

# Mini-Project-1

Tanner Bessette

2025-01-29

I have followed all rules for collaboration for this project, and I have not used generative AI on this project.

## Normal Distribution

Sampling Distribution of the Sample Minimum:

```
n <- 5      # sample size
mu <- 10     # population mean
sigma <- 2   # population standard deviation

# generate a random sample of n observations from a normal population
single_sample <- rnorm(n, mu, sigma) |> round(2)
# look at the sample
single_sample
```

```
[1] 14.04 11.94 10.27  7.76  9.32
```

```
# compute the sample mean
sample_min <- min(single_sample)
# look at the sample mean
sample_min
```

```
[1] 7.76
```

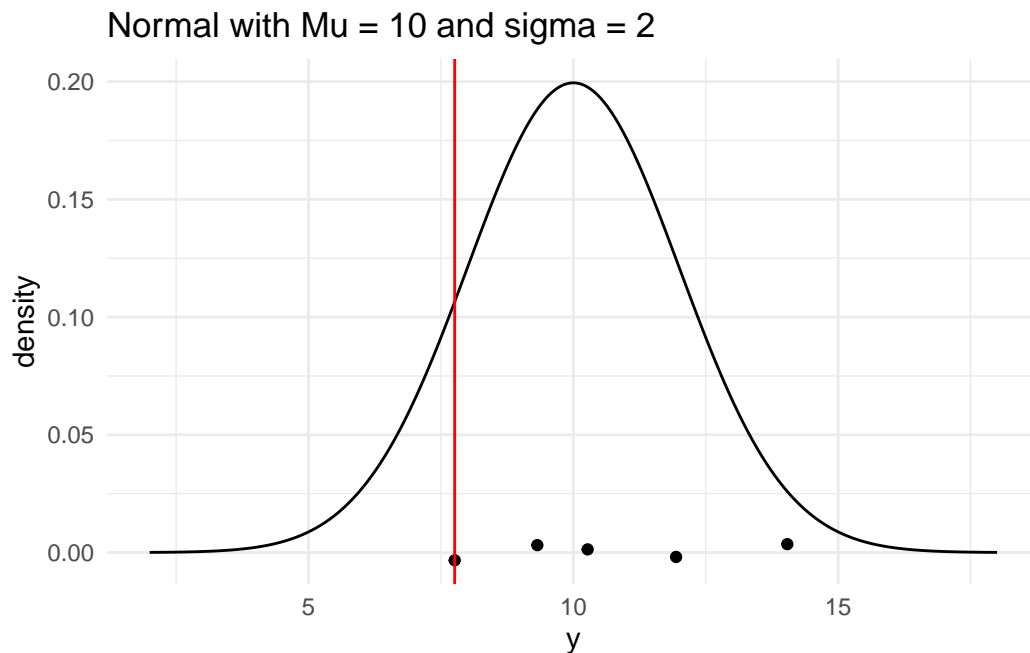
```
# generate a range of values that span the population
plot_df <- tibble(xvals = seq(mu - 4 * sigma, mu + 4 * sigma, length.out = 500)) |>
```

```

mutate(xvals_density = dnorm(xvals, mu, sigma))

## plot the population model density curve
ggplot(data = plot_df, aes(x = xvals, y = xvals_density)) +
  geom_line() +
  theme_minimal() +
  ## add the sample points from your sample
  geom_jitter(data = tibble(single_sample), aes(x = single_sample, y = 0),
             width = 0, height = 0.005) +
  ## add a line for the sample mean
  geom_vline(xintercept = sample_min, colour = "red") +
  labs(x = "y", y = "density",
       title = "Normal with Mu = 10 and sigma = 2")

```



```

n <- 5          # sample size
mu <- 10        # population mean
sigma <- 2      # population standard deviation

generate_samp_min <- function(mu, sigma, n) {

  single_sample <- rnorm(n, mu, sigma)

```

```

    sample_min <- min(single_sample)

    return(sample_min)
}

## test function once:
generate_samp_min(mu = mu, sigma = sigma, n = n)

```

[1] 7.06199

```

nsim <- 5000      # number of simulations

## map through th function -- the \() syntax says to just
## repeat the generate_samp_mean function nsim times
mins <- map_dbl(1:nsim, \() generate_samp_min(mu = mu, sigma = sigma, n = n))

# Calculate E(Ymin) and SE(Ymin)
E_ymin <- mean(mins)
SE_ymin <- sd(mins)
E_ymin

```

[1] 7.66156

```
SE_ymin
```

[1] 1.35776

```

## print some of the 5000 means
## each number represents the sample mean from __one__ sample.
norm_mins_df <- tibble(mins, pop = "Normal(10, 4)")
norm_mins_df

