```

# setting parametric function for SE and 95% conf. interval (assuming distribution is normal = PA)
parametric_approach_func <- function(value){
  # equation for variable that establishes standard error (value represents gene integers in table)
  Gene_Standard_err <- sd(value)/sqrt(20)
  # equation for variable that establishes marginal error (0.25% & 1 - sample size) times value of GSE
  Gene_Margin_err <- qt(.025,19)*Gene_Standard_err
  # Factoring in lower bound of distribution model in this variable (0.25%)
  lower_bound <- mean(value) - Gene_Margin_err
  # factoring in upper bound of distribution model in this variable (0.25%)
  upper_bound <- mean(value) + Gene_Margin_err
  # setting a list so it prints more than one variable when calling my function
  stats_list <- c(Gene_Standard_err, lower_bound, upper_bound)
  return(stats_list)
}

# This is where I calculate the parametric value function onto the 10 established gene columns set in RNA datatable

PA_Gene1_mean <- parametric_approach_func(RNA_data$Gene01)
PA_Gene2_mean <- parametric_approach_func(RNA_data$Gene02)
PA_Gene3_mean <- parametric_approach_func(RNA_data$Gene03)
PA_Gene4_mean <- parametric_approach_func(RNA_data$Gene04)
PA_Gene5_mean <- parametric_approach_func(RNA_data$Gene05)
PA_Gene6_mean <- parametric_approach_func(RNA_data$Gene06)
PA_Gene7_mean <- parametric_approach_func(RNA_data$Gene07)
PA_Gene8_mean <- parametric_approach_func(RNA_data$Gene08)
PA_Gene9_mean <- parametric_approach_func(RNA_data$Gene09)
PA_Gene10_mean <- parametric_approach_func(RNA_data$Gene10)

parametric_approach_table <- rbind(PA_Gene1_mean, PA_Gene2_mean, PA_Gene3_mean,
PA_Gene4_mean, PA_Gene5_mean, PA_Gene6_mean, PA_Gene7_mean, PA_Gene8_mean, PA_Gene9_mean, PA_Gene10_mean)

#View(parametric_approach_table)

# Bootstrap approach add-on

bootstrap_function <- function(value){
  samples = 1000
  sample_size = 20

  # creating a matrix of the 1000 trials among the 20 samples

```

```

boot_sample_matrix <- matrix(sample(value, size = samples * sample_size, repl
ace = TRUE),samples, sample_size)

# calculating the mean for each 1000 samples with 1 row
boot_stats <- apply(boot_sample_matrix, 1, mean)

Gene_Standard_err <- sd(boot_stats)
# equation for variable that establishes marginal error (0.25% & 1 - sample s
ize) times value of GSE
Gene_Margin_err <- qt(.025,19)*Gene_Standard_err
# Factoring in lower bound of distribution model in this variable (0.25%)
lower_bound <- mean(value) - Gene_Margin_err
# factoring in upper bound of distribution model in this variable (0.25%)
upper_bound <- mean(value) + Gene_Margin_err
# setting a list so it prints more than one variable when calling my function
stats_list <- c(Gene_Standard_err, lower_bound, upper_bound)
return(stats_list)
}

```

```

Boot_Gene1_mean <- bootstrap_function(RNA_data$Gene01)
Boot_Gene2_mean <- bootstrap_function(RNA_data$Gene02)
Boot_Gene3_mean <- bootstrap_function(RNA_data$Gene03)
Boot_Gene4_mean <- bootstrap_function(RNA_data$Gene04)
Boot_Gene5_mean <- bootstrap_function(RNA_data$Gene05)
Boot_Gene6_mean <- bootstrap_function(RNA_data$Gene06)
Boot_Gene7_mean <- bootstrap_function(RNA_data$Gene07)
Boot_Gene8_mean <- bootstrap_function(RNA_data$Gene08)
Boot_Gene9_mean <- bootstrap_function(RNA_data$Gene09)
Boot_Gene10_mean <- bootstrap_function(RNA_data$Gene10)

```

```

Boot_strap_table <- rbind(parametric_approach_table, Boot_Gene1_mean, Boot_Gene
2_mean, Boot_Gene3_mean, Boot_Gene4_mean, Boot_Gene5_mean, Boot_Gene6_mean, Boo
t_Gene7_mean, Boot_Gene8_mean, Boot_Gene9_mean, Boot_Gene10_mean)

```

```

bootstrap_var_function <- function(value){
  samples = 1000
  sample_size = 20

  # creating a matrix of the 1000 trials among the 20 samples
  boot_sample_matrix <- matrix(sample(value, size = samples * sample_size, repl
ace = TRUE),samples, sample_size)

  # calculating the mean for each 1000 samples with 1 row
  boot_stats <- apply(boot_sample_matrix, 1, var)

  Gene_Standard_err <- sd(boot_stats)
  # equation for variable that establishes marginal error (0.25% & 1 - sample s

