

4: Part 1 - Data Wrangling

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Spring 2021

Objectives

1. Describe the usefulness of data wrangling and its place in the data pipeline
2. Wrangle datasets with dplyr functions
3. Apply data wrangling skills to a real-world example dataset

Set up your session

Today we will work with a dataset from the North Temperate Lakes Long-Term Ecological Research Station. The NTL-LTER is located in the boreal zone in northern Wisconsin, USA. We will use the chemical and physical limnology dataset, running from 1984-2016.

Opening discussion: why might we be interested in long-term observations of temperature, oxygen, and light in lakes?

Add notes here:

```
getwd()

## [1] "/Users/ataliefischer/Desktop/EDA/Environmental_Data_Analytics_2022/Lessons"

#install.packages(tidyverse)
library(tidyverse)
#install.packages(lubridate)
library(lubridate)
NTL.phys.data <- read.csv("../Data/Raw/NTL-LTER_Lake_ChemistryPhysics_Raw.csv", stringsAsFactors = TRUE)

colnames(NTL.phys.data)

## [1] "lakeid"      "lakename"    "year4"       "daynum"
## [5] "sampledate" "depth"       "temperature_C" "dissolvedOxygen"
## [9] "irradianceWater" "irradianceDeck" "comments"

head(NTL.phys.data)

##   lakeid lakename year4 daynum sampledate depth temperature_C dissolvedOxygen
## 1      L Paul Lake 1984   148    5/27/84  0.00          14.5           9.5
## 2      L Paul Lake 1984   148    5/27/84  0.25           NA           NA
## 3      L Paul Lake 1984   148    5/27/84  0.50           NA           NA
## 4      L Paul Lake 1984   148    5/27/84  0.75           NA           NA
## 5      L Paul Lake 1984   148    5/27/84  1.00          14.5           8.8
## 6      L Paul Lake 1984   148    5/27/84  1.50           NA           NA
##   irradianceWater irradianceDeck comments
## 1             1750             1620    <NA>
## 2             1550             1620    <NA>
## 3             1150             1620    <NA>
```

```
## 4          975          1620      <NA>
## 5          870          1620      <NA>
## 6          610          1620      <NA>
```

```
summary(NTL.phys.data)
```

```
##      lakeid      lakename      year4      daynum
## R      :11288 Peter Lake  :11288 Min.   :1984 Min.   : 55.0
## L      :10325 Paul Lake   :10325 1st Qu.:1991 1st Qu.:166.0
## T      : 6107 Tuesday Lake : 6107 Median :1997 Median :194.0
## W      : 4188 West Long Lake: 4188 Mean   :1999 Mean   :194.3
## E      : 3905 East Long Lake: 3905 3rd Qu.:2006 3rd Qu.:222.0
## M      : 1234 Crampton Lake : 1234 Max.   :2016 Max.   :307.0
## (Other): 1567 (Other)      : 1567
##      sampledate      depth      temperature_C      dissolvedOxygen
## 5/17/94: 84 Min.   : 0.00 Min.   : 0.30 Min.   : 0.00
## 9/5/90 : 64 1st Qu.: 1.50 1st Qu.: 5.30 1st Qu.: 0.30
## 10/1/07: 61 Median : 4.00 Median : 9.30 Median : 5.60
## 9/10/90: 61 Mean   : 4.39 Mean   :11.81 Mean   : 4.97
## 5/10/87: 60 3rd Qu.: 6.50 3rd Qu.:18.70 3rd Qu.: 8.40
## 5/9/88 : 60 Max.   :20.00 Max.   :34.10 Max.   :802.00
## (Other):38224 NA's      :3858 NA's      :4039
## irradianceWater      irradianceDeck      comments
## Min.   : -0.337 Min.   : 1.5 DO Probe bad - Doesn't go to zero: 206
## 1st Qu.: 14.000 1st Qu.: 353.0 DO taken with Jones Lab Meter : 162
## Median : 65.000 Median : 747.0 NA's :38246
## Mean   : 210.242 Mean   : 720.5
## 3rd Qu.: 265.000 3rd Qu.:1042.0
## Max.   :24108.000 Max.   :8532.0
## NA's   :14287 NA's   :15419
```

```
str(NTL.phys.data)
```

```
## 'data.frame': 38614 obs. of 11 variables:
## $ lakeid : Factor w/ 9 levels "C","E","H","L",...: 4 4 4 4 4 4 4 4 4 ...
## $ lakename : Factor w/ 9 levels "Central Long Lake",...: 5 5 5 5 5 5 5 5 5 ...
## $ year4 : int 1984 1984 1984 1984 1984 1984 1984 1984 1984 1984 ...
## $ daynum : int 148 148 148 148 148 148 148 148 148 148 ...
## $ sampledate : Factor w/ 1712 levels "10/1/07","10/1/93",...: 134 134 134 134 134 134 134 134 134 134 ...
## $ depth : num 0 0.25 0.5 0.75 1 1.5 2 3 4 5 ...
## $ temperature_C : num 14.5 NA NA NA 14.5 NA 14.2 11 7 6.1 ...
## $ dissolvedOxygen: num 9.5 NA NA NA 8.8 NA 8.6 11.5 11.9 2.5 ...
## $ irradianceWater: num 1750 1550 1150 975 870 610 420 220 100 34 ...
## $ irradianceDeck : num 1620 1620 1620 1620 1620 1620 1620 1620 1620 1620 ...
## $ comments : Factor w/ 2 levels "DO Probe bad - Doesn't go to zero",...: NA NA NA NA NA NA NA NA NA NA
```

```
dim(NTL.phys.data)
```

```
## [1] 38614 11
```

```
class(NTL.phys.data$sampledate)
```

```
## [1] "factor"
```

```
# Format sampledate as date
```

```
NTL.phys.data$sampledate <- as.Date(NTL.phys.data$sampledate, format = "%m/%d/%y")
```

