

# Solutions: Exercise 2.1 - Survey of ecological models, Part 1

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## Instructions

Create either an R script (.R file) or R Markdown document (.Rmd) to save all of your work for today.

## Exercise 1. Refresh your memory / repeat from last exercise

1. We will learn to write our own function - see my example here: I create a function called `my_fun`, which takes two values ( $x$  and  $y$ ), adds them together, and returns the added value.

```
my_fun <- function(x, y) {  
  z <- x + y  
  return(z)  
}  
my_fun(17, 3)
```

```
## [1] 20
```

Please choose two numbers for  $x$  and  $y$ , and use them to execute `my_fun(x,y)`.

## Solution

```
my_fun(25, 9)
```

```
## [1] 34
```

2. Your turn! Write a function called `times_seven` - it should take a single argument, multiply that value by 7, and return the new value.

## Solution

```
times_seven <- function(x) {  
  z <- x * 7  
  return(z)  
}  
times_seven(17)
```

```
## [1] 119
```

3. See the `for` loops I have written below:

```
# note how the loop changes the value of the variable x for
# each iteration of the loop: first x=1 and 'print(x)' is
# executed. Then x=2, then x=3, and so on.
for (x in 1:5) {
  print(x)
}
```

```
## [1] 1
## [1] 2
## [1] 3
## [1] 4
## [1] 5
```

```
for (i in 1:5) {
  z <- i + 6
  print(z)
}
```

```
## [1] 7
## [1] 8
## [1] 9
## [1] 10
## [1] 11
```

```
a <- rep(NA, 5)
for (i in 1:5) {
  a[i] <- i
}
a
```

```
## [1] 1 2 3 4 5
```

```
b <- c("I", "love", "R")
for (i in 1:length(b)) {
  print(b[i])
}
```

```
## [1] "I"
## [1] "love"
## [1] "R"
```

**Your turn** - For each of three values of volume,  $v \leftarrow c(1.6, 3, 8)$ , calculate the *mass*, where  $m \leftarrow 2.65 * \text{volume} ^ 0.9$ . Please calculate this in a loop. You can print the values within the loop.

**Solution**

```
v <- c(1.6, 3, 8)
for (i in 1:length(v)) {
  m <- 2.65 * v[i]^0.9
  print(m)
}
```

```
## [1] 4.045329
## [1] 7.12287
## [1] 17.21975
```

## Exercise 2. Use functions, for loops, and plotting skills to run simulation of mice in the yard

I built a function to calculate the number of mice in a yard using equation 2.4 from **Otto & Day Ch2**:

```
mice <- function(Nt,d,b,m){  
  Nt1 <- (1+b)*(1-d)*Nt + m  
  return(Nt1)  
}
```

4. I would like you to create the following plot of mouse population size ( $N$ ) over time, using the following values for parameters:  $d = 0.7$ ,  $b = 3$ ,  $m = 4$ ,  $N_t = 42$ .

### Solution

```
## Step 1. Write values for the parameters in the model  
## (and initial values of state variables) d - the  
## *fraction* of mice in yard eaten by cat / day --> 0-1  
d <- 0.7  
# b - the *number* of mice born per mouse / day --> N  
# (0-infinity)  
b <- 3  
# m - the *number* of mice arriving in the yard per day -->  
# N (0-infinity)  
m <- 4  
# NO - the initial number of mice in the yard when we begin  
# the survey  
Nt <- 42  
  
## Step 2. Write a function that will calculate values of  
## number of mice from one time step to the next.  
mice <- function(Nt, d, b, m) {  
  Nt1 <- (1 + b) * (1 - d) * Nt + m  
  return(Nt1)  
}  
  
## Step 3. Call the function mice(Nt,d,b,m)  
  
## Step 4. Follow the mice population size over some time  
## intervals N - a variable where we record the population  
## size over time  
N <- Nt  
  
for (i in 1:100) {  
  Nt1 <- mice(Nt, d, b, m)  
  N <- c(N, Nt1)  
  Nt <- Nt1  
}  
  
# N plot(N)  
plot(N, xlab = "time", ylab = "N_mice", pch = 19, col = "black")
```



```
dat <- as.data.frame(N)
dat$time <- as.numeric(rownames(dat))
# library(ggplot2) ggplot2::ggplot(dat,aes(time,N)) +
# geom_point()
```