```

```

ize) times value of GSE
Gene_Margin_err <- qt(.025,19)*Gene_Standard_err
# Factoring in lower bound of distribution model in this variable (0.25%)
lower_bound <- mean(value) - Gene_Margin_err
# factoring in upper bound of distribution model in this variable (0.25%)
upper_bound <- mean(value) + Gene_Margin_err
# setting a list so it prints more than one variable when calling my function
stats_list <- c(Gene_Standard_err, lower_bound, upper_bound)
return(stats_list)
}

Boot_Gene1_var <- bootstrap_var_function(RNA_data$Gene01)
Boot_Gene2_var <- bootstrap_var_function(RNA_data$Gene02)
Boot_Gene3_var <- bootstrap_var_function(RNA_data$Gene03)
Boot_Gene4_var <- bootstrap_var_function(RNA_data$Gene04)
Boot_Gene5_var <- bootstrap_var_function(RNA_data$Gene05)
Boot_Gene6_var <- bootstrap_var_function(RNA_data$Gene06)
Boot_Gene7_var <- bootstrap_var_function(RNA_data$Gene07)
Boot_Gene8_var <- bootstrap_var_function(RNA_data$Gene08)
Boot_Gene9_var <- bootstrap_var_function(RNA_data$Gene09)
Boot_Gene10_var <- bootstrap_var_function(RNA_data$Gene10)

boot_var_table <- rbind(Boot_strap_table, Boot_Gene1_var, Boot_Gene2_var, Boot_
Gene3_var, Boot_Gene4_var, Boot_Gene5_var, Boot_Gene6_var, Boot_Gene7_var, Boot_
_Gene8_var, Boot_Gene9_var, Boot_Gene10_var)

colnames(boot_var_table) <- c("Standard Error", "Mean", "Variance")

pander(boot_var_table)

```

	Standard Error	Mean	Variance
PA_Gene1_mean	15.88	359	292.6
PA_Gene2_mean	17.11	246.3	174.7
PA_Gene3_mean	16.99	340.9	269.8
PA_Gene4_mean	5.138	108.5	86.99
PA_Gene5_mean	10.41	157.9	114.3
PA_Gene6_mean	0.8385	7.598	4.088
PA_Gene7_mean	0.9658	25.96	21.92
PA_Gene8_mean	63.69	1281	1014
PA_Gene9_mean	11.42	185.1	137.3
PA_Gene10_mean	4.701	59.49	39.81

	Standard Error	Mean	Variance
Boot_Gene1_mean	15.53	358.3	293.3
Boot_Gene2_mean	16.83	245.7	175.3
Boot_Gene3_mean	16.35	339.6	271.1
Boot_Gene4_mean	5.078	108.4	87.11
Boot_Gene5_mean	10.26	157.6	114.6
Boot_Gene6_mean	0.8056	7.529	4.157
Boot_Gene7_mean	0.9319	25.89	21.99
Boot_Gene8_mean	64.36	1282	1013
Boot_Gene9_mean	10.81	183.8	138.6
Boot_Gene10_mean	4.383	58.82	40.47
Boot_Gene1_var	1238	2917	-2266
Boot_Gene2_var	1377	3093	-2672
Boot_Gene3_var	1093	2593	-1982
Boot_Gene4_var	121.9	352.8	-157.3
Boot_Gene5_var	631.9	1459	-1187
Boot_Gene6_var	5.552	17.46	-5.778
Boot_Gene7_var	3.569	31.41	16.47
Boot_Gene8_var	14913	32360	-30065
Boot_Gene9_var	831.5	1902	-1579
Boot_Gene10_var	117.9	296.4	-197.1

Plot these raw data and determine how they are distributed. Using this sample, and the equation from your book for this particular sampling distribution, calculate the mean number of trees per plot and the variance in the number of trees per plot. How do these results compare, and why is this question significant?