Data Wrangling

Data wrangling extends data exploration: it allows you to process data in ways that are useful for you. An important part of data wrangling is creating *tidy datasets*, with the following rules:

1. Each variable has its own column
2. Each observation has its own row
3. Each value has its own cell

What is the best way to wrangle data? There are multiple ways to arrive at a specific outcome in R, and we will illustrate some of those approaches. Your goal should be to write the simplest code that will get you to your desired outcome. However, there is sometimes a trade-off of the opportunity cost to learn a new formulation of code and the time it takes to write complex code that you already know. Remember that the best code is one that is easy to understand for yourself and your collaborators. Remember to comment your code, use informative names for variables and functions, and use reproducible methods to arrive at your output.

Dplyr Wrangling Functions

dplyr is a package in R that includes functions for data manipulation (i.e., data wrangling or data munging). dplyr is included in the tidyverse package, so you should already have it installed on your machine. The functions act as verbs for data wrangling processes. For more information, run this line of code:

```
vignette("dplyr")
```

```
## starting httpd help server ... done
```

Filter

Filtering allows us to choose certain rows (observations) in our dataset.

Here are the relevant commands used in the `filter` function. Add some notes to designate what these commands mean. `== != < <= > >= & |`

```
class(NTL.phys.data$lakeid)
```

```
## [1] "factor"
```

```
class(NTL.phys.data$depth)
```

```
## [1] "numeric"
```

```
# matrix filtering: filter rows that have "0" in the column "depth"  
NTL.phys.data.surface1 <- NTL.phys.data[NTL.phys.data$depth == 0,]
```

```
# dplyr filtering  
NTL.phys.data.surface2 <- filter(NTL.phys.data, depth == 0)  
NTL.phys.data.surface3 <- filter(NTL.phys.data, depth < 0.25)
```

```
# Did the methods arrive at the same result?  
head(NTL.phys.data.surface1)
```

```
##   lakeid   lakename year4 daynum sampledate depth temperature_C  
## 1      L    Paul Lake  1984   148 1984-05-27     0          14.5  
## 18     R    Peter Lake  1984   149 1984-05-28     0          14.8  
## 40     T Tuesday Lake  1984   150 1984-05-29     0          15.0  
## 56     L    Paul Lake  1984   155 1984-06-03     0          18.8  
## 72     R    Peter Lake  1984   156 1984-06-04     0          18.8  
## 90     T Tuesday Lake  1984   157 1984-06-05     0          21.0
```

```
##      dissolvedOxygen irradianceWater irradianceDeck comments
## 1          9.5          1750          1620      <NA>
## 18         9.2          1630          1540      <NA>
## 40         9.5          1850          1960      <NA>
## 56         8.0          1100          1050      <NA>
## 72         9.0           275           275      <NA>
## 90         8.4          1200          1200      <NA>
```

```
dim(NTL.phys.data.surface1)
```

```
## [1] 1902  11
```

```
head(NTL.phys.data.surface2)
```

```
##      lakeid      lakename year4 daynum sampleddate depth temperature_C
## 1         L      Paul Lake  1984   148  1984-05-27     0          14.5
## 2         R      Peter Lake  1984   149  1984-05-28     0          14.8
## 3         T Tuesday Lake  1984   150  1984-05-29     0          15.0
## 4         L      Paul Lake  1984   155  1984-06-03     0          18.8
## 5         R      Peter Lake  1984   156  1984-06-04     0          18.8
## 6         T Tuesday Lake  1984   157  1984-06-05     0          21.0
##      dissolvedOxygen irradianceWater irradianceDeck comments
## 1          9.5          1750          1620      <NA>
## 2          9.2          1630          1540      <NA>
## 3          9.5          1850          1960      <NA>
## 4          8.0          1100          1050      <NA>
## 5          9.0           275           275      <NA>
## 6          8.4          1200          1200      <NA>
```

