Workshop 2.4: Data manipulation

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Section 1

Data manipulation

Important data manipulation libraries

Task	Function	Package
Sorting	order()	base
	arrange()	dplyr
Re-ordering factor levels	factor(,levels=)	base
	reorder(,new.order=)	gdata
Re-labelling	factor(,lab=)	base
	recode()	dplyr
	revalue(,replace=)	plyr
Re-naming columns	colnames()	base
	rename(,replace=)	dplyr
Filtering/Subsetting	indexing	base
	subset(,subset=,select=)	base
	select(,...)	dplyr

Important data manipulation libraries

Task	Function	Package
Transformations	transform(),	base
	within()	
	mutate()	dplyr
Adding columns	within()	base
	mutate()	dplyr
Reshaping data	gather(), spread()	tidyr
	melt(), cast()	reshape2
Aggregating	tapply()	base
	group_by()	dplyr
	cast()	reshape2
	summaryBy()	doBy
Merging/joining	merge()	base
	*_join()	dplyr

The grammar of data manipulation

VERBS

- `arrange()` - sorting data
- `select()` - subset columns
- `rename()` - rename columns
- `filter()` - subset rows
- `slice()`
- `mutate()` - adding colums
- `summarise()` - aggregate(group_by())
- `count()` - tally

The grammar of data manipulation

TIDYING VERBS

- gather() - melt to long format
- spread() - cast to wide format
- unite() - combine columns
- separate() - separate columns

MULTI DATA.FRAME VERBS

- *_join() - merging data

The grammar of data manipulation

PIPING

- %>%

```
data %>%
    select(...) %>%
        group_by(...) %>%
            summarise(...)
```

The grammar of data manipulation

https://www.rstudio.com/resources/cheatsheets/data-transformation.pdf

Data Transformation with dplyr : : CHEAT SHEET

dplyr functions work with pipes and expect **tidy data**. In tidy data:

Each **variable** is in its own **column**

&

Each **observation**, or **case**, is in its own **row**

pipes

x %>% f(y) becomes **f(x, y)**

Summarise Cases

These apply **summary functions** to columns to create a new table of summary statistics. Summary functions take vectors as input and return one value (see back).

summary function

summarise(.data, …)
Compute table of summaries.
summarise(mtcars, avg = mean(mpg))

count(x, ..., wt = NULL, sort = FALSE)
Count number of rows in each group defined by the variables in … Also **tally**().
count(iris, Species)

VARIATIONS

summarise_all() - Apply funs to every column.
summarise_at() - Apply funs to specific columns.
summarise_if() - Apply funs to all cols of one type.

Group Cases

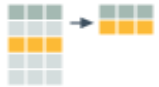
Use **group_by()** to create a "grouped" copy of a table. dplyr functions will manipulate each "group" separately and then combine the results.

```
mtcars %>%
group_by(cyl) %>%
summarise(avg = mean(mpg))
```

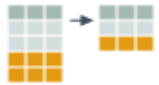
Manipulate Cases

EXTRACT CASES

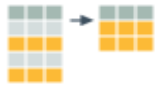
Row functions return a subset of rows as a new table.



filter(.data, …) Extract rows that meet logical criteria. *filter(iris, Sepal.Length > 7)*

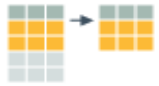


distinct(.data, ..., .keep_all = FALSE) Remove rows with duplicate values.
distinct(iris, Species)



sample_frac(tbl, size = 1, replace = FALSE, weight = NULL, .env = parent.frame()) Randomly select fraction of rows.
sample_frac(iris, 0.5, replace = TRUE)

sample_n(tbl, size, replace = FALSE, weight = NULL, .env = parent.frame()) Randomly select size rows. *sample_n(iris, 10, replace = TRUE)*



slice(.data, …) Select rows by position.
slice(iris, 10:15)

top_n(x, n, wt) Select and order top n entries (by group if grouped data). *top_n(iris, 5, Sepal.Width)*

Logical and boolean operators to use with filter()

<	<=	is.na()	%in%	|	xor()
>	>=	!is.na()	!	&	

See **?base::logic** and **?Comparison** for help.

ARRANGE CASES

arrange(.data, …) Order rows by values of a column or columns (low to high), use with **desc()** to order from high to low.
arrange(mtcars, mpg)
arrange(mtcars, desc(mpg))

Manipulate

EXTRACT VARIABLES

Column functions return

pull(.da
a vecto
pull(iris

select(.
Extract
select(i

Use these helpers with
e.g. select(iris, starts_wi

contains(match)
ends_with(match)
matches(match)
nu
on
sta

MAKE NEW VARIABLES

These apply **vectorized** vectors as input and retu (see back).

mutate
Comput
mutate(

transm
Comput
transm

mutate
column
mutate
mutate

mutate
specific
the help
mutate

Data files

```
> load(url("http://www.flutterbys.com.au/stats/downloads/
+     data/manipulationDatasets.RData"))
```

Between	Plot	Cond	Time	Temp	LAT	LONG
A1	P1	H	1	15.74	17.26	146.2
A1	P1	M	2	23.84	14.07	144.9
A1	P1	L	3	13.64	20.75	144.7
A1	P2	H	4	37.95	18.41	142.1
A1	P2	M	1	25.3	18.47	144
A1	P2	L	2	13.8	20.39	145.8
A2	P3	H	3	26.87	20.14	147.7
A2	P3	M	4	29.38	19.69	144.8
A2	P3	L	1	27.76	20.34	145.8
A2	P4	H	2	18.95	20.06	144.9
A2	P4	M	3	37.12	18.65	142.2
A2	P4	L	4	25.9	14.52	144.2

Data manipulation packages

```
> library(dplyr)
> library(tidyr)
> #OR better still
> library(tidyverse)
```

Data files

```
> head(data.1)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
3      A1   P1    L    3 13.64371 20.74986 144.6884
4      A1   P2    H    4 37.95281 18.41013 142.0585
5      A1   P2    M    1 25.29508 18.46762 144.0437
6      A1   P2    L    2 13.79532 20.38767 145.8359
```

```
> #OR
> data.1 %>% head
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
3      A1   P1    L    3 13.64371 20.74986 144.6884
4      A1   P2    H    4 37.95281 18.41013 142.0585
5      A1   P2    M    1 25.29508 18.46762 144.0437
6      A1   P2    L    2 13.79532 20.38767 145.8359
```

Data files

```
> summary(data.1)
```

```
 Between Plot   Cond       Time            Temp            LAT             LONG
A1:6   P1:3   H:4   Min.   :1.00   Min.   :13.64   Min.   :14.07   Min.   :142.1
A2:6   P2:3   L:4   1st Qu.:1.75   1st Qu.:18.14   1st Qu.:18.12   1st Qu.:144.1
       P3:3   M:4   Median :2.50   Median :25.60   Median :19.17   Median :144.8
       P4:3         Mean   :2.50   Mean   :24.69   Mean   :18.56   Mean   :144.8
                    3rd Qu.:3.25   3rd Qu.:28.16   3rd Qu.:20.19   3rd Qu.:145.8
                    Max.   :4.00   Max.   :37.95   Max.   :20.75   Max.   :147.7
```

Data files

```
> summary(data.1)
```

```
 Between Plot   Cond       Time            Temp            LAT             LONG
A1:6   P1:3   H:4   Min.   :1.00   Min.   :13.64   Min.   :14.07   Min.   :142.1
A2:6   P2:3   L:4   1st Qu.:1.75   1st Qu.:18.14   1st Qu.:18.12   1st Qu.:144.1
       P3:3   M:4   Median :2.50   Median :25.60   Median :19.17   Median :144.8
       P4:3         Mean   :2.50   Mean   :24.69   Mean   :18.56   Mean   :144.8
                    3rd Qu.:3.25   3rd Qu.:28.16   3rd Qu.:20.19   3rd Qu.:145.8
                    Max.   :4.00   Max.   :37.95   Max.   :20.75   Max.   :147.7
```

```
> data.1 %>% summary
```

```
 Between Plot   Cond       Time            Temp            LAT             LONG
A1:6   P1:3   H:4   Min.   :1.00   Min.   :13.64   Min.   :14.07   Min.   :142.1
A2:6   P2:3   L:4   1st Qu.:1.75   1st Qu.:18.14   1st Qu.:18.12   1st Qu.:144.1
       P3:3   M:4   Median :2.50   Median :25.60   Median :19.17   Median :144.8
       P4:3         Mean   :2.50   Mean   :24.69   Mean   :18.56   Mean   :144.8
                    3rd Qu.:3.25   3rd Qu.:28.16   3rd Qu.:20.19   3rd Qu.:145.8
                    Max.   :4.00   Max.   :37.95   Max.   :20.75   Max.   :147.7
```

Data files

```
> str(data.1)
```

```
'data.frame':   12 obs. of  7 variables:
 $ Between: Factor w/ 2 levels "A1","A2": 1 1 1 1 1 1 2 2 2 2 ...
 $ Plot   : Factor w/ 4 levels "P1","P2","P3",..: 1 1 1 2 2 2 3 3 3 4 ...
 $ Cond   : Factor w/ 3 levels "H","L","M": 1 3 2 1 3 2 1 3 2 1 ...
 $ Time   : int  1 2 3 4 1 2 3 4 1 2 ...
 $ Temp   : num  15.7 23.8 13.6 38 25.3 ...
 $ LAT    : num  17.3 14.1 20.7 18.4 18.5 ...
 $ LONG   : num  146 145 145 142 144 ...
 - attr(*, "out.attrs")=List of 2
  ..$ dim     : Named int  3 4
  .. ..- attr(*, "names")= chr  "Cond" "Plot"
  ..$ dimnames:List of 2
  .. ..$ Cond: chr  "Cond=H" "Cond=M" "Cond=L"
  .. ..$ Plot: chr  "Plot=P1" "Plot=P2" "Plot=P3" "Plot=P4"
```