#Part 3

```
Num_of_trees_obs_in_plot <- c(0,1,2,3,4,5,6,7,8,9,10,11)
Num_of_plots_with_this_many_trees <- c(74,149,228,181,169,84,49,24,19,12,9,4)
```

#making data frame of said vectors generated above

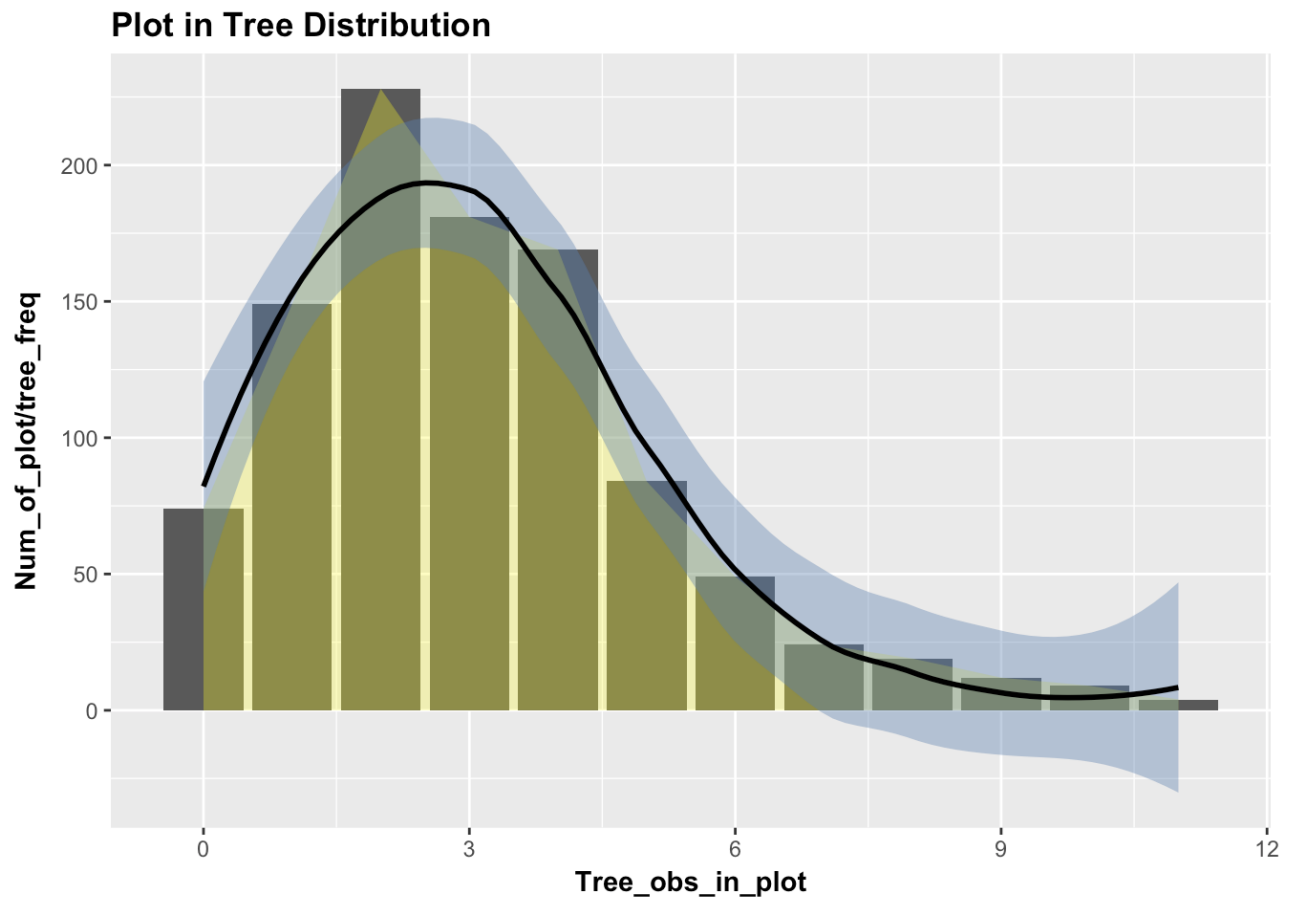
```
tree_plot_dataframe <- data.frame(Num_of_trees_obs_in_plot, Num_of_plots_with_t
his_many_trees)
mle_list <- rep.int(tree_plot_dataframe$Num_of_trees_obs_in_plot, tree_plot_dat
aframe$Num_of_plots_with_this_many_trees)
```

#calculating mean and variance

```
mean_of_trees <- mean(mle_list)
var_of_trees <- var(mle_list)
```

```
ggplot(data = tree_plot_dataframe) +
  geom_col(aes(x = tree_plot_dataframe[,1], y = tree_plot_dataframe[,2])) +
  geom_area(aes(x = tree_plot_dataframe[,1], y = tree_plot_dataframe[,2]), alph
a = 0.3, fill = "yellow") +
  geom_smooth(aes(x = tree_plot_dataframe[,1], y = tree_plot_dataframe[,2]), co
lor = "black", fill = "steel blue") +
  labs(x=expression(bold("Tree_obs_in_plot")), y=expression(bold("Num_of_plot/tre
e_freq")), title=expression(bold("Plot in Tree Distribution")))
```

```
## `geom_smooth()` using method = 'loess'
```