```

```

# A tibble: 5,000 x 2
  mins pop
  <dbl> <chr>
1  7.73 Normal(10, 4)
2  7.31 Normal(10, 4)

```

```

3  7.13 Normal(10, 4)
4  8.41 Normal(10, 4)
5  9.24 Normal(10, 4)
6  9.64 Normal(10, 4)
7  8.61 Normal(10, 4)
8  4.02 Normal(10, 4)
9  9.07 Normal(10, 4)
10 7.51 Normal(10, 4)
# i 4,990 more rows

```

```

Normal_Min_Hisotgram <-
  ggplot(data = norm_mins_df, aes(x = mins)) +
  geom_histogram(colour = "deeppink4", fill = "deeppink1",
                 bins = 20) +
  theme_minimal() +
  labs(x = "Observed Sample Means",
       title = paste("Sampling Distribution of the
                      Sample Min"))

```

$$E(Y_{min}) = 7.6848$$

$$SE(Y_{min}) = 1.3464$$

Sampling distribution of the sample maximum:

```

n <- 5      # sample size
mu <- 10    # population mean
sigma <- 2  # population standard deviation

# generate a random sample of n observations from a normal population
single_sample <- rnorm(n, mu, sigma) |> round(2)
# look at the sample
single_sample

```

```
[1] 14.68  7.56  9.58 12.26 11.68
```

```

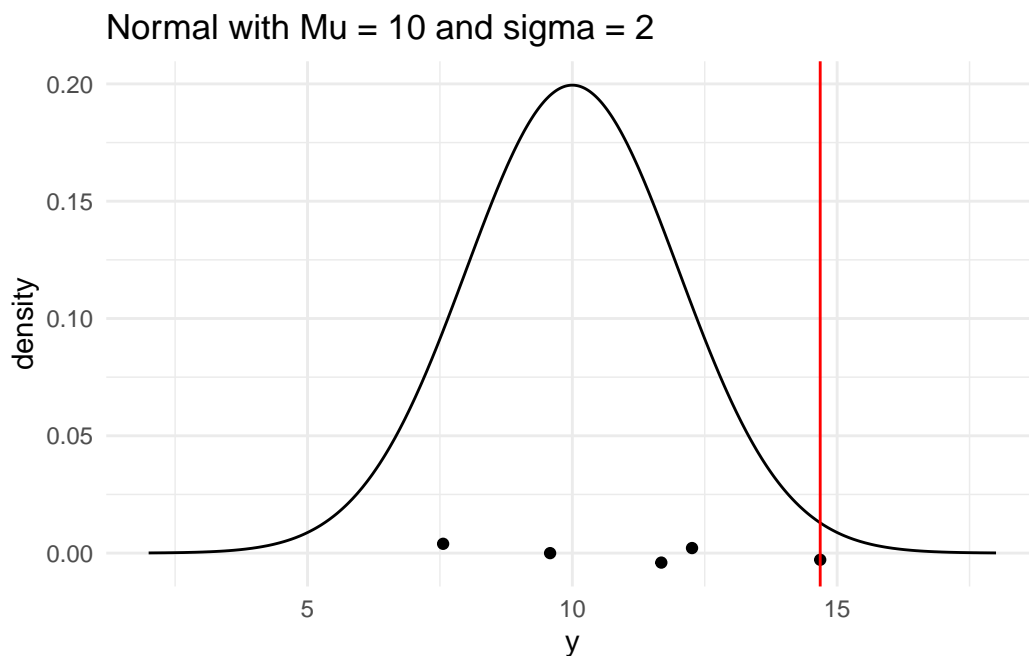
# compute the sample mean
sample_max <- max(single_sample)
# look at the sample mean
sample_max

```

[1] 14.68

```
# generate a range of values that span the population
plot_df <- tibble(xvals = seq(mu - 4 * sigma, mu + 4 * sigma, length.out = 500)) |>
  mutate(xvals_density = dnorm(xvals, mu, sigma))

## plot the population model density curve
ggplot(data = plot_df, aes(x = xvals, y = xvals_density)) +
  geom_line() +
  theme_minimal() +
  ## add the sample points from your sample
  geom_jitter(data = tibble(single_sample), aes(x = single_sample, y = 0),
             width = 0, height = 0.005) +
  ## add a line for the sample mean
  geom_vline(xintercept = sample_max, colour = "red") +
  labs(x = "y", y = "density",
       title = "Normal with Mu = 10 and sigma = 2")
```



```
n <- 5           # sample size
mu <- 10         # population mean
sigma <- 2       # population standard deviation
```

```

generate_samp_max <- function(mu, sigma, n) {

  single_sample <- rnorm(n, mu, sigma)
  sample_max <- max(single_sample)

  return(sample_max)
}

## test function once:
generate_samp_max(mu = mu, sigma = sigma, n = n)