Dense summary

```
> glimpse(data.1)
```

```
Observations: 12
Variables: 7
$ Between <fct> A1, A1, A1, A1, A1, A1, A2, A2, A2, A2, A2, A2
$ Plot    <fct> P1, P1, P1, P2, P2, P2, P3, P3, P3, P4, P4, P4
$ Cond    <fct> H, M, L, H, M, L, H, M, L, H, M, L
$ Time    <int> 1, 2, 3, 4, 1, 2, 3, 4, 1, 2, 3, 4
$ Temp   <dbl> 15.73546, 23.83643, 13.64371, 37.95281, 25.29508, 13.79532, 26.87
$ LAT    <dbl> 17.25752, 14.07060, 20.74986, 18.41013, 18.46762, 20.38767, 20.14
$ LONG   <dbl> 146.2397, 144.8877, 144.6884, 142.0585, 144.0437, 145.8359, 147.7
```

Section 2

Sorting data

Sorting data (arrange)

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

Sorting by LAT

```
> arrange(data.1, LAT)
```

```
   Between Plot Cond Time     Temp      LAT     LONG
1       A1   P1    M    2 23.83643 14.07060 144.8877
2       A2   P4    L    4 25.89843 14.52130 144.1700
3       A1   P1    H    1 15.73546 17.25752 146.2397
4       A1   P2    H    4 37.95281 18.41013 142.0585
5       A1   P2    M    1 25.29508 18.46762 144.0437
6       A2   P4    M    3 37.11781 18.64913 142.2459
7       A2   P3    M    4 29.38325 19.68780 144.7944
8       A2   P4    H    2 18.94612 20.06427 144.8924
9       A2   P3    H    3 26.87429 20.14244 147.7174
10      A2   P3    L    1 27.75781 20.33795 145.7753
11      A1   P2    L    2 13.79532 20.38767 145.8359
12      A1   P1    L    3 13.64371 20.74986 144.6884
```

Sorting data (arrange)

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

Sorting by LAT (descending order)

```
> arrange(data.1, -LAT)
```

```
   Between Plot Cond Time     Temp      LAT     LONG
1       A1   P1    L    3 13.64371 20.74986 144.6884
2       A1   P2    L    2 13.79532 20.38767 145.8359
3       A2   P3    L    1 27.75781 20.33795 145.7753
4       A2   P3    H    3 26.87429 20.14244 147.7174
5       A2   P4    H    2 18.94612 20.06427 144.8924
6       A2   P3    M    4 29.38325 19.68780 144.7944
7       A2   P4    M    3 37.11781 18.64913 142.2459
8       A1   P2    M    1 25.29508 18.46762 144.0437
9       A1   P2    H    4 37.95281 18.41013 142.0585
10      A1   P1    H    1 15.73546 17.25752 146.2397
11      A2   P4    L    4 25.89843 14.52130 144.1700
12      A1   P1    M    2 23.83643 14.07060 144.8877
```

Sorting data (arrange)

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

Sorting by Cond and then TEMP

```
> arrange(data.1, Cond,Temp)
```

```
   Between Plot Cond Time     Temp      LAT     LONG
1       A1   P1    H    1 15.73546 17.25752 146.2397
2       A2   P4    H    2 18.94612 20.06427 144.8924
3       A2   P3    H    3 26.87429 20.14244 147.7174
4       A1   P2    H    4 37.95281 18.41013 142.0585
5       A1   P1    L    3 13.64371 20.74986 144.6884
6       A1   P2    L    2 13.79532 20.38767 145.8359
7       A2   P4    L    4 25.89843 14.52130 144.1700
8       A2   P3    L    1 27.75781 20.33795 145.7753
9       A1   P1    M    2 23.83643 14.07060 144.8877
10      A1   P2    M    1 25.29508 18.46762 144.0437
11      A2   P3    M    4 29.38325 19.68780 144.7944
12      A2   P4    M    3 37.11781 18.64913 142.2459
```

Sorting data (arrange)

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

Sort by the sum of Temp and LAT

```
> arrange(data.1,Temp+LAT)
```

```
   Between Plot Cond Time     Temp      LAT     LONG
1       A1   P1    H    1 15.73546 17.25752 146.2397
2       A1   P2    L    2 13.79532 20.38767 145.8359
3       A1   P1    L    3 13.64371 20.74986 144.6884
4       A1   P1    M    2 23.83643 14.07060 144.8877
5       A2   P4    H    2 18.94612 20.06427 144.8924
6       A2   P4    L    4 25.89843 14.52130 144.1700
7       A1   P2    M    1 25.29508 18.46762 144.0437
8       A2   P3    H    3 26.87429 20.14244 147.7174
9       A2   P3    L    1 27.75781 20.33795 145.7753
10      A2   P3    M    4 29.38325 19.68780 144.7944
11      A2   P4    M    3 37.11781 18.64913 142.2459
12      A1   P2    H    4 37.95281 18.41013 142.0585
```

Your turn

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

- sort by Between and then Cond

Your turn

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

- sort by Between and then Cond

```
> arrange(data.1,Between,Cond)
```

```
   Between Plot Cond Time     Temp      LAT     LONG
1       A1   P1    H    1 15.73546 17.25752 146.2397
2       A1   P2    H    4 37.95281 18.41013 142.0585
3       A1   P1    L    3 13.64371 20.74986 144.6884
4       A1   P2    L    2 13.79532 20.38767 145.8359
5       A1   P1    M    2 23.83643 14.07060 144.8877
6       A1   P2    M    1 25.29508 18.46762 144.0437
7       A2   P3    H    3 26.87429 20.14244 147.7174
8       A2   P4    H    2 18.94612 20.06427 144.8924
9       A2   P3    L    1 27.75781 20.33795 145.7753
10      A2   P4    L    4 25.89843 14.52130 144.1700
11      A2   P3    M    4 29.38325 19.68780 144.7944
12      A2   P4    M    3 37.11781 18.64913 142.2459
```

Your turn

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

- sort by Condition and then the ratio of Temp to LAT

Your turn

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

- sort by Condition and then the ratio of Temp to LAT

```
> arrange(data.1,Cond,Temp/LAT)
```

```
   Between Plot Cond Time     Temp      LAT     LONG
1       A1   P1    H    1 15.73546 17.25752 146.2397
2       A2   P4    H    2 18.94612 20.06427 144.8924
3       A2   P3    H    3 26.87429 20.14244 147.7174
4       A1   P2    H    4 37.95281 18.41013 142.0585
5       A1   P1    L    3 13.64371 20.74986 144.6884
6       A1   P2    L    2 13.79532 20.38767 145.8359
7       A2   P3    L    1 27.75781 20.33795 145.7753
8       A2   P4    L    4 25.89843 14.52130 144.1700
9       A1   P2    M    1 25.29508 18.46762 144.0437
```

Section 3

Manipulating factors

Manipulating factors

```
> head(data.1, 2)
```

```
  Between Plot Cond Time      Temp      LAT      LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> levels(data.1$Cond)
```

```
[1] "H" "L" "M"
```

- re-levelling
- re-labelling

- technically these operations are performed on single variables (vectors)

Re-levelling (sorting) factors

```
> data.3 <- data.1
> levels(data.3$Cond)
```

```
[1] "H" "L" "M"
```

```
> data.3$Cond <- factor(data.3$Cond, levels=c("L","M","H"))
> levels(data.3$Cond)
```

```
[1] "L" "M" "H"
```

```
> head(data.3)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
3      A1   P1    L    3 13.64371 20.74986 144.6884
4      A1   P2    H    4 37.95281 18.41013 142.0585
5      A1   P2    M    1 25.29508 18.46762 144.0437
6      A1   P2    L    2 13.79532 20.38767 145.8359
```

Re-levelling (sorting) factors

```
> data.3 <- data.1
> levels(data.3$Cond)
```

```
[1] "H" "L" "M"
```

```
> data.3$Cond <- factor(data.3$Cond, labels=c("High","Low","Medium"))
> levels(data.3$Cond)
```

```
[1] "High"   "Low"    "Medium"
```

```
> head(data.3)
```

```
  Between Plot   Cond Time     Temp      LAT     LONG
1      A1   P1   High    1 15.73546 17.25752 146.2397
2      A1   P1 Medium    2 23.83643 14.07060 144.8877
3      A1   P1    Low    3 13.64371 20.74986 144.6884
4      A1   P2   High    4 37.95281 18.41013 142.0585
5      A1   P2 Medium    1 25.29508 18.46762 144.0437
6      A1   P2    Low    2 13.79532 20.38767 145.8359
```

Re-levelling (sorting) factors

```
> data.3 <- data.1
> levels(data.3$Cond)
```

```
[1] "H" "L" "M"
```

```
> data.3$Cond <- factor(data.3$Cond, levels=c('L','M','H'),
+                       labels=c("Low","Medium","High"))
> levels(data.3$Cond)
```

```
[1] "Low"    "Medium" "High"
```

```
> head(data.3)
```

```
  Between Plot   Cond Time     Temp      LAT     LONG
1      A1   P1   High    1 15.73546 17.25752 146.2397
2      A1   P1 Medium    2 23.83643 14.07060 144.8877
3      A1   P1    Low    3 13.64371 20.74986 144.6884
4      A1   P2   High    4 37.95281 18.41013 142.0585
5      A1   P2 Medium    1 25.29508 18.46762 144.0437
6      A1   P2    Low    2 13.79532 20.38767 145.8359
```