create a maximum likelihood function for the range of parameter values, estimate the MLE and confidence intervals

```
# set of parameters
lambda <- seq(1,10,by=0.001)

ln_poisson_probs <- log((exp(1)^-lambda)*(lambda^mean_of_trees)/factorial(mean_
of_trees))

print(ln_poisson_probs)
```

```
## [1] -2.910837 -2.908745 -2.906655 -2.904569 -2.902486 -2.900406
## [7] -2.898330 -2.896256 -2.894185 -2.892117 -2.890052 -2.887991
## [13] -2.885932 -2.883877 -2.881824 -2.879774 -2.877728 -2.875684
## [19] -2.873644 -2.871606 -2.869571 -2.867540 -2.865511 -2.863485
## [25] -2.861462 -2.859443 -2.857426 -2.855412 -2.853401 -2.851393
## [31] -2.849388 -2.847385 -2.845386 -2.843390 -2.841396 -2.839405
## [37] -2.837418 -2.835433 -2.833451 -2.831472 -2.829495 -2.827522
## [43] -2.825551 -2.823584 -2.821619 -2.819657 -2.817698 -2.815741
## [49] -2.813788 -2.811837 -2.809889 -2.807944 -2.806002 -2.804062
## [55] -2.802126 -2.800192 -2.798261 -2.796332 -2.794407 -2.792484
## [61] -2.790564 -2.788647 -2.786732 -2.784820 -2.782911 -2.781005
## [67] -2.779101 -2.777200 -2.775302 -2.773407 -2.771514 -2.769624
## [73] -2.767736 -2.765852 -2.763970 -2.762090 -2.760214 -2.758340
## [79] -2.756468 -2.754600 -2.752734 -2.750871 -2.749010 -2.747152
## [85] -2.745296 -2.743444 -2.741594 -2.739746 -2.737901 -2.736059
## [91] -2.734219 -2.732382 -2.730548 -2.728716 -2.726887 -2.725060
## [97] -2.723236 -2.721414 -2.719595 -2.717779 -2.715965 -2.714154
## [103] -2.712345 -2.710539 -2.708735 -2.706934 -2.705136 -2.703340
## [109] -2.701546 -2.699755 -2.697967 -2.696181 -2.694397 -2.692616
## [115] -2.690838 -2.689062 -2.687288 -2.685517 -2.683749 -2.681983
## [121] -2.680219 -2.678458 -2.676699 -2.674943 -2.673190 -2.671438
## [127] -2.669689 -2.667943 -2.666199 -2.664458 -2.662718 -2.660982
## [133] -2.659248 -2.657516 -2.655786 -2.654059 -2.652335 -2.650612
## [139] -2.648893 -2.647175 -2.645460 -2.643747 -2.642037 -2.640329
## [145] -2.638624 -2.636920 -2.635220 -2.633521 -2.631825 -2.630131
## [151] -2.628440 -2.626751 -2.625064 -2.623379 -2.621697 -2.620017
## [157] -2.618340 -2.616665 -2.614992 -2.613321 -2.611653 -2.609987
## [163] -2.608324 -2.606662 -2.605003 -2.603347 -2.601692 -2.600040
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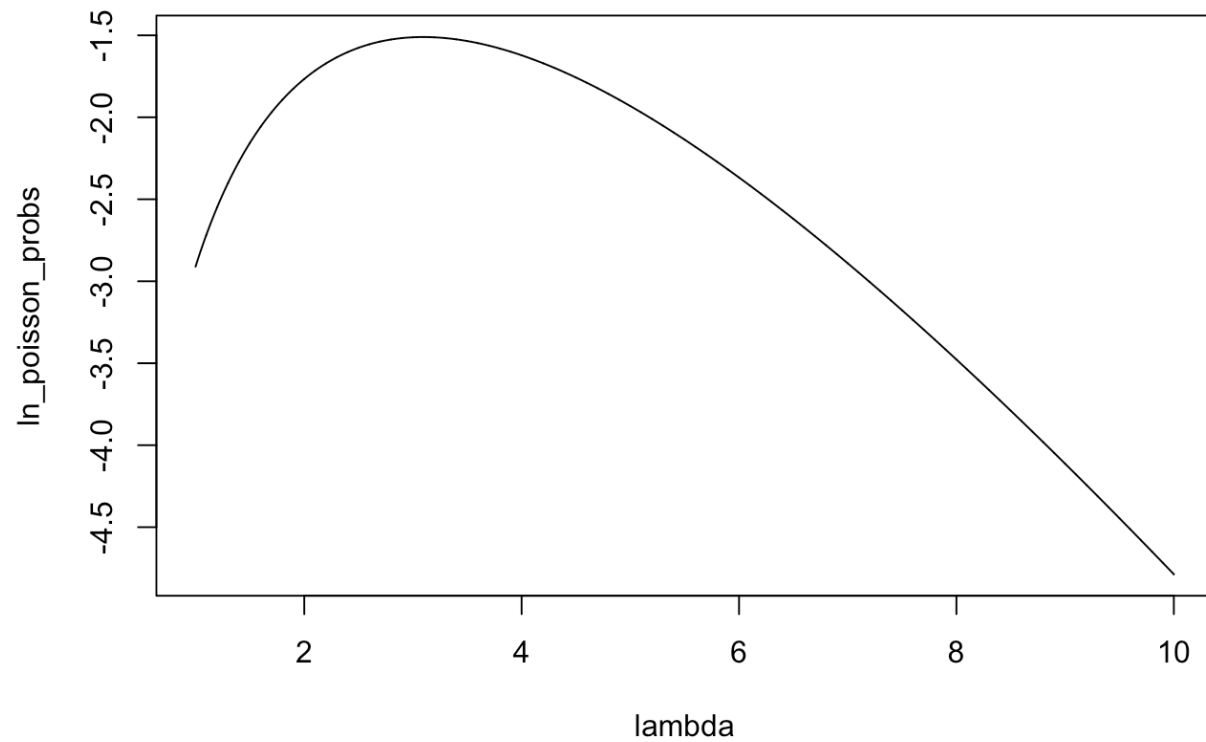
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## [8503] -4.447111 -4.447786 -4.448460 -4.449135 -4.449809 -4.450484
## [8509] -4.451158 -4.451833 -4.452508 -4.453182 -4.453857 -4.454532
## [8515] -4.455207 -4.455881 -4.456556 -4.457231 -4.457906 -4.458581
```

```
## [8521] -4.459256 -4.459931 -4.460606 -4.461281 -4.461956 -4.462632
## [8527] -4.463307 -4.463982 -4.464657 -4.465333 -4.466008 -4.466683
## [8533] -4.467359 -4.468034 -4.468710 -4.469385 -4.470061 -4.470736
## [8539] -4.471412 -4.472088 -4.472763 -4.473439 -4.474115 -4.474791
## [8545] -4.475466 -4.476142 -4.476818 -4.477494 -4.478170 -4.478846
## [8551] -4.479522 -4.480198 -4.480874 -4.481550 -4.482226 -4.482903
## [8557] -4.483579 -4.484255 -4.484931 -4.485608 -4.486284 -4.486960
## [8563] -4.487637 -4.488313 -4.488990 -4.489666 -4.490343 -4.491020
## [8569] -4.491696 -4.492373 -4.493050 -4.493726 -4.494403 -4.495080
## [8575] -4.495757 -4.496434 -4.497110 -4.497787 -4.498464 -4.499141
## [8581] -4.499818 -4.500495 -4.501173 -4.501850 -4.502527 -4.503204
## [8587] -4.503881 -4.504559 -4.505236 -4.505913 -4.506591 -4.507268
## [8593] -4.507945 -4.508623 -4.509300 -4.509978 -4.510656 -4.511333
## [8599] -4.512011 -4.512689 -4.513366 -4.514044 -4.514722 -4.515400
## [8605] -4.516077 -4.516755 -4.517433 -4.518111 -4.518789 -4.519467
## [8611] -4.520145 -4.520823 -4.521501 -4.522180 -4.522858 -4.523536
## [8617] -4.524214 -4.524892 -4.525571 -4.526249 -4.526928 -4.527606
## [8623] -4.528284 -4.528963 -4.529641 -4.530320 -4.530998 -4.531677
## [8629] -4.532356 -4.533034 -4.533713 -4.534392 -4.535071 -4.535750
## [8635] -4.536428 -4.537107 -4.537786 -4.538465 -4.539144 -4.539823
## [8641] -4.540502 -4.541181 -4.541860 -4.542539 -4.543219 -4.543898
## [8647] -4.544577 -4.545256 -4.545936 -4.546615 -4.547294 -4.547974
## [8653] -4.548653 -4.549333 -4.550012 -4.550692 -4.551371 -4.552051
## [8659] -4.552731 -4.553410 -4.554090 -4.554770 -4.555450 -4.556129
## [8665] -4.556809 -4.557489 -4.558169 -4.558849 -4.559529 -4.560209
## [8671] -4.560889 -4.561569 -4.562249 -4.562929 -4.563610 -4.564290
## [8677] -4.564970 -4.565650 -4.566331 -4.567011 -4.567691 -4.568372
## [8683] -4.569052 -4.569733 -4.570413 -4.571094 -4.571774 -4.572455
## [8689] -4.573135 -4.573816 -4.574497 -4.575178 -4.575858 -4.576539
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## [8701] -4.581306 -4.581987 -4.582668 -4.583349 -4.584030 -4.584711
## [8707] -4.585393 -4.586074 -4.586755 -4.587437 -4.588118 -4.588799
## [8713] -4.589481 -4.590162 -4.590844 -4.591525 -4.592207 -4.592888
## [8719] -4.593570 -4.594252 -4.594933 -4.595615 -4.596297 -4.596979
## [8725] -4.597660 -4.598342 -4.599024 -4.599706 -4.600388 -4.601070
## [8731] -4.601752 -4.602434 -4.603116 -4.603798 -4.604480 -4.605163
## [8737] -4.605845 -4.606527 -4.607209 -4.607892 -4.608574 -4.609256
## [8743] -4.609939 -4.610621 -4.611304 -4.611986 -4.612669 -4.613351
## [8749] -4.614034 -4.614717 -4.615399 -4.616082 -4.616765 -4.617447
## [8755] -4.618130 -4.618813 -4.619496 -4.620179 -4.620862 -4.621545
## [8761] -4.622228 -4.622911 -4.623594 -4.624277 -4.624960 -4.625643
## [8767] -4.626326 -4.627010 -4.627693 -4.628376 -4.629059 -4.629743
## [8773] -4.630426 -4.631110 -4.631793 -4.632477 -4.633160 -4.633844
## [8779] -4.634527 -4.635211 -4.635894 -4.636578 -4.637262 -4.637946
## [8785] -4.638629 -4.639313 -4.639997 -4.640681 -4.641365 -4.642049
## [8791] -4.642733 -4.643417 -4.644101 -4.644785 -4.645469 -4.646153
## [8797] -4.646837 -4.647521 -4.648205 -4.648890 -4.649574 -4.650258
## [8803] -4.650943 -4.651627 -4.652312 -4.652996 -4.653680 -4.654365
## [8809] -4.655050 -4.655734 -4.656419 -4.657103 -4.657788 -4.658473
```

```
## [8815] -4.659157 -4.659842 -4.660527 -4.661212 -4.661897 -4.662582
## [8821] -4.663267 -4.663952 -4.664637 -4.665322 -4.666007 -4.666692
## [8827] -4.667377 -4.668062 -4.668747 -4.669432 -4.670118 -4.670803
## [8833] -4.671488 -4.672174 -4.672859 -4.673544 -4.674230 -4.674915
## [8839] -4.675601 -4.676286 -4.676972 -4.677658 -4.678343 -4.679029
## [8845] -4.679715 -4.680400 -4.681086 -4.681772 -4.682458 -4.683144
## [8851] -4.683829 -4.684515 -4.685201 -4.685887 -4.686573 -4.687259
## [8857] -4.687945 -4.688632 -4.689318 -4.690004 -4.690690 -4.691376
## [8863] -4.692063 -4.692749 -4.693435 -4.694122 -4.694808 -4.695494
## [8869] -4.696181 -4.696867 -4.697554 -4.698240 -4.698927 -4.699614
## [8875] -4.700300 -4.700987 -4.701674 -4.702361 -4.703047 -4.703734
## [8881] -4.704421 -4.705108 -4.705795 -4.706482 -4.707169 -4.707856
## [8887] -4.708543 -4.709230 -4.709917 -4.710604 -4.711291 -4.711978
## [8893] -4.712666 -4.713353 -4.714040 -4.714727 -4.715415 -4.716102
## [8899] -4.716790 -4.717477 -4.718165 -4.718852 -4.719540 -4.720227
## [8905] -4.720915 -4.721602 -4.722290 -4.722978 -4.723665 -4.724353
## [8911] -4.725041 -4.725729 -4.726417 -4.727105 -4.727793 -4.728480
## [8917] -4.729168 -4.729856 -4.730545 -4.731233 -4.731921 -4.732609
## [8923] -4.733297 -4.733985 -4.734673 -4.735362 -4.736050 -4.736738
## [8929] -4.737427 -4.738115 -4.738803 -4.739492 -4.740180 -4.740869
## [8935] -4.741557 -4.742246 -4.742935 -4.743623 -4.744312 -4.745001
## [8941] -4.745689 -4.746378 -4.747067 -4.747756 -4.748445 -4.749134
## [8947] -4.749823 -4.750511 -4.751200 -4.751889 -4.752579 -4.753268
## [8953] -4.753957 -4.754646 -4.755335 -4.756024 -4.756713 -4.757403
## [8959] -4.758092 -4.758781 -4.759471 -4.760160 -4.760850 -4.761539
## [8965] -4.762228 -4.762918 -4.763608 -4.764297 -4.764987 -4.765676
## [8971] -4.766366 -4.767056 -4.767745 -4.768435 -4.769125 -4.769815
## [8977] -4.770505 -4.771195 -4.771885 -4.772574 -4.773264 -4.773954
## [8983] -4.774645 -4.775335 -4.776025 -4.776715 -4.777405 -4.778095
## [8989] -4.778785 -4.779476 -4.780166 -4.780856 -4.781547 -4.782237
## [8995] -4.782927 -4.783618 -4.784308 -4.784999 -4.785689 -4.786380
## [9001] -4.787071
```

```
plot(lambda, ln_poisson_probs, type = "l")
```



```
LNL_function_dataframe <- data.frame(lambda, ln_poisson_probs)

Confidence_interval <- subset(LNL_function_dataframe, ln_poisson_probs>=max(ln_
poisson_probs)-0.00192)

print(Confidence_interval)
```