```

[1] 12.23739

```

nsim <- 5000      # number of simulations

## map through th function -- the \() syntax says to just
## repeat the generate_samp_mean function nsim times
maxes <- map_dbl(1:nsim, \() generate_samp_max(mu = mu, sigma = sigma, n = n))

# Calculate E(Ymax) and SE(Ymax)
E_ymax <- mean(maxes)
SE_ymax <- sd(maxes)
E_ymax

```

[1] 12.33514

```
SE_ymax
```

[1] 1.356834

```

## print some of the 5000 means
## each number represents the sample mean from __one__ sample.
norm_maxes_df <- tibble(maxes, pop = "Normal(10, 4)")
norm_maxes_df

```

```

# A tibble: 5,000 x 2
  maxes pop

```

```

      <dbl> <chr>
1  13.0 Normal(10, 4)
2  11.7 Normal(10, 4)
3  12.1 Normal(10, 4)
4  10.9 Normal(10, 4)
5  10.3 Normal(10, 4)
6  13.0 Normal(10, 4)
7  13.1 Normal(10, 4)
8  13.1 Normal(10, 4)
9  11.2 Normal(10, 4)
10 11.6 Normal(10, 4)
# i 4,990 more rows

```

```

Normal_Max_Histogram <-
  ggplot(data = norm_maxes_df, aes(x = maxes)) +
  geom_histogram(colour = "deeppink4", fill = "deeppink1",
                 bins = 20) +
  theme_minimal() +
  labs(x = "Observed Sample Means",
       title = "Sampling Distribution of
               the Sample Max")

```

$$E(Y_{max}) = 12.3333$$

$$SE(Y_{max}) = 1.35581$$

## Uniform Distribution

Sampling distribution of the sample minimum:

```
n <- 5          # sample size
theta_1 <- 7
theta_2 <- 13

generate_samp_min <- function(theta_1, theta_2, n) {

  single_sample <- runif(n, theta_1, theta_2)
  sample_min <- min(single_sample)

  return(sample_min)
}

## test function once:
generate_samp_min(theta_1 = theta_1, theta_2 = theta_2, n = n)
```

```
[1] 8.205544
```

```
nsim <- 5000    # number of simulations

## map through the function -- the \() syntax says to just
## repeat the generate_samp_mean function nsim times
mins <- map_dbl(1:nsim, \() generate_samp_min(theta_1 = theta_1, theta_2 = theta_2, n = n)

# Calculate E(Ymin) and SE(Ymin)
E_ymin_unif <- mean(mins)
SE_ymin_unif <- sd(mins)
E_ymin_unif
```

```
[1] 7.996323
```

```
SE_ymin_unif
```

```
[1] 0.8478432
```



```
## print some of the 5000 means
## each number represents the sample mean from __one__ sample.
unif_mins_df <- tibble(mins, pop = "Uniform(7, 13)")
unif_mins_df
```

```
# A tibble: 5,000 x 2
  mins pop
  <dbl> <chr>
1  8.86 Uniform(7, 13)
2  8.35 Uniform(7, 13)
3  7.38 Uniform(7, 13)
4  8.00 Uniform(7, 13)
5  8.15 Uniform(7, 13)
6  7.99 Uniform(7, 13)
7  9.42 Uniform(7, 13)
8  8.29 Uniform(7, 13)
9  9.78 Uniform(7, 13)
10 7.05 Uniform(7, 13)
# i 4,990 more rows
```

```
Unif_Min_Histogram <- ggplot(data = unif_mins_df, aes(x = mins)) +
  geom_histogram(colour = "deeppink4", fill = "deeppink1",
    bins = 20) +
  theme_minimal() +
  labs(x = "Observed Sample Means",
    title = paste("Sampling Distribution of the
      Sample Min"))
```

$$E(Y_{min}) = 8.0031$$

$$SE(Y_{min}) = 0.8446$$

Sampling distribution of the sample maximum:

```
n <- 5          # sample size
theta_1 <- 7
theta_2 <- 13

generate_samp_max <- function(theta_1, theta_2, n) {

  single_sample <- runif(n, theta_1, theta_2)
  sample_max <- max(single_sample)
```

```

    return(sample_max)
}

## test function once:
generate_samp_max(theta_1 = theta_1, theta_2 = theta_2, n = n)