Re-labelling factors

```
> data.3 <- data.1 %>% mutate(Cond=recode(Cond,'L'='Low', 'M'='Medium'))
> levels(data.3$Cond)
```

```
[1] "H"      "Low"    "Medium"
```

```
> data.3
```

```
   Between Plot   Cond Time     Temp      LAT      LONG
1       A1   P1      H    1 15.73546 17.25752 146.2397
2       A1   P1 Medium    2 23.83643 14.07060 144.8877
3       A1   P1    Low    3 13.64371 20.74986 144.6884
4       A1   P2      H    4 37.95281 18.41013 142.0585
5       A1   P2 Medium    1 25.29508 18.46762 144.0437
6       A1   P2    Low    2 13.79532 20.38767 145.8359
7       A2   P3      H    3 26.87429 20.14244 147.7174
8       A2   P3 Medium    4 29.38325 19.68780 144.7944
9       A2   P3    Low    1 27.75781 20.33795 145.7753
10      A2   P4      H    2 18.94612 20.06427 144.8924
11      A2   P4 Medium    3 37.11781 18.64913 142.2459
12      A2   P4    Low    4 25.89843 14.52130 144.1700
```

Re-levelling & labelling

```
> data.3 <- data.1 %>% mutate(Cond=recode_factor(Cond,'L'='Low', 'M'='Mediu
> levels(data.3$Cond)
```

```
[1] "Low"    "Medium" "H"
```

```
> data.3
```

```
   Between Plot   Cond Time     Temp      LAT      LONG
1       A1   P1      H    1 15.73546 17.25752 146.2397
2       A1   P1 Medium    2 23.83643 14.07060 144.8877
3       A1   P1    Low    3 13.64371 20.74986 144.6884
4       A1   P2      H    4 37.95281 18.41013 142.0585
5       A1   P2 Medium    1 25.29508 18.46762 144.0437
6       A1   P2    Low    2 13.79532 20.38767 145.8359
7       A2   P3      H    3 26.87429 20.14244 147.7174
8       A2   P3 Medium    4 29.38325 19.68780 144.7944
9       A2   P3    Low    1 27.75781 20.33795 145.7753
10      A2   P4      H    2 18.94612 20.06427 144.8924
11      A2   P4 Medium    3 37.11781 18.64913 142.2459
12      A2   P4    Low    4 25.89843 14.52130 144.1700
```

Re-levelling & labelling

You might also want to check out the `forcats` package

Section 4

Subset columns

Selecting columns (select)

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> select(data.1, Between,Plot,Cond,Time,Temp)
```

```
   Between Plot Cond Time     Temp
1       A1   P1    H    1 15.73546
2       A1   P1    M    2 23.83643
3       A1   P1    L    3 13.64371
4       A1   P2    H    4 37.95281
5       A1   P2    M    1 25.29508
6       A1   P2    L    2 13.79532
7       A2   P3    H    3 26.87429
8       A2   P3    M    4 29.38325
9       A2   P3    L    1 27.75781
10      A2   P4    H    2 18.94612
11      A2   P4    M    3 37.11781
12      A2   P4    L    4 25.89843
```

Selecting columns (select)

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> select(data.1, -LAT,-LONG)
```

```
   Between Plot Cond Time     Temp
1       A1   P1    H    1 15.73546
2       A1   P1    M    2 23.83643
3       A1   P1    L    3 13.64371
4       A1   P2    H    4 37.95281
5       A1   P2    M    1 25.29508
6       A1   P2    L    2 13.79532
7       A2   P3    H    3 26.87429
8       A2   P3    M    4 29.38325
9       A2   P3    L    1 27.75781
10      A2   P4    H    2 18.94612
11      A2   P4    M    3 37.11781
12      A2   P4    L    4 25.89843
```

Selecting columns (select)

HELPER FUNCTIONS

- contains()
- ends_with()
- starts_with()
- matches()
- everything()
- ?

must evaluate to indices

Selecting columns (select)

HELPER FUNCTIONS

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> select(data.1, contains('L'))
```

```
   Plot      LAT     LONG
1    P1 17.25752 146.2397
2    P1 14.07060 144.8877
3    P1 20.74986 144.6884
4    P2 18.41013 142.0585
5    P2 18.46762 144.0437
6    P2 20.38767 145.8359
7    P3 20.14244 147.7174
8    P3 19.68780 144.7944
9    P3 20.33795 145.7753
```

Selecting columns (select)

HELPER FUNCTIONS

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> select(data.1, starts_with('L'))
```

```
       LAT     LONG
1  17.25752 146.2397
2  14.07060 144.8877
3  20.74986 144.6884
4  18.41013 142.0585
5  18.46762 144.0437
6  20.38767 145.8359
7  20.14244 147.7174
8  19.68780 144.7944
9  20.33795 145.7753
```

Selecting columns (select)

HELPER FUNCTIONS

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> select(data.1, ends_with('t'))
```

```
   Plot      LAT
1    P1 17.25752
2    P1 14.07060
3    P1 20.74986
4    P2 18.41013
5    P2 18.46762
6    P2 20.38767
7    P3 20.14244
8    P3 19.68780
9    P3 20.33795
```

Selecting columns (select)

HELPER FUNCTIONS

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> select(data.1, matches('^T[a-z]m.'))
```

```
   Time     Temp
1     1 15.73546
2     2 23.83643
3     3 13.64371
4     4 37.95281
5     1 25.29508
6     2 13.79532
7     3 26.87429
8     4 29.38325
9     1 27.75781
```

Regular expressions (regexp)

https://www.rstudio.com/resources/cheatsheets/raw/master/regex.pdf

Basic Regular Expressions in R

Cheat Sheet

Character Classes

[[:digit:]] or \\d	Digits; `[0-9]`
\\D	Non-digits; `[^0-9]`
[[:lower:]]	Lower-case letters; `[a-z]`
[[:upper:]]	Upper-case letters; `[A-Z]`
[[:alpha:]]	Alphabetic characters; `[A-z]`
[[:alnum:]]	Alphanumeric characters `[A-z0-9]`
\\w	Word characters; `[A-z0-9_]`
\\W	Non-word characters
[[:xdigit:]] or \\x	Hexadec. digits; `[0-9A-Fa-f]`
[[:blank:]]	Space and tab
[[:space:]] or \\s	Space, tab, vertical tab, newline, form feed, carriage return
\\S	Not space; `[^[:space:]]`
[[:punct:]]	Punctuation characters; `!"#$%&'()*+,-./:;<=>?@[]^_`{|}~`
[[:graph:]]	Graphical characters; `[[:alnum:][:punct:]]`
[[:print:]]	Printable characters; `[[:alnum:][:punct:]\\s]`
[[:cntrl:]] or \\c	Control characters; `\n, \r` etc.

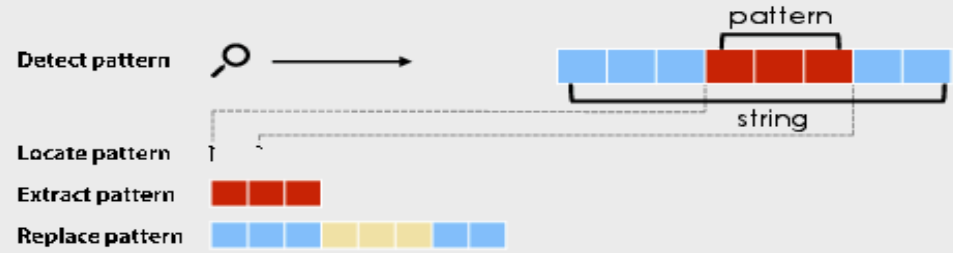
Special Metacharacters

\n	New line
\r	Carriage return
\t	Tab
\v	Vertical tab
\f	Form feed

Lookaraounds and Conditionals*

(?=)	Lookahead (requires PERL = TRUE), e.g. `(?=yx)`: position followed by "xy"
(?!)	Negative lookahead (PERL = TRUE); position NOT followed by pattern
(?<=)	Lookbehind (PERL = TRUE), e.g. `(?<=yx)`: position following "xy"

Functions for Pattern Matching




```
> string <- c("Hiphopopotamus", "Rhymenoceros", "time for bottomless lyrics")
> pattern <- "t.m"
```

Detect Patterns

grep(pattern, string)
```
[1] 1 3
```
grep(pattern, string, value = TRUE)
```
[1] "Hiphopopotamus"
[2] "time for bottomless lyrics"
```
grepl(pattern, string)
```
[1]  TRUE FALSE  TRUE
```
stringr::str_detect(string, pattern)
```
[1]  TRUE FALSE  TRUE
```

Locate Patterns

regexpr(pattern, string)
find starting position and length of first match

gregexpr(pattern, string)
find starting position and length of all matches

stringr::**str_locate(string, pattern)**
find starting and end position of first match

stringr::**str_locate_all(string, pattern)**
find starting and end position of all matches

Split a String using a Pattern

strsplit(string, pattern) or stringr::**str_split(string, pattern)**

Extract Patte

regmatches(strin
extract first mat

regmatches(strin
extract all match
`[[1]] "tam" [`

stringr::**str_extrac**
extract first mat

stringr::**str_extrac**
extract all match

stringr::**str_extrac**
extract all match

stringr::**str_match**
extract first mat

stringr::**str_match**
extract all match

Replace Patte

sub(pattern, repl
replace first mat

gsub(pattern, re
replace all matc

stringr::**str_replac**
replace first mat

stringr::**str_replac**
replace all matc

Character Classes and Groups

.	Any character except `\n`
|	Or, e.g. `(a|b)`
[...]	List permitted characters, e.g. `[abc]`
[a-z]	Specify character ranges
[^...]	List excluded characters
(...)	Grouping, enables back referencing using `\\#` where # is an integer

Anchors

^	Start of the string
$	End of the string
\\b	Empty string at either edge of a word
\\B	NOT the edge of a word
\\<	Beginning of a word
\\>	End of a word

*
+
?
{n}
{n,}
{n,m

General Modes

By default R uses *extended* regular expressions. You can switch to *PCRE regular expressions* using `PERL = TRUE` for base or by wrapping patterns with `perl()` for stringr.