To do this, you should approach the problem in a few steps:

- Step 1. Save  $d$ ,  $b$ ,  $m$ , and  $N_t$  as their own variables.
- Step 2. Write the *mice* function.
- Step 3. Make sure the function works by calling it one time using the values given in Step 1. It should return a value for  $N_{t+1} = 54.4$ .
- Step 4. Create a new variable called  $N$ , which can hold the values generated by the function.
- Step 5. Write a *for* loop that will take the calculated value of  $N_{t+1}$ , and use it as the next time step's value of  $N_t$ . Repeat this for  $i = 100$  time steps.
- Step 6. Use R's *plot* function (or you can use *ggplot* if you like) to plot  $N$  over time.

I demonstrate how this can work below. I use a different function as an example,  $P(t+1) = \frac{bP(t)}{1+cP(t)}$ :

```
# Step 1. Example parameters
b <- 1.7
c <- .15
Pt <- 6

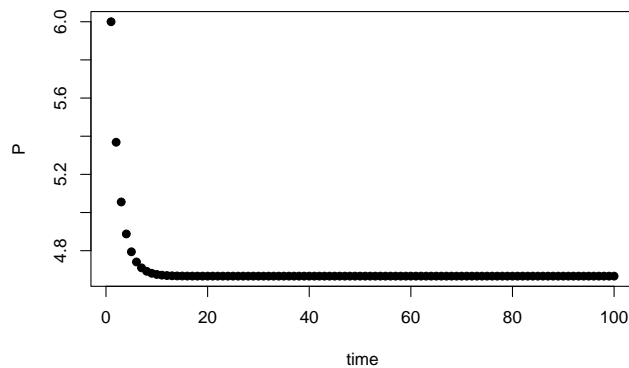
# Step 2. Example equation function
example_equation_function <- function(b,c,Pt){
  Pt1 <- (b*Pt) / (1 + c*Pt)
  return(Pt1)
}

# Step 3. Make sure the function works
Pt1 <- example_equation_function(b,c,Pt)

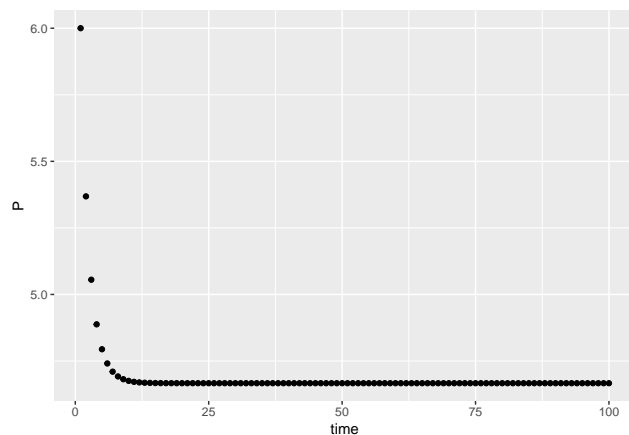
# Step 4. Create a new variable to hold future values of P
P <- rep(NA,100)

# Step 5. Create a for loop to iteratively calculate P
P[1] <- Pt
for(i in 2:100){
  P[i] <- example_equation_function(b,c,Pt)
  Pt <- P[i]
}
```

```
# Step 6. Plot P over time
plot(P,xlab="time",ylab="P",pch=19,col="black")
```



```
dat <- as.data.frame(P)
dat$time <- as.numeric(rownames(dat))
library(ggplot2)
ggplot2::ggplot(dat,aes(time,P)) + geom_point()
```