##	lambda	ln_poisson_probs
## 1988	2.987	-1.512372
## 1989	2.988	-1.512337
## 1990	2.989	-1.512301
## 1991	2.990	-1.512267
## 1992	2.991	-1.512232
## 1993	2.992	-1.512198
## 1994	2.993	-1.512164
## 1995	2.994	-1.512130
## 1996	2.995	-1.512097
## 1997	2.996	-1.512064
## 1998	2.997	-1.512032
## 1999	2.998	-1.512000
## 2000	2.999	-1.511968
## 2001	3.000	-1.511937
## 2002	3.001	-1.511906
## 2003	3.002	-1.511875
## 2004	3.003	-1.511844
## 2005	3.004	-1.511814
## 2006	3.005	-1.511785
## 2007	3.006	-1.511755
## 2008	3.007	-1.511726
## 2009	3.008	-1.511697
## 2010	3.009	-1.511669
## 2011	3.010	-1.511641
## 2012	3.011	-1.511613
## 2013	3.012	-1.511586
## 2014	3.013	-1.511559
## 2015	3.014	-1.511532
## 2016	3.015	-1.511506
## 2017	3.016	-1.511480
## 2018	3.017	-1.511454
## 2019	3.018	-1.511429
## 2020	3.019	-1.511404
## 2021	3.020	-1.511380
## 2022	3.021	-1.511355
## 2023	3.022	-1.511331
## 2024	3.023	-1.511308
## 2025	3.024	-1.511285
## 2026	3.025	-1.511262
## 2027	3.026	-1.511239
## 2028	3.027	-1.511217
## 2029	3.028	-1.511195
## 2030	3.029	-1.511173
## 2031	3.030	-1.511152
## 2032	3.031	-1.511131
## 2033	3.032	-1.511111
## 2034	3.033	-1.511090