```

[1] 12.41057

```

nsim <- 5000      # number of simulations

## map through th function -- the \() syntax says to just
## repeat the generate_samp_mean function nsim times
maxes <- map_dbl(1:nsim, \() generate_samp_max(theta_1 = theta_1, theta_2 = theta_2, n =

# Calculate E(Ymax) and SE(Ymax)
E_ymax_unif <- mean(maxes)
SE_ymax_unif <- sd(maxes)
E_ymax_unif

```

[1] 11.99878

```
SE_ymax_unif
```

[1] 0.8418832

```

## print some of the 5000 means
## each number represents the sample mean from __one__ sample.
unif_maxes_df <- tibble(maxes, pop = "Uniform(7, 13)")
unif_maxes_df

```

```

# A tibble: 5,000 x 2
  maxes pop
  <dbl> <chr>
1 11.8  Uniform(7, 13)
2 12.0  Uniform(7, 13)
3  9.69 Uniform(7, 13)
4 12.9  Uniform(7, 13)

```

```

5 12.9 Uniform(7, 13)
6 10.3 Uniform(7, 13)
7 12.6 Uniform(7, 13)
8 12.3 Uniform(7, 13)
9 12.8 Uniform(7, 13)
10 12.1 Uniform(7, 13)
# i 4,990 more rows

```

```

Unif_Max_Histogram <- ggplot(data = unif_maxes_df, aes(x = maxes)) +
  geom_histogram(colour = "deeppink4", fill = "deeppink1",
    bins = 20) +
  theme_minimal() +
  labs(x = "Observed Sample Means",
    title = paste("Samp. Dist. of Samp. Max.
      Uniform(7, 13)"))

```

$$E(Y_{max}) = 11.9965$$

$$SE(Y_{max}) = 0.8471$$

## Exponential Distribution

Sampling distribution of the sample minimum:

```
n <- 5          # sample size
lambda <- 0.5

generate_samp_min <- function(lambda, n) {

  single_sample <- rexp(n, lambda)
  sample_min <- min(single_sample)

  return(sample_min)
}

## test function once:
generate_samp_min(lambda = lambda, n = n)
```

```
[1] 0.0800897
```

```
nsim <- 5000    # number of simulations

## map through the function -- the \() syntax says to just
## repeat the generate_samp_mean function nsim times
mins <- map_dbl(1:nsim, \() generate_samp_min(
  lambda = lambda, n = n))

# Calculate E(Ymin) and SE(Ymin)
E_ymin_exp <- mean(mins)
SE_ymin_exp <- sd(mins)
E_ymin_exp
```

```
[1] 0.4015463
```

```
SE_ymin_exp
```

```
[1] 0.4001794
```

```
## print some of the 5000 means
## each number represents the sample mean from __one__ sample.
exp_mins_df <- tibble(mins, pop = "Exp(0.5)")
exp_mins_df
```

```
# A tibble: 5,000 x 2
```

```
  mins pop
<dbl> <chr>
1 0.364 Exp(0.5)
2 0.179 Exp(0.5)
3 2.32  Exp(0.5)
4 0.0792 Exp(0.5)
5 0.365 Exp(0.5)
6 0.0919 Exp(0.5)
7 0.0650 Exp(0.5)
8 0.225 Exp(0.5)
9 0.217 Exp(0.5)
10 0.256 Exp(0.5)
# i 4,990 more rows
```

```
Exp_Min_Histogram <- ggplot(data = exp_mins_df,
                             aes(x = mins)) +
  geom_histogram(colour = "deeppink4", fill = "deeppink1",
                 bins = 20) +
  theme_minimal() +
  labs(x = "Observed Sample Means",
       title = "Samp. Dist. of Samp. Min. Exp(0.5)")
```

$$E(Y_{min}) = 0.3955$$

$$SE(Y_{min}) = 0.3922$$

Sampling distribution of the sample maximum:

```
n <- 5          # sample size
lambda <- 0.5

generate_samp_max <- function(lambda, n) {

  single_sample <- rexp(n, lambda)
  sample_max <- max(single_sample)
```

```

    return(sample_max)
}

## test function once:
generate_samp_max(lambda = lambda, n = n)

```

[1] 4.098288

```

nsim <- 5000      # number of simulations

## map through th function -- the \() syntax says to just
## repeat the generate_samp_mean function nsim times
maxes <- map_dbl(1:nsim, \(i) generate_samp_max(
  lambda = lambda, n = n))

# Calculate E(Ymax) and SE(Ymax)
E_ymax_exp <- mean(maxes)
SE_ymax_exp <- sd(maxes)
E_ymax_exp

```

[1] 4.599737

```
SE_ymax_exp
```

[1] 2.471394

```

## print some of the 5000 means
## each number represents the sample mean from __one__ sample.
exp_maxes_df <- tibble(maxes, pop = "Exp(0.5)")
exp_maxes_df