Escaping Characters

Metacharacters (`. * +` etc.) can be used as literal characters by escaping them. Characters can be escaped using `\\` or by enclosing them in `\\Q...\\E`.

Gre

By de
match
used

Gree

Selecting columns (select)

HELPER FUNCTIONS

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> select(data.1, Between:Temp)
```

```
   Between Plot Cond Time     Temp
1       A1   P1    H    1 15.73546
2       A1   P1    M    2 23.83643
3       A1   P1    L    3 13.64371
4       A1   P2    H    4 37.95281
5       A1   P2    M    1 25.29508
6       A1   P2    L    2 13.79532
7       A2   P3    H    3 26.87429
8       A2   P3    M    4 29.38325
9       A2   P3    L    1 27.75781
```

Your turn

```
> head(nasa)
```

```
       lat   long month year cloudhigh cloudlow
1 36.20000 -113.8     1 1995      26.0       7.5
2 33.70435 -113.8     1 1995      20.0      11.5
3 31.20870 -113.8     1 1995      16.0      16.5
4 28.71304 -113.8     1 1995      13.0      20.5
5 26.21739 -113.8     1 1995       7.5      26.0
6 23.72174 -113.8     1 1995       8.0      30.0
  cloudmid ozone pressure surftemp temperature
1     34.5   304      835    272.7       272.1
2     32.5   304      940    279.5       282.2
3     26.0   298      960    284.7       285.2
4     14.5   276      990    289.3       290.7
5     10.5   274     1000    292.2       292.7
6      9.5   264     1000    294.1       293.6
```

Select `lat`, `long`, and `cloud..` columns

Your turn

```
> head(nasa)
```

```
     lat  long month year cloudhigh cloudlow cloudmid ozone pressure surftemp te
1 36.20000 -113.8    1 1995     26.0     7.5    34.5   304      835    272.7      272.
2 33.70435 -113.8    1 1995     20.0    11.5    32.5   304      940    279.5      282.
3 31.20870 -113.8    1 1995     16.0    16.5    26.0   298      960    284.7      285.
4 28.71304 -113.8    1 1995     13.0    20.5    14.5   276      990    289.3      290.
5 26.21739 -113.8    1 1995      7.5    26.0    10.5   274     1000    292.2      292.
6 23.72174 -113.8    1 1995      8.0    30.0     9.5   264     1000    294.1      293.
```

```
> head(select(nasa, lat, long, starts_with("cloud")))
```

```
       lat   long cloudhigh cloudlow cloudmid
1 36.20000 -113.8      26.0      7.5     34.5
2 33.70435 -113.8      20.0     11.5     32.5
3 31.20870 -113.8      16.0     16.5     26.0
4 28.71304 -113.8      13.0     20.5     14.5
5 26.21739 -113.8       7.5     26.0     10.5
6 23.72174 -113.8       8.0     30.0      9.5
```

Your turn

```
> tikus[1:10,c(1:3,76:77)]
```

	Psammocora contigua	Psammocora digitata	Pocillopora damicornis	time	rep
V1	0	0	79	81	1
V2	0	0	51	81	2
V3	0	0	42	81	3
V4	0	0	15	81	4
V5	0	0	9	81	5
V6	0	0	72	81	6
V7	0	0	0	81	7
V8	0	0	16	81	8
V9	0	0	0	81	9
V10	0	0	16	81	10

Select `rep`, `time` and only Species that DONT contain `pora`

Your turn

Select `rep`, `time` and only Species that DONT contain `pora`

```
> dplyr::select(tikus, -contains('pora'))
> ## OR if we wanted to alter the order...
> dplyr::select(tikus, rep, time, everything(),-contains('pora'))
```

Select awkward names

```
> dplyr::select(tikus, `Pocillopora damicornis`)
```

	Pocillopora damicornis
V1	79
V2	51
V3	42
V4	15
V5	9
V6	72
V7	0
V8	16
V9	0
V10	16
V11	0
V12	0
V13	0
V14	0
V15	0
V16	0
V17	0
V18	0
V19	0
V20	0
V21	0
V22	0

Re-naming columns (vectors)

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> rename(data.1, Condition=Cond, Temperature=Temp)
```

```
   Between Plot Condition Time Temperature      LAT     LONG
1       A1   P1         H    1    15.73546 17.25752 146.2397
2       A1   P1         M    2    23.83643 14.07060 144.8877
3       A1   P1         L    3    13.64371 20.74986 144.6884
4       A1   P2         H    4    37.95281 18.41013 142.0585
5       A1   P2         M    1    25.29508 18.46762 144.0437
6       A1   P2         L    2    13.79532 20.38767 145.8359
7       A2   P3         H    3    26.87429 20.14244 147.7174
8       A2   P3         M    4    29.38325 19.68780 144.7944
9       A2   P3         L    1    27.75781 20.33795 145.7753
10      A2   P4         H    2    18.94612 20.06427 144.8924
11      A2   P4         M    3    37.11781 18.64913 142.2459
12      A2   P4         L    4    25.89843 14.52130 144.1700
```

Section 5

Filtering

Filtering

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> filter(data.1, Cond=='H')
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P2    H    4 37.95281 18.41013 142.0585
3      A2   P3    H    3 26.87429 20.14244 147.7174
4      A2   P4    H    2 18.94612 20.06427 144.8924
```

```
> filter(data.1, Cond %in% c('H','M'))
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
3      A1   P2    H    4 37.95281 18.41013 142.0585
4      A1   P2    M    1 25.29508 18.46762 144.0437
5      A2   P3    H    3 26.87429 20.14244 147.7174
6      A2   P3    M    4 29.38325 19.68780 144.7944
7      A2   P4    H    2 18.94612 20.06427 144.8924
```

Filtering

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> filter(data.1, Cond=='H' & Temp<25)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A2   P4    H    2 18.94612 20.06427 144.8924
```

```
> filter(data.1, Cond=='H' | Temp<25)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
3      A1   P1    L    3 13.64371 20.74986 144.6884
4      A1   P2    H    4 37.95281 18.41013 142.0585
5      A1   P2    L    2 13.79532 20.38767 145.8359
6      A2   P3    H    3 26.87429 20.14244 147.7174
7      A2   P4    H    2 18.94612 20.06427 144.8924
```

Your turn

```
> head(data.1, 2)
```

```
  Between Plot Cond Time      Temp       LAT      LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

Keep only those rows with Temp less than 20 and LAT greater than 20 or LONG less than 145

Your turn

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

Keep only those rows with Temp less than 20 and LAT greater than 20, or LONG less than 145

```
> filter(data.1, Temp<20 & (LAT>20 |  LONG <145))
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    L    3 13.64371 20.74986 144.6884
2      A1   P2    L    2 13.79532 20.38767 145.8359
3      A2   P4    H    2 18.94612 20.06427 144.8924
```

Your turn

```
> glimpse(nasa)
```

```
Observations: 41,472
Variables: 11
$ lat         <dbl> 36.200000, 33.704348, 31.208696, 28.713043, 26.217391, 23.7217
$ long        <dbl> -113.8000, -113.8000, -113.8000, -113.8000, -113.8000, -113.80
$ month       <int> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,.
$ year        <int> 1995, 1995, 1995, 1995, 1995, 1995, 1995, 1995, 1995, 1995, 199
$ cloudhigh   <dbl> 26.0, 20.0, 16.0, 13.0, 7.5, 8.0, 14.5, 19.5, 22.5, 21.0, 19.0
$ cloudlow    <dbl> 7.5, 11.5, 16.5, 20.5, 26.0, 30.0, 29.5, 26.5, 27.5, 26.0, 28.
$ cloudmid    <dbl> 34.5, 32.5, 26.0, 14.5, 10.5, 9.5, 11.0, 17.5, 18.5, 16.5, 12.
$ ozone       <dbl> 304, 304, 298, 276, 274, 264, 258, 252, 250, 250, 248, 248, 250
$ pressure    <dbl> 835, 940, 960, 990, 1000, 1000, 1000, 1000, 1000, 1000, 1000,
$ surftemp    <dbl> 272.7, 279.5, 284.7, 289.3, 292.2, 294.1, 295.0, 298.3, 300.1
$ temperature <dbl> 272.1, 282.2, 285.2, 290.7, 292.7, 293.6, 294.6, 296.9, 297.
```

Filter to the largest ozone value for the second month of the last year

Your turn

Filter to the largest ozone value for the second month of the last year

```
> filter(nasa,year==max(year) & month==2) %>% arrange(-ozone) %>% head(5)
> filter(nasa,year==max(year) & month==2) %>% arrange(-ozone) %>% slice(1:5
> ##OR
> filter(nasa,year==max(year) & month==2 ) %>% top_n(5, ozone)
```

Your turn

Filter to all ozone values between 320 and 325 in the first month of the last year