##	2035	3.034	-1.511071
##	2036	3.035	-1.511051
##	2037	3.036	-1.511032
##	2038	3.037	-1.511013
##	2039	3.038	-1.510994
##	2040	3.039	-1.510976
##	2041	3.040	-1.510958
##	2042	3.041	-1.510941
##	2043	3.042	-1.510924
##	2044	3.043	-1.510907
##	2045	3.044	-1.510890
##	2046	3.045	-1.510874
##	2047	3.046	-1.510858
##	2048	3.047	-1.510843
##	2049	3.048	-1.510827
##	2050	3.049	-1.510813
##	2051	3.050	-1.510798
##	2052	3.051	-1.510784
##	2053	3.052	-1.510770
##	2054	3.053	-1.510756
##	2055	3.054	-1.510743
##	2056	3.055	-1.510730
##	2057	3.056	-1.510718
##	2058	3.057	-1.510706
##	2059	3.058	-1.510694
##	2060	3.059	-1.510682
##	2061	3.060	-1.510671
##	2062	3.061	-1.510660
##	2063	3.062	-1.510650
##	2064	3.063	-1.510639
##	2065	3.064	-1.510629
##	2066	3.065	-1.510620
##	2067	3.066	-1.510611
##	2068	3.067	-1.510602
##	2069	3.068	-1.510593
##	2070	3.069	-1.510585
##	2071	3.070	-1.510577
##	2072	3.071	-1.510569
##	2073	3.072	-1.510562
##	2074	3.073	-1.510555
##	2075	3.074	-1.510549
##	2076	3.075	-1.510542
##	2077	3.076	-1.510536
##	2078	3.077	-1.510531
##	2079	3.078	-1.510525
##	2080	3.079	-1.510520
##	2081	3.080	-1.510516
##	2082	3.081	-1.510511
##	2083	3.082	-1.510507