### Exercise 3. Use functions, for loops, and plotting skills to run simulation of exponential population growth

I show below a simulation for exponential population growth in discrete time,

$$n_{t+1} = Rn(t)$$

I created the below plot of population size (n) over time (t) using the following values for parameters:  $R = 1.7$ ,  $N_0 = 42$ , evaluated for 100 time steps.

```
## Step 1. Write values for the parameters in the model
## (and initial values of state variables) R - the
## population growth rate, expressed as the number of
## individuals that replace an individual in the population
## (where R=1 is each individual replacing itself, and
## therefore no change in population size over time) --> N
```

```
## (-infinity - infinity)
R <- 1.7
# NO - the initial population size
NO <- 42

## Step 2. Write a function that will calculate values of
## number of individuals from one time step to the next.
disc_exp <- function(R, NO) {
  Nt1 <- R * NO
  return(Nt1)
}

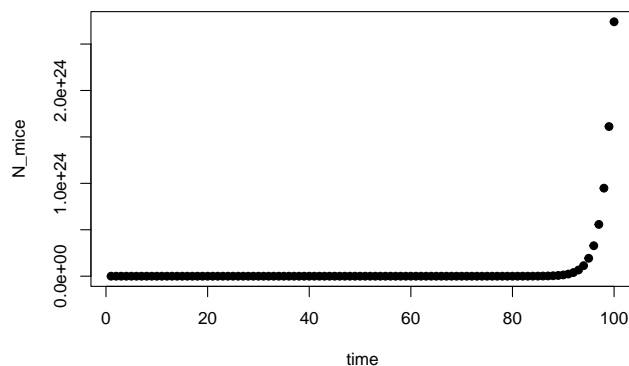
## Step 3. Call the function
disc_exp(R, NO)
```

```
## [1] 71.4
```

```
# Step 4. Create a new variable to hold future values of N
N <- rep(NA, 100)

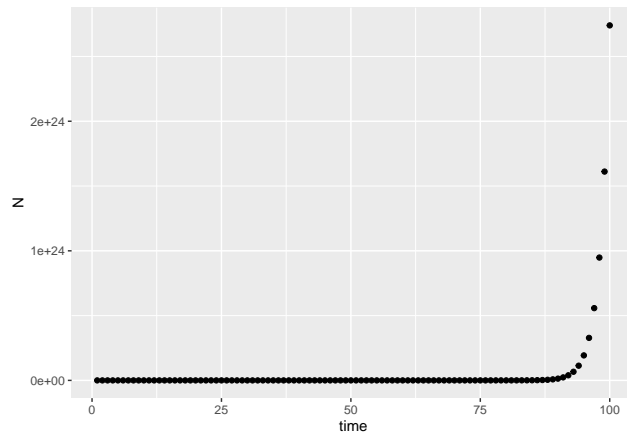
# Step 5. Create a for loop to iteratively calculate N
N[1] <- NO
for (i in 2:100) {
  N[i] <- disc_exp(R, NO)
  NO <- N[i]
}

# Step 6. Plot N over time
plot(N, xlab = "time", ylab = "N_mice", pch = 19, col = "black")
```



```
dat <- as.data.frame(N)
dat$time <- as.numeric(rownames(dat))

library(ggplot2)
ggplot2::ggplot(dat, aes(time, N)) + geom_point()
```