```
dim(NTL.phys.data.surface2)
```

```
## [1] 1902  11
```

```
head(NTL.phys.data.surface3)
```

```
##      lakeid      lakename year4 daynum sampleddate depth temperature_C
## 1         L      Paul Lake  1984   148  1984-05-27     0          14.5
## 2         R      Peter Lake  1984   149  1984-05-28     0          14.8
## 3         T Tuesday Lake  1984   150  1984-05-29     0          15.0
## 4         L      Paul Lake  1984   155  1984-06-03     0          18.8
## 5         R      Peter Lake  1984   156  1984-06-04     0          18.8
## 6         T Tuesday Lake  1984   157  1984-06-05     0          21.0
##      dissolvedOxygen irradianceWater irradianceDeck comments
## 1          9.5          1750          1620      <NA>
## 2          9.2          1630          1540      <NA>
## 3          9.5          1850          1960      <NA>
## 4          8.0          1100          1050      <NA>
## 5          9.0           275           275      <NA>
## 6          8.4          1200          1200      <NA>
```

```
dim(NTL.phys.data.surface3)
```

```
## [1] 1902  11
```

```
# Choose multiple conditions to filter
```

```
summary(NTL.phys.data$lakename)
```

```
## Central Long Lake      Crampton Lake      East Long Lake  Hummingbird Lake
```

```
##           539           1234           3905           430
##      Paul Lake      Peter Lake      Tuesday Lake      Ward Lake
##      10325          11288          6107          598
##      West Long Lake
##      4188

NTL.phys.data.PeterPaul1 <- filter(NTL.phys.data, lakename == "Paul Lake" | lakename == "Peter Lake")
NTL.phys.data.PeterPaul2 <- filter(NTL.phys.data, lakename != "Central Long Lake" &
                                   lakename != "Crampton Lake" & lakename != "East Long Lake" &
                                   lakename != "Hummingbird Lake" & lakename != "Tuesday Lake" &
                                   lakename != "Ward Lake" & lakename != "West Long Lake")
NTL.phys.data.PeterPaul3 <- filter(NTL.phys.data, lakename %in% c("Paul Lake", "Peter Lake"))

# Choose a range of conditions of a numeric or integer variable
summary(NTL.phys.data$daynum)

##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##      55.0  166.0   194.0   194.3   222.0   307.0

NTL.phys.data.JunethruOctober1 <- filter(NTL.phys.data, daynum > 151 & daynum < 305)
NTL.phys.data.JunethruOctober2 <- filter(NTL.phys.data, daynum > 151, daynum < 305)
NTL.phys.data.JunethruOctober3 <- filter(NTL.phys.data, daynum >= 152 & daynum <= 304)
NTL.phys.data.JunethruOctober4 <- filter(NTL.phys.data, daynum %in% c(152:304))

# Exercise:
# filter NTL.phys.data for the year 1999
# what code do you need to use, based on the class of the variable?
class(NTL.phys.data$year4)

## [1] "integer"

NTL.phys.data.1999 <- filter(NTL.phys.data, year4 == 1999)

# Exercise:
# filter NTL.phys.data for Tuesday Lake from 1990 through 1999.
NTL.phys.data.TuesdayLake1990thru1999 <- filter(NTL.phys.data, lakename == "Tuesday Lake" & year4 %in% c(1990:1999))
summary(NTL.phys.data.TuesdayLake1990thru1999)
```

lakeid	lakename	year4	daynum
T	Tuesday Lake	1990	143
C	Central Long Lake	1991	171
E	Crampton Lake	1994	199
H	East Long Lake	1994	197
L	Hummingbird Lake	1997	224
M	Paul Lake	1999	253
(Other)	(Other)		