##	2084	3.083	-1.510504
##	2085	3.084	-1.510500
##	2086	3.085	-1.510497
##	2087	3.086	-1.510495
##	2088	3.087	-1.510492
##	2089	3.088	-1.510490
##	2090	3.089	-1.510489
##	2091	3.090	-1.510487
##	2092	3.091	-1.510486
##	2093	3.092	-1.510485
##	2094	3.093	-1.510485
##	2095	3.094	-1.510485
##	2096	3.095	-1.510485
##	2097	3.096	-1.510486
##	2098	3.097	-1.510487
##	2099	3.098	-1.510488
##	2100	3.099	-1.510489
##	2101	3.100	-1.510491
##	2102	3.101	-1.510493
##	2103	3.102	-1.510496
##	2104	3.103	-1.510498
##	2105	3.104	-1.510502
##	2106	3.105	-1.510505
##	2107	3.106	-1.510509
##	2108	3.107	-1.510513
##	2109	3.108	-1.510517
##	2110	3.109	-1.510522
##	2111	3.110	-1.510527
##	2112	3.111	-1.510532
##	2113	3.112	-1.510538
##	2114	3.113	-1.510544
##	2115	3.114	-1.510550
##	2116	3.115	-1.510557
##	2117	3.116	-1.510564
##	2118	3.117	-1.510571
##	2119	3.118	-1.510579
##	2120	3.119	-1.510587
##	2121	3.120	-1.510595
##	2122	3.121	-1.510604
##	2123	3.122	-1.510613
##	2124	3.123	-1.510622
##	2125	3.124	-1.510631
##	2126	3.125	-1.510641
##	2127	3.126	-1.510651
##	2128	3.127	-1.510662
##	2129	3.128	-1.510672
##	2130	3.129	-1.510683
##	2131	3.130	-1.510695
##	2132	3.131	-1.510707