```
> glimpse(nasa)
```

```
Observations: 41,472
Variables: 11
$ lat         <dbl> 36.200000, 33.704348, 31.208696, 28.713043, 26.217391, 23.7217
$ long        <dbl> -113.8000, -113.8000, -113.8000, -113.8000, -113.8000, -113.80
$ month       <int> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,.
$ year        <int> 1995, 1995, 1995, 1995, 1995, 1995, 1995, 1995, 1995, 1995, 199
$ cloudhigh   <dbl> 26.0, 20.0, 16.0, 13.0, 7.5, 8.0, 14.5, 19.5, 22.5, 21.0, 19.0
$ cloudlow    <dbl> 7.5, 11.5, 16.5, 20.5, 26.0, 30.0, 29.5, 26.5, 27.5, 26.0, 28.
$ cloudmid    <dbl> 34.5, 32.5, 26.0, 14.5, 10.5, 9.5, 11.0, 17.5, 18.5, 16.5, 12.
$ ozone       <dbl> 304, 304, 298, 276, 274, 264, 258, 252, 250, 250, 248, 248, 250
$ pressure    <dbl> 835, 940, 960, 990, 1000, 1000, 1000, 1000, 1000, 1000, 1000,
$ surftemp    <dbl> 272.7, 279.5, 284.7, 289.3, 292.2, 294.1, 295.0, 298.3, 300.1
$ temperature <dbl> 272.1, 282.2, 285.2, 290.7, 292.7, 293.6, 294.6, 296.9, 297.
```

Your turn

Filter to all ozone values between 320 and 325 in the first month of the last year

```
> filter(nasa,ozone > 320 & ozone<325, month==first(month), year==last(year
> ##OR
> filter(nasa,between(ozone,320,325), month==first(month), year==last(year)
```

Slicing

FILTERING BY ROW NUMBER

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> slice(data.1, 1:4)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
3      A1   P1    L    3 13.64371 20.74986 144.6884
4      A1   P2    H    4 37.95281 18.41013 142.0585
```

```
> slice(data.1, c(1:4,7))
```

Sampling

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> sample_n(data.1, 10, replace=TRUE)
```

```
     Between Plot Cond Time     Temp      LAT     LONG
5         A1   P2    M    1 25.29508 18.46762 144.0437
5.1       A1   P2    M    1 25.29508 18.46762 144.0437
6         A1   P2    L    2 13.79532 20.38767 145.8359
11        A2   P4    M    3 37.11781 18.64913 142.2459
11.1      A2   P4    M    3 37.11781 18.64913 142.2459
5.2       A1   P2    M    1 25.29508 18.46762 144.0437
10        A2   P4    H    2 18.94612 20.06427 144.8924
12        A2   P4    L    4 25.89843 14.52130 144.1700
6.1       A1   P2    L    2 13.79532 20.38767 145.8359
9         A2   P3    L    1 27.75781 20.33795 145.7753
```

Sampling

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> sample_frac(data.1, 0.5, replace=TRUE)
```

```
   Between Plot Cond Time     Temp      LAT     LONG
5       A1   P2    M    1 25.29508 18.46762 144.0437
4       A1   P2    H    4 37.95281 18.41013 142.0585
10      A2   P4    H    2 18.94612 20.06427 144.8924
3       A1   P1    L    3 13.64371 20.74986 144.6884
9       A2   P3    L    1 27.75781 20.33795 145.7753
2       A1   P1    M    2 23.83643 14.07060 144.8877
```

Effects of filtering

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> #examine the levels of the Cond factor
> levels(data.1$Cond)
```

```
[1] "H" "L" "M"
```

Effects of filtering

```
> #subset the dataset to just Cond H
> data.3<-filter(data.1,Plot=='P1')
> #examine subset data
> data.3
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
3      A1   P1    L    3 13.64371 20.74986 144.6884
```

```
> #examine the levels of the Cond factor
> levels(data.3$Cond)
```

```
[1] "H" "L" "M"
```

```
> levels(data.3$Plot)
```

```
[1] "P1" "P2" "P3" "P4"
```

```
> levels(data.3$Between)
```

```
[1] "A1" "A2"
```

Effects of filtering

CORRECTION - ALL FACTORS

```
> #subset the dataset to just Cond H
> data.3<-filter(data.1,Plot=='P1')
> #drop the unused factor levels from all factors
> data.3<-droplevels(data.3)
> #examine the levels of each factor
> levels(data.3$Cond)
```

```
[1] "H" "L" "M"
```

```
> levels(data.3$Plot)
```

```
[1] "P1"
```

```
> levels(data.3$Between)
```

```
[1] "A1"
```

Effects of filtering

CORRECTION - SINGLE FACTOR

```
> #subset the dataset to just Cond H
> data.3<-filter(data.1,Plot=='P1')
> #drop the unused factor levels from Cond
> data.3$Plot<-factor(data.3$Plot)
> #examine the levels of each factor
> levels(data.3$Cond)
```

```
[1] "H" "L" "M"
```

```
> levels(data.3$Plot)
```

```
[1] "P1"
```

```
> levels(data.3$Between)
```

Section 6

Adding columns

Mutate

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> mutate(data.1, LL=LAT+LONG)
```

```
   Between Plot Cond Time     Temp      LAT     LONG       LL
1       A1   P1    H    1 15.73546 17.25752 146.2397 163.4972
2       A1   P1    M    2 23.83643 14.07060 144.8877 158.9583
3       A1   P1    L    3 13.64371 20.74986 144.6884 165.4383
4       A1   P2    H    4 37.95281 18.41013 142.0585 160.4686
5       A1   P2    M    1 25.29508 18.46762 144.0437 162.5113
6       A1   P2    L    2 13.79532 20.38767 145.8359 166.2236
7       A2   P3    H    3 26.87429 20.14244 147.7174 167.8598
8       A2   P3    M    4 29.38325 19.68780 144.7944 164.4822
9       A2   P3    L    1 27.75781 20.33795 145.7753 166.1133
10      A2   P4    H    2 18.94612 20.06427 144.8924 164.9567
11      A2   P4    M    3 37.11781 18.64913 142.2459 160.8950
12      A2   P4    L    4 25.89843 14.52130 144.1700 158.6913
```

Mutate

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> mutate(data.1, logTemp=log(Temp))
```

```
   Between Plot Cond Time     Temp      LAT     LONG  logTemp
1       A1   P1    H    1 15.73546 17.25752 146.2397 2.755917
2       A1   P1    M    2 23.83643 14.07060 144.8877 3.171215
3       A1   P1    L    3 13.64371 20.74986 144.6884 2.613279
4       A1   P2    H    4 37.95281 18.41013 142.0585 3.636343
5       A1   P2    M    1 25.29508 18.46762 144.0437 3.230610
6       A1   P2    L    2 13.79532 20.38767 145.8359 2.624329
7       A2   P3    H    3 26.87429 20.14244 147.7174 3.291170
8       A2   P3    M    4 29.38325 19.68780 144.7944 3.380425
9       A2   P3    L    1 27.75781 20.33795 145.7753 3.323517
10      A2   P4    H    2 18.94612 20.06427 144.8924 2.941599
11      A2   P4    M    3 37.11781 18.64913 142.2459 3.614097
12      A2   P4    L    4 25.89843 14.52130 144.1700 3.254182
```

Mutate

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> mutate(data.1, MeanTemp=mean(Temp), cTemp=Temp-MeanTemp)
> ## OR if just want the centered variable..
> #mutate(data.1, cTemp=Temp-mean(Temp))
```

```
   Between Plot Cond Time     Temp      LAT     LONG MeanTemp       cTemp
1       A1   P1    H    1 15.73546 17.25752 146.2397 24.68638  -8.9509150
2       A1   P1    M    2 23.83643 14.07060 144.8877 24.68638  -0.8499436
3       A1   P1    L    3 13.64371 20.74986 144.6884 24.68638 -11.0426630
4       A1   P2    H    4 37.95281 18.41013 142.0585 24.68638  13.2664312
5       A1   P2    M    1 25.29508 18.46762 144.0437 24.68638   0.6087009
6       A1   P2    L    2 13.79532 20.38767 145.8359 24.68638 -10.8910607
7       A2   P3    H    3 26.87429 20.14244 147.7174 24.68638   2.1879137
8       A2   P3    M    4 29.38325 19.68780 144.7944 24.68638   4.6968702
9       A2   P3    L    1 27.75781 20.33795 145.7753 24.68638   3.0714367
10      A2   P4    H    2 18.94612 20.06427 144.8924 24.68638  -5.7402607
11      A2   P4    M    3 37.11781 18.64913 142.2459 24.68638  12.4314348
12      A2   P4    L    4 25.89843 14.52130 144.1700 24.68638   1.2120555
```

Mutate

WINDOW FUNCTIONS

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> mutate(data.1, leadTemp=lead(Temp), lagTemp=lag(Temp))
```