```

```

# A tibble: 5,000 x 2
  maxes pop
  <dbl> <chr>
1  4.50 Exp(0.5)
2  2.86 Exp(0.5)
3  1.89 Exp(0.5)

```

```

4  7.00 Exp(0.5)
5  3.26 Exp(0.5)
6  2.99 Exp(0.5)
7  5.17 Exp(0.5)
8  5.84 Exp(0.5)
9  2.58 Exp(0.5)
10 6.33 Exp(0.5)
# i 4,990 more rows

```

```

Exp_Max_Histogram <- ggplot(data = exp_maxes_df,
                             aes(x = maxes)) +
  geom_histogram(colour = "deeppink4", fill = "deeppink1",
                 bins = 20) +
  theme_minimal() +
  labs(x = "Observed Sample Means",
       title = "Samp. Dist. of Samp. Max. Exp(0.5)")

```

$$E(Y_{max}) = 4.5812$$

$$SE(Y_{max}) = 2.4562$$

## Beta Distribution

Sampling distribution of the sample minimum:

```
n <- 5          # sample size
alpha <- 8
beta <- 2

generate_samp_min <- function(alpha, beta, n) {

  single_sample <- rbeta(n, alpha, beta)
  sample_min <- min(single_sample)

  return(sample_min)
}

## test function once:
generate_samp_min(alpha = alpha, beta = beta, n = n)
```

```
[1] 0.650141
```

```
nsim <- 5000    # number of simulations

## map through the function -- the \() syntax says to just
## repeat the generate_samp_mean function nsim times
mins <- map_dbl(1:nsim, \() generate_samp_min(
  alpha = alpha, beta = beta, n = n))

# Calculate E(Ymin) and SE(Ymin)
E_ymin_beta <- mean(mins)
SE_ymin_beta <- sd(mins)
E_ymin_beta
```

```
[1] 0.6469552
```

```
SE_ymin_beta
```

```
[1] 0.1064372
```



```

## print some of the 5000 means
## each number represents the sample mean from __one__ sample.
beta_mins_df <- tibble(mins, pop = "Beta(8, 2)")
beta_mins_df

# A tibble: 5,000 x 2
  mins pop
  <dbl> <chr>
1 0.860 Beta(8, 2)
2 0.731 Beta(8, 2)
3 0.446 Beta(8, 2)
4 0.546 Beta(8, 2)
5 0.778 Beta(8, 2)
6 0.731 Beta(8, 2)
7 0.576 Beta(8, 2)
8 0.462 Beta(8, 2)
9 0.749 Beta(8, 2)
10 0.689 Beta(8, 2)
# i 4,990 more rows

Beta_Min_Histogram <- ggplot(data = beta_mins_df,
                             aes(x = mins)) +
  geom_histogram(colour = "deeppink4", fill = "deeppink1",
                 bins = 20) +
  theme_minimal() +
  labs(x = "Observed Sample Means",
       title = "Samp. Dist. of Samp. Min. Beta(8, 2)")

```

$$E(Y_{min}) = 0.6471$$

$$SE(Y_{min}) = 0.1079$$

Sampling distribution of the sample maximum:

```

n <- 5          # sample size
alpha <- 8
beta <- 2

generate_samp_max <- function(alpha, beta, n) {

  single_sample <- rbeta(n, alpha, beta)
  sample_max <- max(single_sample)
}

```

```

    return(sample_max)
  }

  ## test function once:
  generate_samp_max(alpha = alpha, beta = beta, n = n)

```

```
[1] 0.9628768
```

```

nsim <- 5000      # number of simulations

## map through th function -- the \() syntax says to just
## repeat the generate_samp_mean function nsim times
maxes <- map_dbl(1:nsim, \() generate_samp_max(
  alpha = alpha, beta = beta, n = n))

# Calculate E(Ymax) and SE(Ymax)
E_ymax_beta <- mean(maxes)
SE_ymax_beta <- sd(maxes)
E_ymax_beta

```

```
[1] 0.9220068
```

```
SE_ymax_beta
```

```
[1] 0.04533354
```

```

## print some of the 5000 means
## each number represents the sample mean from __one__ sample.
beta_maxes_df <- tibble(maxes, pop = "Beta(8, 2)")
beta_maxes_df

```

```

# A tibble: 5,000 x 2
  maxes pop
  <dbl> <chr>
1 0.944 Beta(8, 2)
2 0.887 Beta(8, 2)
3 0.972 Beta(8, 2)

```

```

4 0.859 Beta(8, 2)
5 0.854 Beta(8, 2)
6 0.965 Beta(8, 2)
7 0.882 Beta(8, 2)
8 0.909 Beta(8, 2)
9 0.953 Beta(8, 2)
10 0.968 Beta(8, 2)
# i 4,990 more rows