##	2133	3.132	-1.510719
##	2134	3.133	-1.510731
##	2135	3.134	-1.510744
##	2136	3.135	-1.510757
##	2137	3.136	-1.510770
##	2138	3.137	-1.510784
##	2139	3.138	-1.510797
##	2140	3.139	-1.510812
##	2141	3.140	-1.510826
##	2142	3.141	-1.510841
##	2143	3.142	-1.510856
##	2144	3.143	-1.510872
##	2145	3.144	-1.510888
##	2146	3.145	-1.510904
##	2147	3.146	-1.510920
##	2148	3.147	-1.510937
##	2149	3.148	-1.510954
##	2150	3.149	-1.510971
##	2151	3.150	-1.510989
##	2152	3.151	-1.511007
##	2153	3.152	-1.511025
##	2154	3.153	-1.511044
##	2155	3.154	-1.511063
##	2156	3.155	-1.511082
##	2157	3.156	-1.511102
##	2158	3.157	-1.511121
##	2159	3.158	-1.511142
##	2160	3.159	-1.511162
##	2161	3.160	-1.511183
##	2162	3.161	-1.511204
##	2163	3.162	-1.511225
##	2164	3.163	-1.511247
##	2165	3.164	-1.511269
##	2166	3.165	-1.511292
##	2167	3.166	-1.511314
##	2168	3.167	-1.511337
##	2169	3.168	-1.511360
##	2170	3.169	-1.511384
##	2171	3.170	-1.511408
##	2172	3.171	-1.511432
##	2173	3.172	-1.511457
##	2174	3.173	-1.511481
##	2175	3.174	-1.511506
##	2176	3.175	-1.511532
##	2177	3.176	-1.511558
##	2178	3.177	-1.511584
##	2179	3.178	-1.511610
##	2180	3.179	-1.511637
##	2181	3.180	-1.511664

```
## 2182 3.181 -1.511691
## 2183 3.182 -1.511718
## 2184 3.183 -1.511746
## 2185 3.184 -1.511774
## 2186 3.185 -1.511803
## 2187 3.186 -1.511832
## 2188 3.187 -1.511861
## 2189 3.188 -1.511890
## 2190 3.189 -1.511920
## 2191 3.190 -1.511950
## 2192 3.191 -1.511980
## 2193 3.192 -1.512011
## 2194 3.193 -1.512042
## 2195 3.194 -1.512073
## 2196 3.195 -1.512104
## 2197 3.196 -1.512136
## 2198 3.197 -1.512168
## 2199 3.198 -1.512201
## 2200 3.199 -1.512234
## 2201 3.200 -1.512267
## 2202 3.201 -1.512300
## 2203 3.202 -1.512334
## 2204 3.203 -1.512367
## 2205 3.204 -1.512402
```