sampledate	depth	temperature_C	dissolvedOxygen
Min. :1990-05-23	Min. : 0.000	Min. : 3.90	Min. : 0.000
1st Qu.:1991-07-12	1st Qu.: 1.500	1st Qu.: 4.30	1st Qu.: 0.200
Median :1994-08-26	Median : 4.000	Median : 5.70	Median : 0.500
Mean :1994-11-05	Mean : 4.609	Mean : 9.99	Mean : 3.066
3rd Qu.:1997-08-08	3rd Qu.: 7.000	3rd Qu.:16.90	3rd Qu.: 7.000
Max. :1999-08-30	Max. :12.000	Max. :27.40	Max. :14.600
		NA's :182	NA's :182

irradianceWater	irradianceDeck	comments
Min. : 0.30	Min. : 62.4	DO Probe bad - Doesn't go to zero: 0

```
## 1st Qu.: 12.72 1st Qu.: 350.8 DO taken with Jones Lab Meter : 0
## Median : 75.00 Median : 739.3 NA's :1971
## Mean : 232.17 Mean : 699.9
## 3rd Qu.: 333.75 3rd Qu.:1018.2
## Max. :2000.00 Max. :1519.0
## NA's :985 NA's :1003
```

Question: Why don't we filter using row numbers?

Answer:

Arrange

Arranging allows us to change the order of rows in our dataset. By default, the arrange function will arrange rows in ascending order.

```
NTL.phys.data.depth.ascending <- arrange(NTL.phys.data, depth)
NTL.phys.data.depth.descending <- arrange(NTL.phys.data, desc(depth))
```

Exercise:

Arrange NTL.phys.data by temperature, in descending order.
Which dates, lakes, and depths have the highest temperatures?

```
NTL.phys.data.temp.descending <- arrange(NTL.phys.data, desc(temperature_C))
```

Select

Selecting allows us to choose certain columns (variables) in our dataset.

```
NTL.phys.data.temps <- select(NTL.phys.data, lakename, sampledate:temperature_C)
```

Mutate

Mutating allows us to add new columns that are functions of existing columns. Operations include addition, subtraction, multiplication, division, log, and other functions.

```
NTL.phys.data.temps <- mutate(NTL.phys.data.temps, temperature_F = (temperature_C*9/5) + 32)
```

Lubridate

A package that makes coercing date much easier is `lubridate`. A guide to the package can be found at <https://lubridate.tidyverse.org/>. The cheat sheet within that web page is excellent too. This package can do many things (hint: look into this package if you are having unique date-type issues), but today we will be using two of its functions for our NTL dataset.

add a month column to the dataset

```
NTL.phys.data.PeterPaul1 <- mutate(NTL.phys.data.PeterPaul1, month = month(sampledate))
```

reorder columns to put month with the rest of the date variables

```
NTL.phys.data.PeterPaul1 <- select(NTL.phys.data.PeterPaul1, lakeid:daynum, month, sampledate:comments)
```

find out the start and end dates of the dataset

```
interval(NTL.phys.data.PeterPaul1$sampledate[1], NTL.phys.data.PeterPaul1$sampledate[21613])
```

```
## [1] 1984-05-27 UTC--2016-08-16 UTC
```

```
interval(first(NTL.phys.data.PeterPaul1$sampledate), last(NTL.phys.data.PeterPaul1$sampledate))
```

```
## [1] 1984-05-27 UTC--2016-08-16 UTC
```

Pipes

Sometimes we will want to perform multiple functions on a single dataset on our way to creating a processed dataset. We could do this in a series of subsequent functions or create a custom function. However, there is another method to do this that looks cleaner and is easier to read. This method is called a pipe. We designate a pipe with `%>%`. A good way to think about the function of a pipe is with the word “then.”

Let’s say we want to take our raw dataset (`NTL.phys.data`), *then* filter the data for Peter and Paul lakes, *then* select temperature and observation information, and *then* add a column for temperature in Fahrenheit:

```
NTL.phys.data.processed <-  
  NTL.phys.data %>%  
  filter(lakename == "Paul Lake" | lakename == "Peter Lake") %>%  
  select(lakename, sampledate:temperature_C) %>%  
  mutate(temperature_F = (temperature_C*9/5) + 32)
```

Notice that we did not place the dataset name inside the wrangling function but rather at the beginning.

Saving processed datasets

```
write.csv(NTL.phys.data.PeterPaul1, row.names = FALSE, file = "../Data/Processed/NTL-LTER_Lake_Chemistry")
```

Closing Discussion

When we wrangle a raw dataset into a processed dataset, we create a code file that contains only the wrangling code. We then save the processed dataset as a new spreadsheet and then create a separate code file to analyze and visualize the dataset. Why do we keep the wrangling code separate from the analysis code?