```
   Between Plot Cond Time     Temp      LAT     LONG leadTemp  lagTemp
1       A1   P1    H    1 15.73546 17.25752 146.2397 23.83643       NA
2       A1   P1    M    2 23.83643 14.07060 144.8877 13.64371 15.73546
3       A1   P1    L    3 13.64371 20.74986 144.6884 37.95281 23.83643
4       A1   P2    H    4 37.95281 18.41013 142.0585 25.29508 13.64371
5       A1   P2    M    1 25.29508 18.46762 144.0437 13.79532 37.95281
6       A1   P2    L    2 13.79532 20.38767 145.8359 26.87429 25.29508
7       A2   P3    H    3 26.87429 20.14244 147.7174 29.38325 13.79532
8       A2   P3    M    4 29.38325 19.68780 144.7944 27.75781 26.87429
9       A2   P3    L    1 27.75781 20.33795 145.7753 18.94612 29.38325
```

Mutate

WINDOW FUNCTIONS

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> mutate(data.1, rankTime=min_rank(Time),denseRankTime=dense_rank(Time))
```

```
   Between Plot Cond Time     Temp      LAT     LONG rankTime denseRankTime
1       A1   P1    H    1 15.73546 17.25752 146.2397        1             1
2       A1   P1    M    2 23.83643 14.07060 144.8877        4             2
3       A1   P1    L    3 13.64371 20.74986 144.6884        7             3
4       A1   P2    H    4 37.95281 18.41013 142.0585       10             4
5       A1   P2    M    1 25.29508 18.46762 144.0437        1             1
6       A1   P2    L    2 13.79532 20.38767 145.8359        4             2
7       A2   P3    H    3 26.87429 20.14244 147.7174        7             3
8       A2   P3    M    4 29.38325 19.68780 144.7944       10             4
9       A2   P3    L    1 27.75781 20.33795 145.7753        1             1
```

Mutate

WINDOW FUNCTIONS

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> mutate(data.1, rowTemp=row_number(Temp), rowTime=row_number(Time))
```

```
   Between Plot Cond Time     Temp      LAT     LONG rowTemp rowTime
1       A1   P1    H    1 15.73546 17.25752 146.2397       3       1
2       A1   P1    M    2 23.83643 14.07060 144.8877       5       4
3       A1   P1    L    3 13.64371 20.74986 144.6884       1       7
4       A1   P2    H    4 37.95281 18.41013 142.0585      12      10
5       A1   P2    M    1 25.29508 18.46762 144.0437       6       2
6       A1   P2    L    2 13.79532 20.38767 145.8359       2       5
7       A2   P3    H    3 26.87429 20.14244 147.7174       8       8
8       A2   P3    M    4 29.38325 19.68780 144.7944      10      11
9       A2   P3    L    1 27.75781 20.33795 145.7753       9       3
```

Mutate

WINDOW FUNCTIONS

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> mutate(data.1, ntile(Temp,4))
```

```
   Between Plot Cond Time     Temp      LAT     LONG ntile(Temp, 4)
1       A1   P1    H    1 15.73546 17.25752 146.2397               1
2       A1   P1    M    2 23.83643 14.07060 144.8877               2
3       A1   P1    L    3 13.64371 20.74986 144.6884               1
4       A1   P2    H    4 37.95281 18.41013 142.0585               4
5       A1   P2    M    1 25.29508 18.46762 144.0437               2
6       A1   P2    L    2 13.79532 20.38767 145.8359               1
7       A2   P3    H    3 26.87429 20.14244 147.7174               3
8       A2   P3    M    4 29.38325 19.68780 144.7944               4
9       A2   P3    L    1 27.75781 20.33795 145.7753               3
```

Mutate

WINDOW FUNCTIONS

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> mutate(data.1, between(Temp,20,30))
```

```
   Between Plot Cond Time     Temp      LAT     LONG between(Temp, 20, 30)
1       A1   P1    H    1 15.73546 17.25752 146.2397                FALSE
2       A1   P1    M    2 23.83643 14.07060 144.8877                 TRUE
3       A1   P1    L    3 13.64371 20.74986 144.6884                FALSE
4       A1   P2    H    4 37.95281 18.41013 142.0585                FALSE
5       A1   P2    M    1 25.29508 18.46762 144.0437                 TRUE
6       A1   P2    L    2 13.79532 20.38767 145.8359                FALSE
7       A2   P3    H    3 26.87429 20.14244 147.7174                 TRUE
8       A2   P3    M    4 29.38325 19.68780 144.7944                 TRUE
9       A2   P3    L    1 27.75781 20.33795 145.7753                 TRUE
```

Mutate

WINDOW FUNCTIONS

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> mutate(data.1, fTemp=ifelse(Temp<20, 'Low',
+                      ifelse(between(Temp,20,30), 'Medium', 'High')))
> ## OR
> mutate(data.1, fTemp=case_when(Temp<20 ~ 'Low',
+                                between(Temp, 20, 30) ~ 'Medium',
+                                Temp>30 ~ 'High'))
```

```
   Between Plot Cond Time     Temp      LAT     LONG  fTemp
1       A1   P1    H    1 15.73546 17.25752 146.2397    Low
2       A1   P1    M    2 23.83643 14.07060 144.8877 Medium
3       A1   P1    L    3 13.64371 20.74986 144.6884    Low
4       A1   P2    H    4 37.95281 18.41013 142.0585   High
```

Mutate

WINDOW FUNCTIONS

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> mutate(data.1, fTemp=cut(Temp, breaks=c(0,20,30,100),
+                          labels=c('Low','Medium','High')))
```

```
   Between Plot Cond Time     Temp      LAT     LONG  fTemp
1       A1   P1    H    1 15.73546 17.25752 146.2397    Low
2       A1   P1    M    2 23.83643 14.07060 144.8877 Medium
3       A1   P1    L    3 13.64371 20.74986 144.6884    Low
4       A1   P2    H    4 37.95281 18.41013 142.0585   High
5       A1   P2    M    1 25.29508 18.46762 144.0437 Medium
6       A1   P2    L    2 13.79532 20.38767 145.8359    Low
7       A2   P3    H    3 26.87429 20.14244 147.7174 Medium
8       A2   P3    M    4 29.38325 19.68780 144.7944 Medium
```

Section 7

Summarising (aggregating) data

Summarise

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> summarise(data.1, MeanTemp=mean(Temp), VarTemp=var(Temp), N=n())
```

```
  MeanTemp  VarTemp  N
1 24.68638 65.72792 12
```

```
> SE <- function(x) sd(x)/sqrt(length(x))
> summarise(data.1, MeanTemp=mean(Temp), VarTemp=var(Temp), SEM=SE(Temp))
```

```
  MeanTemp  VarTemp      SEM
1 24.68638 65.72792 2.340369
```

Summarise

```
> summarise_all(data.1, .funs=funs(mean,var))
```

```
  Between_mean Plot_mean Cond_mean Time_mean Temp_mean LAT_mean LONG_mean Betwee
1           NA        NA        NA       2.5  24.68638 18.56219  144.7791   0.2727273
   Plot_var  Cond_var Time_var Temp_var  LAT_var LONG_var
1 1.363636 0.7272727 1.363636 65.72792 5.048825 2.512696
```

```
> summarise_at(data.1, vars(Temp,LAT),.funs=funs(mean,var))
```

```
  Temp_mean LAT_mean Temp_var  LAT_var
1  24.68638 18.56219 65.72792 5.048825
```

```
> summarise_if(data.1, is.numeric, .funs=funs(mean,var))
```

```
  Time_mean Temp_mean LAT_mean LONG_mean Time_var Temp_var  LAT_var LONG_var
1       2.5  24.68638 18.56219  144.7791 1.363636 65.72792 5.048825 2.512696
```

Summarise

```
> count(data.1, Cond)
```

```
# A tibble: 3 x 2
  Cond      n
  <fct> <int>
1 H         4
2 L         4
3 M         4
```

```
> count(data.1, Cond,between(Temp,20,30))
```

```
# A tibble: 6 x 3
  Cond  `between(Temp, 20, 30)`     n
  <fct> <lgl>                  <int>
1 H     FALSE                      3
2 H     TRUE                       1
3 L     FALSE                      2
4 L     TRUE                       2
5 M     FALSE                      1
6 M     TRUE                       3
```

Section 8

Piping

Piping

```
> head(data.1, 6)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
3      A1   P1    L    3 13.64371 20.74986 144.6884
4      A1   P2    H    4 37.95281 18.41013 142.0585
5      A1   P2    M    1 25.29508 18.46762 144.0437
6      A1   P2    L    2 13.79532 20.38767 145.8359
```

```
> data.1 %>% filter(Cond=='H') %>%
+     select(Cond, starts_with('t'))
```

```
  Cond Time     Temp
1    H    1 15.73546
2    H    4 37.95281
3    H    3 26.87429
4    H    2 18.94612
```

Section 9

Grouping
(=aggregating)

Grouping

```
> head(data.1, 6)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
3      A1   P1    L    3 13.64371 20.74986 144.6884
4      A1   P2    H    4 37.95281 18.41013 142.0585
5      A1   P2    M    1 25.29508 18.46762 144.0437
6      A1   P2    L    2 13.79532 20.38767 145.8359
```

```
> data.1 %>% group_by(Between,Plot) %>%
+     summarise(Mean=mean(Temp))
```

```
# A tibble: 4 x 3
# Groups:   Between [?]
  Between Plot   Mean
  <fct>   <fct> <dbl>
1 A1      P1     17.7
2 A1      P2     25.7
3 A2      P3     28.0
4 A2      P4     27.3
```