```

```

Beta_Max_Histogram <- ggplot(data = beta_maxes_df,
                             aes(x = maxes)) +
  geom_histogram(colour = "deeppink4", fill = "deeppink1",
                 bins = 20) +
  theme_minimal() +
  labs(x = "Observed Sample Means",
       title = "Samp. Dist. of Samp. Max. Beta(8, 2)")

```

$$E(Y_{max}) = 0.9219$$

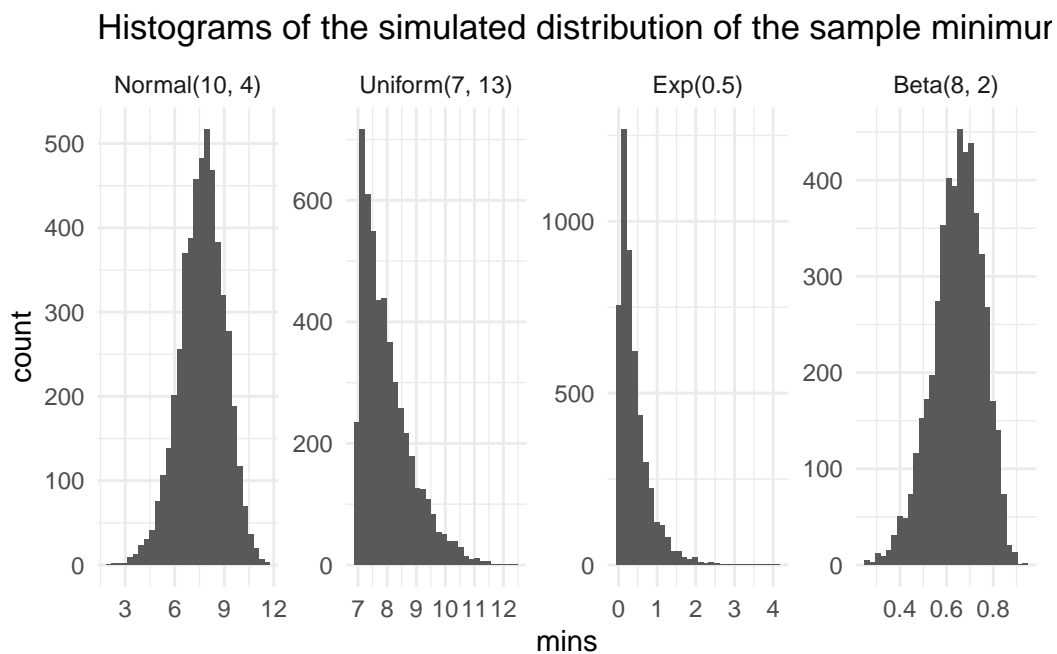
$$SE(Y_{max}) = 0.0464$$

## Histograms of the simulated distribution of the sample minimum

```
pop_plot <- bind_rows(norm_mins_df, unif_mins_df,
                      exp_mins_df, beta_mins_df) |>
  mutate(pop = fct_relevel(pop,
                           c("Normal(10, 4)", "Uniform(7, 13)",
                             "Exp(0.5)", "Beta(8, 2)")))

ggplot(data = pop_plot, aes(x = mins)) +
  geom_histogram() +
  theme_minimal() +
  facet_wrap(~ pop, nrow = 1, scales = "free") +
  labs(title = "Histograms of the simulated distribution of the sample minimum")
```

`stat\_bin()` using `bins = 30`. Pick better value with `binwidth`.