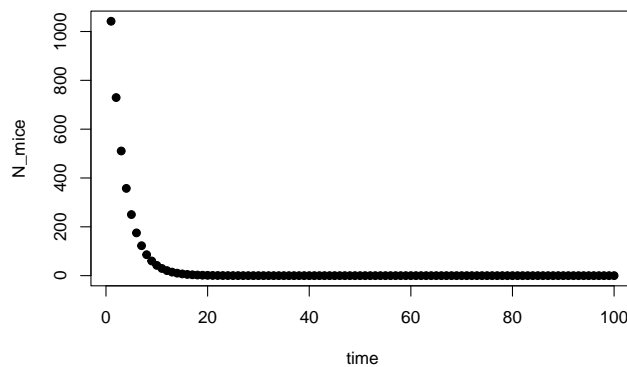


5. Please create a plot for parameters:  $R = 0.7$ ,  $N_0 = 1042$ .

### Solution

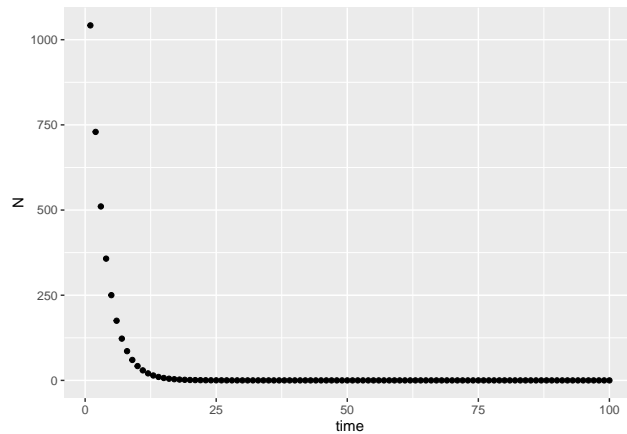
```
R <- 0.7
N0 <- 1042

N <- rep(NA, 100)
N[1] <- N0
for (i in 2:100) {
  N[i] <- disc_exp(R, N0)
  N0 <- N[i]
}
plot(N, xlab = "time", ylab = "N_mice", pch = 19, col = "black")
```



```
dat <- as.data.frame(N)
dat$time <- as.numeric(rownames(dat))

library(ggplot2)
ggplot2::ggplot(dat, aes(time, N)) + geom_point()
```



6. Please modify the simulation in #5 to create a simulation of the logistic growth model in discrete time (equation 3.5a in Otto & Day Chapter 3), using parameter values  $n_0 = 4$ ,  $K = 1400$ ,  $r = 1.21$ , evaluated for 100 time steps:

$$n_{t+1} = n(t) + rn(t)\left(1 - \frac{n(t)}{K}\right)$$

Hint: You can use the following formula:

```
disc_log <- function(r,Nt=NO,K){
  Nt1 <- Nt + r*Nt*(1-Nt/K)
  return(Nt1)
}
```

### Solution

```
# Step 1. parameters
r <- 1.21
K <- 1400
NO <- 4

# Step 2. equation function
disc_log <- function(r, Nt = NO, K) {
  Nt1 <- Nt + r * Nt * (1 - Nt/K)
  return(Nt1)
}

# Step 3. Make sure the function works
Nt1 <- disc_log(r, NO, K)

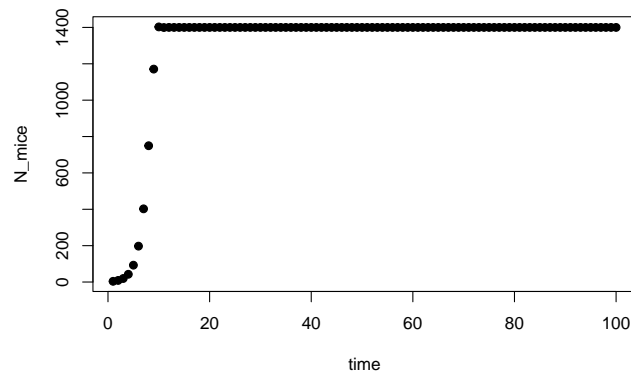
# Step 4. Create a new variable to hold future values of N
N <- rep(NA, 100)

# Step 5. Create a for loop to iteratively calculate N
N[1] <- NO
for (i in 2:100) {
  N[i] <- disc_log(r, NO, K)
  NO <- N[i]
}
```



```
# Step 6. Plot N over time
```

```
plot(N, xlab = "time", ylab = "N_mice", pch = 19, col = "black")
```



```
dat <- as.data.frame(N)
```

```
dat$time <- as.numeric(rownames(dat))
```

```
library(ggplot2)
```

```
ggplot2::ggplot(dat, aes(time, N)) + geom_point()
```