Grouping

```
> head(data.1, 6)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
3      A1   P1    L    3 13.64371 20.74986 144.6884
4      A1   P2    H    4 37.95281 18.41013 142.0585
5      A1   P2    M    1 25.29508 18.46762 144.0437
6      A1   P2    L    2 13.79532 20.38767 145.8359
```

```
> data.1 %>% group_by(Between,Plot) %>%
+     summarise(Mean=mean(Temp), Var=var(Temp), N=n(),First=first(Temp))
```

```
# A tibble: 4 x 6
# Groups:   Between [?]
  Between Plot   Mean    Var     N First
  <fct>   <fct> <dbl>  <dbl> <int> <dbl>
1 A1      P1     17.7  29.0      3  15.7
2 A1      P2     25.7 146.       3  38.0
3 A2      P3     28.0   1.62     3  26.9
4 A2      P4     27.3  84.1      3  18.9
```

Grouping

mutate vs summarise

```
> data.1 %>% group_by(Between,Plot) %>%
+     summarise(Mean=mean(Temp))
```

```
# A tibble: 4 x 3
# Groups:   Between [?]
  Between Plot   Mean
  <fct>   <fct> <dbl>
1 A1      P1     17.7
2 A1      P2     25.7
3 A2      P3     28.0
4 A2      P4     27.3
```

```
> data.1 %>% group_by(Between,Plot) %>%
+     mutate(Mean=mean(Temp))
```

```
# A tibble: 12 x 8
# Groups:   Between, Plot [4]
   Between Plot  Cond   Time  Temp   LAT  LONG  Mean
   <fct>   <fct> <fct> <int> <dbl> <dbl> <dbl> <dbl>
 1 A1      P1    H         1  15.7  17.3  146.  17.7
 2 A1      P1    M         2  23.8  14.1  145.  17.7
 3 A1      P1    L         3  13.6  20.7  145.  17.7
```

Grouping

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> data.1 %>% group_by(Between,Plot) %>%
+     mutate(Mean=mean(Temp), cTemp=Temp-Mean)
```

```
# A tibble: 12 x 9
# Groups:   Between, Plot [4]
   Between Plot  Cond   Time  Temp   LAT  LONG  Mean   cTemp
   <fct>   <fct> <fct> <int> <dbl> <dbl> <dbl> <dbl>   <dbl>
 1 A1      P1    H         1  15.7  17.3  146.  17.7  -2.00
 2 A1      P1    M         2  23.8  14.1  145.  17.7   6.10
 3 A1      P1    L         3  13.6  20.7  145.  17.7  -4.09
 4 A1      P2    H         4  38.0  18.4  142.  25.7  12.3
 5 A1      P2    M         1  25.3  18.5  144.  25.7  -0.386
 6 A1      P2    L         2  13.8  20.4  146.  25.7 -11.9
 7 A2      P3    H         3  26.9  20.1  148.  28.0  -1.13
 8 A2      P3    M         4  29.4  19.7  145.  28.0   1.38
 9 A2      P3    L         1  27.8  20.3  146.  28.0  -0.247
10 A2      P4    H         2  18.9  20.1  145.  27.3  -8.37
11 A2      P4    M         3  37.1  18.6  142.  27.3   9.80
```

Grouping

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> data.1 %>% group_by(Between,Plot) %>%
+     summarise_each(funs(mean))
```

```
# A tibble: 4 x 7
# Groups:   Between [?]
  Between Plot   Cond  Time  Temp   LAT  LONG
  <fct>   <fct> <dbl> <dbl> <dbl> <dbl> <dbl>
1 A1      P1       NA  2.00  17.7  17.4  145.
2 A1      P2       NA  2.33  25.7  19.1  144.
3 A2      P3       NA  2.67  28.0  20.1  146.
4 A2      P4       NA  3.00  27.3  17.7  144.
```

Grouping

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> data.1 %>% select(-Cond,-Time) %>% group_by(Between,Plot) %>%
+     summarise_all(funs(mean))
```

```
# A tibble: 4 x 5
# Groups:   Between [?]
  Between Plot   Temp   LAT  LONG
  <fct>   <fct> <dbl> <dbl> <dbl>
1 A1      P1     17.7  17.4  145.
2 A1      P2     25.7  19.1  144.
3 A2      P3     28.0  20.1  146.
4 A2      P4     27.3  17.7  144.
```

Grouping

```
> head(data.1, 2)
```

```
  Between Plot Cond Time     Temp      LAT     LONG
1      A1   P1    H    1 15.73546 17.25752 146.2397
2      A1   P1    M    2 23.83643 14.07060 144.8877
```

```
> data.1 %>% group_by(Between,Plot) %>%
+     summarise_at(vars(Temp, LAT, LONG), funs(mean,SE))
```

```
# A tibble: 4 x 8
# Groups:   Between [?]
  Between Plot  Temp_mean LAT_mean LONG_mean Temp_SE LAT_SE LONG_SE
  <fct>   <fct>     <dbl>    <dbl>     <dbl>   <dbl>  <dbl>   <dbl>
1 A1      P1         17.7     17.4      145.   3.11   1.93    0.487
2 A1      P2         25.7     19.1      144.   6.98   0.650   1.09
3 A2      P3         28.0     20.1      146.   0.735  0.193   0.859
4 A2      P4         27.3     17.7      144.   5.29   1.66    0.790
```

Your turn

Calculate for each year, the mean abundance of Pocillopora damicornis

```
> tikus[1:10,c(1:3,76:77)]
```

	Psammocora contigua	Psammocora digitata	Pocillopora damicornis	time	rep
V1	0	0	79	81	1
V2	0	0	51	81	2
V3	0	0	42	81	3
V4	0	0	15	81	4
V5	0	0	9	81	5
V6	0	0	72	81	6
V7	0	0	0	81	7
V8	0	0	16	81	8
V9	0	0	0	81	9
V10	0	0	16	81	10

Your turn

Calculate for each year, the mean abundance of Pocillopora damicornis

```
> tikus %>% group_by(time) %>%
+     summarise(MeanAbundance=mean(`Pocillopora damicornis`))
```

```
# A tibble: 6 x 2
  time  MeanAbundance
  <fct>         <dbl>
1 81             30.0
2 83              0.
3 84              0.
4 85              0.
5 87              1.80
6 88              4.00
```

Your turn

Calculate for each year, the number of samples as well as the mean and variance of ozone

```
> nasa = as.data.frame(nasa)
> head(nasa)
```

```
     lat  long month year cloudhigh cloudlow cloudmid ozone pressure surftemp te
1 36.20000 -113.8     1 1995      26.0      7.5     34.5   304      835    272.7      272.
2 33.70435 -113.8     1 1995      20.0     11.5     32.5   304      940    279.5      282.
3 31.20870 -113.8     1 1995      16.0     16.5     26.0   298      960    284.7      285.
4 28.71304 -113.8     1 1995      13.0     20.5     14.5   276      990    289.3      290.
5 26.21739 -113.8     1 1995       7.5     26.0     10.5   274     1000    292.2      292.
6 23.72174 -113.8     1 1995       8.0     30.0      9.5   264     1000    294.1      293.
```

Your turn

Calculate for each year, the number of samples as well as the mean and variance of ozone

```
> nasa %>% group_by(year) %>%
+     summarise(N=n(),Mean=mean(ozone), Var=var(ozone))
```

```
# A tibble: 6 x 4
   year     N  Mean   Var
  <int> <int> <dbl> <dbl>
1  1995  6912  264.  258.
2  1996  6912  267.  326.
3  1997  6912  266.  327.
4  1998  6912  267.  507.
5  1999  6912  270.  368.
6  2000  6912  269.  353.
```

Section 10

Reshaping data

Reshaping data frames

WIDE DATA

	Between	Plot	Time.0	Time.1	Time.2
R1	A1	P1	8	14	14
R2	A1	P2	10	12	11
R3	A2	P3	7	11	8
R4	A2	P4	11	9	2

WIDE TO LONG (MELT)

```
> data.w %>% gather(Time,Count,Time.0:Time.2)
> ## OR
> data.w %>% gather(Time,Count, -Between, -Plot)
```

Between Plot Time Count

Reshaping data frames

LONG DATA

Resp1	Resp2	Between	Plot	Subplot	Within
8	17	A1	P1	S1	B1
10	18	A1	P1	S1	B2
7	17	A1	P1	S2	B1
11	21	A1	P1	S2	B2
14	19	A2	P2	S3	B1
12	13	A2	P2	S3	B2
11	24	A2	P2	S4	B1
9	18	A2	P2	S4	B2
14	25	A3	P3	S5	B1
11	18	A3	P3	S5	B2
8	27	A3	P3	S6	B1
2	22	A3	P3	S6	B2
8	17	A1	P4	S7	B1

Reshaping data frames

```
> head(data,2)
```

```
  Resp1 Resp2 Between Plot Subplot Within
1     8    17      A1   P1      S1     B1
2    10    18      A1   P1      S1     B2
```

WIDEN (CAST)

Widen Resp1 for repeated measures (Within)

```
> data %>% select(-Resp2) %>% spread(Within,Resp1)
```

```
   Between Plot Subplot B1 B2
1       A1   P1      S1  8 10
2       A1   P1      S2  7 11
3       A1   P4      S7  8 10
4       A1   P4      S8  7 12
5       A2   P2      S3 14 12
6       A2   P2      S4 11  9
7       A2   P5      S9 11 12
8       A2   P5     S10 12 10
```

Reshaping data frames

Widen Resp1 and Resp2 for repeated measures (Within)

```
> head(data,2)
```

```
  Resp1 Resp2 Between Plot Subplot Within
1     8    17      A1   P1      S1     B1
2    10    18      A1   P1      S1     B2
```