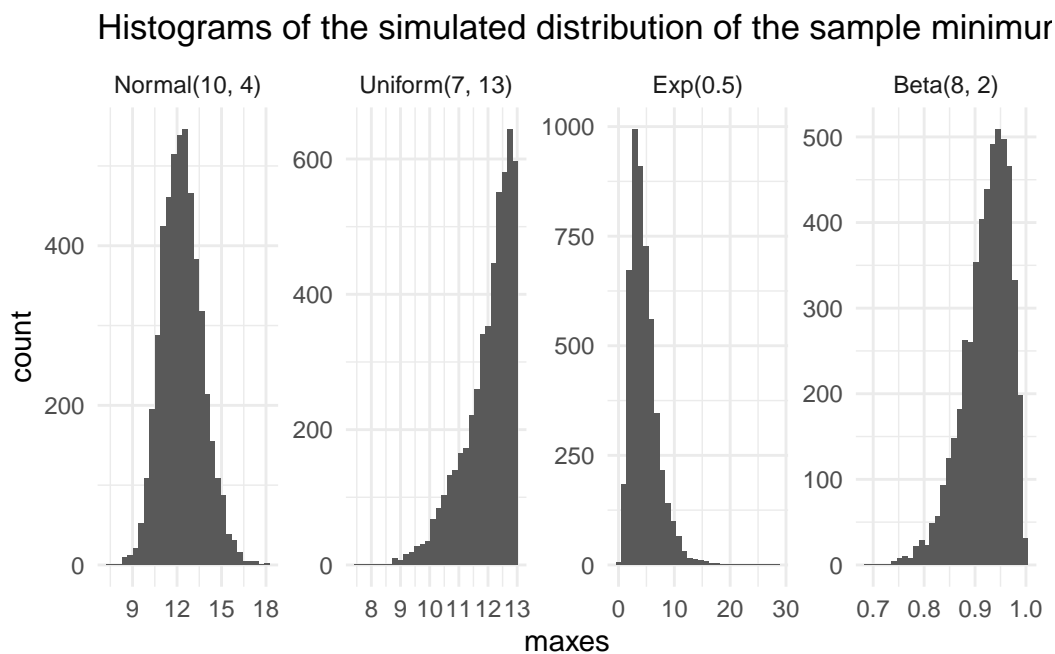


## Histograms of the simulated distribution of the sample maximum

```
pop_plot_2 <- bind_rows(norm_maxes_df, unif_maxes_df,  
                        exp_maxes_df, beta_maxes_df) |>  
  mutate(pop = fct_relevel(pop,  
                            c("Normal(10, 4)", "Uniform(7, 13)",  
                              "Exp(0.5)", "Beta(8, 2)")))

ggplot(data = pop_plot_2, aes(x = maxes)) +  
  geom_histogram() +  
  theme_minimal() +  
  facet_wrap(~ pop, nrow = 1, scales = "free") +  
  labs(title = "Histograms of the simulated distribution of the sample minimum")
```

`stat\_bin()` using `bins = 30`. Pick better value with `binwidth`.



## Table of Results

Table 1: Table of Results

	$N(\mu = 10, \sigma^2 = 4)$	$\text{Unif}(\theta_1 = 7, \theta_2 = 13)$	$\text{Exp}(\lambda = 0.5)$	$\text{Beta}(\alpha = 8, \beta = 2)$
$E(Y_{min})$	7.6848	8.0031	0.3955	0.6471
$E(Y_{max})$	12.3333	11.9965	4.5812	0.9219
$SE(Y_{min})$	1.3464	0.8446	0.3922	0.1079
$SE(Y_{max})$	1.3558	0.8471	2.4562	0.0464

## Questions

**Question 1:** For the normal distribution and the uniform distribution,  $SE(Y_{min})$  and  $SE(Y_{max})$  are nearly identical, and I think that we can make the result that we expect  $SE(Y_{min})$  and  $SE(Y_{max})$  to be the same for Normal and Uniform distributions. However, for the Exponential and the Beta distributions, a rule appears less clear-cut to make. It makes sense to make a general rule that we expect  $SE(Y_{max})$  to be significantly higher than  $SE(Y_{min})$  for the Exponential distribution, and we expect  $SE(Y_{min})$  to be significantly higher than  $SE(Y_{max})$  for the Beta distribution.

**Question 2:** (Choosing the third option, exponential)

Note: I looked up how to calculate integrals in R so I could keep the work in the same file.

Calculate the pdfs:

$$\begin{aligned} Y_{min} \text{ pdf: } &= n(1 - F(y))^{n-1} * f(y) \\ &= n(1 + e^{-\lambda*y})^{n-1} * \lambda * e^{-\lambda*y} \end{aligned}$$

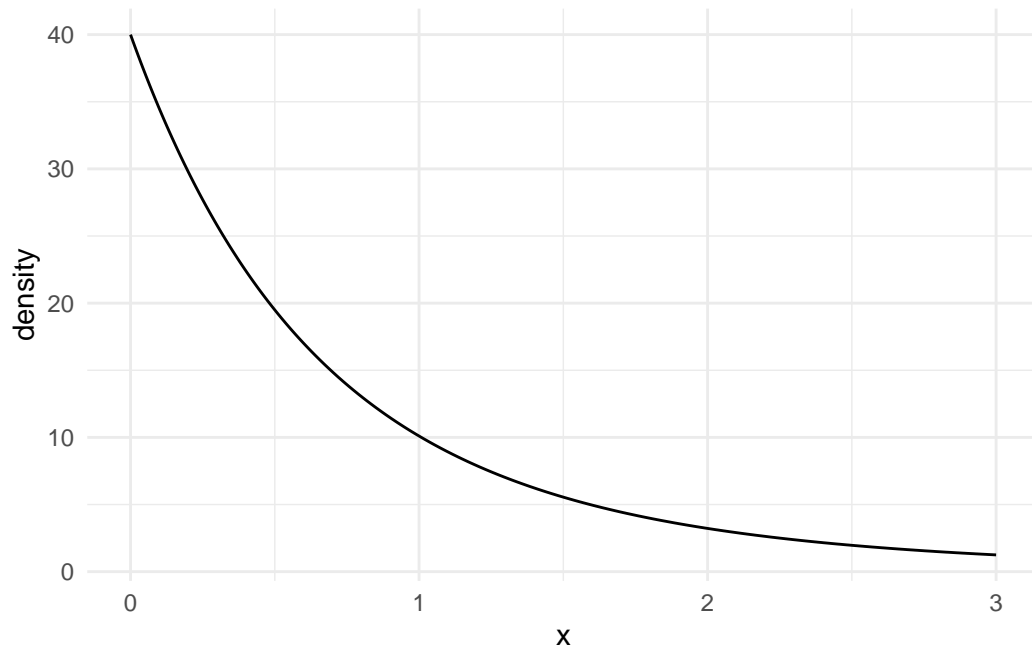
$$Y_{max} \text{ pdf: } = n(-e^{-\lambda*y})^{n-1} * \lambda * e^{-\lambda*y}$$

Plot the pdfs in R:

pdf of  $Y_{min}$ :

```
n <- 5
## CHANGE 0 and 3 to represent where you want your graph to start and end
## on the x-axis
x <- seq(0, 3, length.out = 1000)
## CHANGE to be the pdf you calculated. Note that, as of now,
## this is not a proper density (it does not integrate to 1).
density <-
  n * (1 + exp(-lambda * x))^(n - 1) * lambda * exp(-lambda * x)

## put into tibble and plot
samp_min_df <- tibble(x, density)
ggplot(data = samp_min_df, aes(x = x, y = density)) +
  geom_line() +
  theme_minimal()
```



pdf of  $Y_{max}$ :

```
n <- 5
## CHANGE 0 and 3 to represent where you want your graph to start and end
## on the x-axis
x <- seq(0, 3, length.out = 1000)
## CHANGE to be the pdf you calculated. Note that, as of now,
## this is not a proper density (it does not integrate to 1).
density <- n * (-exp(-lambda * x))^(n-1) * lambda * exp(-lambda * x)

## put into tibble and plot
samp_min_df <- tibble(x, density)
ggplot(data = samp_min_df, aes(x = x, y = density)) +
  geom_line() +
  theme_minimal()
```





Use integrals to calculate expected value and standard error for  $Y_{min}$ :

```
function_ymin <- function(x) {
  x * n * (1 - exp(-lambda * x))^(n - 1) * lambda * exp(-lambda * x)
}

E_ymin <- integrate(function_ymin, lower = 0, upper = Inf)
```

Calculate expected value and standard error for  $Y_{max}$ :

```
function_ymax <- function(x) {
  x * n * (-exp(-lambda * x))^(n-1) * lambda * exp(-lambda * x)
}

E_ymax = integrate(function_ymax, lower = 0, upper = Inf)
```

My answers are essentially swapped, with my  $E(Y_{min})$  being what my  $E(Y_{max})$  was in the table. I am assuming I accidentally swapped something somewhere that I can't find, so I believe that my answers are nearly equal to the simulated answers, but are slightly off. (roughly just 0.01 off from my simulated expected values).

Calculate standard errors using integrals:

$Y_{min}$  se:

```
function_ymin_se <- function(x) {  
  x^2 * n * (1 - exp(-lambda * x))^(n - 1) * lambda * exp(-lambda * x)  
}  
  
E_ymin2 <- integrate(function_ymin_se, lower = 0, upper = Inf)  
  
# E_ymin = 4.56667  
# E(ymin^2) = 26.7089  
se_ymin <- sqrt(26.7089 - 4.5667^2)  
se_ymin # = 2.4195
```

[1] 2.419535

$Y_{max}$  se:

```
function_ymax_se <- function(x) {  
  x^2 * n * (-exp(-lambda * x))^(n-1) * lambda * exp(-lambda * x)  
}  
  
E_ymax2 = integrate(function_ymax_se, lower = 0, upper = Inf)  
  
# E_ymax = 0.4  
# E(ymax^2) = 0.32  
se_ymax <- sqrt(0.32 - 0.32^2)  
se_ymax # = 0.4665
```

[1] 0.4664762

Both of the SE's are also similar to what we calculated in the simulation, but this time a little farther off from the results from the simulation than it was with the expected values. (About  $\sim 0.15$  and  $\sim 0.07$  off).