```
> data %>% gather(Resp,Count,Resp1:Resp2)
```

```
   Between Plot Subplot Within  Resp Count
1       A1   P1      S1     B1 Resp1     8
2       A1   P1      S1     B2 Resp1    10
3       A1   P1      S2     B1 Resp1     7
4       A1   P1      S2     B2 Resp1    11
5       A2   P2      S3     B1 Resp1    14
6       A2   P2      S3     B2 Resp1    12
7       A2   P2      S4     B1 Resp1    11
8       A2   P2      S4     B2 Resp1     9
9       A3   P3      S5     B1 Resp1    14
10      A3   P3      S5     B2 Resp1    11
11      A3   P3      S6     B1 Resp1     8
12      A3   P3      S6     B2 Resp1     2
13      A1   P4      S7     B1 Resp1     8
```

Reshaping data frames

Widen Resp1 and Resp2 for repeated measures (Within)

```
> head(data,2)
```

```
  Resp1 Resp2 Between Plot Subplot Within
1     8    17      A1   P1      S1     B1
2    10    18      A1   P1      S1     B2
```

```
> data %>% gather(Resp,Count,Resp1:Resp2) %>% unite(WR,Within,Resp)
```

```
   Between Plot Subplot       WR Count
1       A1   P1      S1 B1_Resp1     8
2       A1   P1      S1 B2_Resp1    10
3       A1   P1      S2 B1_Resp1     7
4       A1   P1      S2 B2_Resp1    11
5       A2   P2      S3 B1_Resp1    14
6       A2   P2      S3 B2_Resp1    12
7       A2   P2      S4 B1_Resp1    11
8       A2   P2      S4 B2_Resp1     9
9       A3   P3      S5 B1_Resp1    14
10      A3   P3      S5 B2_Resp1    11
11      A3   P3      S6 B1_Resp1     8
12      A3   P3      S6 B2_Resp1     2
13      A1   P4      S7 B1_Resp1     8
```

Reshaping data frames

Widen Resp1 and Resp2 for repeated measures (Within)

```
> head(data,2)
```

```
  Resp1 Resp2 Between Plot Subplot Within
1     8    17      A1   P1      S1     B1
2    10    18      A1   P1      S1     B2
```

```
> data %>% gather(Resp,Count,Resp1:Resp2) %>% unite(WR,Within,Resp) %>%
+     spread(WR,Count)
```

```
   Between Plot Subplot B1_Resp1 B1_Resp2 B2_Resp1 B2_Resp2
1       A1   P1      S1        8       17       10       18
2       A1   P1      S2        7       17       11       21
3       A1   P4      S7        8       17       10       22
4       A1   P4      S8        7       16       12       13
5       A2   P2      S3       14       19       12       13
6       A2   P2      S4       11       24        9       18
7       A2   P5      S9       11       23       12       19
8       A2   P5     S10       12       23       10       21
9       A3   P3      S5       14       25       11       18
10      A3   P3      S6        8       27        2       22
11      A3   P6     S11        3       17       11       16
12      A3   P6     S12       13       26        7       28
```

Section 11

Combining data

Merging data frames

Bio data (missing Subplot 3)

	Resp1	Resp2	Between	Plot	Subplot
1	8	18	A1	P1	S1
2	10	21	A1	P1	S2
4	11	23	A1	P2	S4
5	14	22	A2	P3	S5
6	12	24	A2	P3	S6
7	11	23	A2	P4	S7
8	9	20	A2	P4	S8
9	14	11	A3	P5	S9
10	11	22	A3	P5	S10
11	8	24	A3	P6	S11
12	2	16	A3	P6	S12

Physio-chemical data (missing S7)

	Chem1	Chem2	Between	Plot	Subplot

Merging data frames

Merge bio and chem data (only keep full matches - an inner join)

```
> inner_join(data.bio, data.chem)
```

	Resp1	Resp2	Between	Plot	Subplot	Chem1	Chem2
1	8	18	A1	P1	S1	1.452878	0.8858208
2	10	21	A1	P1	S2	3.266253	0.1800177
3	11	23	A1	P2	S4	13.400350	1.5762780
4	14	22	A2	P3	S5	3.779183	1.6222430
5	12	24	A2	P3	S6	1.196657	4.2369184
6	9	20	A2	P4	S8	5.687807	2.9859003
7	14	11	A3	P5	S9	4.834518	4.1328919
8	11	22	A3	P5	S10	2.002931	3.6043314
9	8	24	A3	P6	S11	12.326867	1.7763576
10	2	16	A3	P6	S12	4.014221	0.2255188

- S3 and S7 absent

Merging data frames

Merge bio and chem data (keep all data - outer join)

```
> full_join(data.bio,data.chem)
```

	Resp1	Resp2	Between	Plot	Subplot	Chem1	Chem2
1	8	18	A1	P1	S1	1.452878	0.8858208
2	10	21	A1	P1	S2	3.266253	0.1800177
3	11	23	A1	P2	S4	13.400350	1.5762780
4	14	22	A2	P3	S5	3.779183	1.6222430
5	12	24	A2	P3	S6	1.196657	4.2369184
6	11	23	A2	P4	S7	NA	NA
7	9	20	A2	P4	S8	5.687807	2.9859003
8	14	11	A3	P5	S9	4.834518	4.1328919
9	11	22	A3	P5	S10	2.002931	3.6043314
10	8	24	A3	P6	S11	12.326867	1.7763576
11	2	16	A3	P6	S12	4.014221	0.2255188
12	NA	NA	A1	P2	S3	1.178652	5.0780682

- note the order of Subplot

Merging data frames

Merge bio and chem data (only keep full BIO matches - left join)

```
> left_join(data.bio, data.chem)
```

	Resp1	Resp2	Between	Plot	Subplot	Chem1	Chem2
1	8	18	A1	P1	S1	1.452878	0.8858208
2	10	21	A1	P1	S2	3.266253	0.1800177
3	11	23	A1	P2	S4	13.400350	1.5762780
4	14	22	A2	P3	S5	3.779183	1.6222430
5	12	24	A2	P3	S6	1.196657	4.2369184
6	11	23	A2	P4	S7	NA	NA
7	9	20	A2	P4	S8	5.687807	2.9859003
8	14	11	A3	P5	S9	4.834518	4.1328919
9	11	22	A3	P5	S10	2.002931	3.6043314
10	8	24	A3	P6	S11	12.326867	1.7763576
11	2	16	A3	P6	S12	4.014221	0.2255188

Merging data frames

Merge bio and chem data (only keep full CHEM matches - right join)

```
> right_join(data.bio, data.chem)
```

	Resp1	Resp2	Between	Plot	Subplot	Chem1	Chem2
1	8	18	A1	P1	S1	1.452878	0.8858208
2	10	21	A1	P1	S2	3.266253	0.1800177
3	NA	NA	A1	P2	S3	1.178652	5.0780682
4	11	23	A1	P2	S4	13.400350	1.5762780
5	14	22	A2	P3	S5	3.779183	1.6222430
6	12	24	A2	P3	S6	1.196657	4.2369184
7	9	20	A2	P4	S8	5.687807	2.9859003
8	14	11	A3	P5	S9	4.834518	4.1328919
9	11	22	A3	P5	S10	2.002931	3.6043314
10	8	24	A3	P6	S11	12.326867	1.7763576
11	2	16	A3	P6	S12	4.014221	0.2255188

Section 12

VLOOKUP

VLOOKUP

Biological data set (data.bio)

	Resp1	Resp2	Between	Plot	Subplot
1	8	18	A1	P1	S1
2	10	21	A1	P1	S2
4	11	23	A1	P2	S4
5	14	22	A2	P3	S5
6	12	24	A2	P3	S6
7	11	23	A2	P4	S7
8	9	20	A2	P4	S8
9	14	11	A3	P5	S9
10	11	22	A3	P5	S10
11	8	24	A3	P6	S11
12	2	16	A3	P6	S12

Geographical data set (lookup table) (data.geo)

	Plot	LAT	LONG
1	P1	17.9605	145.4326
2	P2	17.5210	146.1983
3	P3	17.0011	146.3839
4	P4	18.2350	146.7934
5	P5	18.9840	146.0345
6	P6	20.1154	146.4672

VLOOKUP

Incorporate (merge) the lat/longs into the bio data

```
> left_join(data.bio,data.geo,by=c("Plot"))
```

	Resp1	Resp2	Between	Plot	Subplot	LAT	LONG
1	8	18	A1	P1	S1	17.9605	145.4326
2	10	21	A1	P1	S2	17.9605	145.4326
3	11	23	A1	P2	S4	17.5210	146.1983
4	14	22	A2	P3	S5	17.0011	146.3839
5	12	24	A2	P3	S6	17.0011	146.3839
6	11	23	A2	P4	S7	18.2350	146.7934
7	9	20	A2	P4	S8	18.2350	146.7934
8	14	11	A3	P5	S9	18.9840	146.0345
9	11	22	A3	P5	S10	18.9840	146.0345
10	8	24	A3	P6	S11	20.1154	146.4672
11	2	16	A3	P6	S12	20.1154	146.4672

Section 13

Applied examples

Tikus Island coral data

	Psammocora contigua	Psammocora digitata	time	rep
1	0	0	81	1
2	0	0	81	2
3	0	0	81	3
4	0	0	81	4
5	0	0	81	5
6	0	0	81	6
7	0	0	81	7
8	0	0	81	8
9	0	0	81	9
10	0	0	81	10

```
Observations: 60
Variables: 77
$ `Psammocora contigua`    <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...
$ `Psammocora digitata`    <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...
$ `Pocillopora damicornis` <int> 79, 51, 42, 15, 9, 72, 0, 16, 0,...
$ `Pocillopora verrucosa`  <int> 32, 21, 35, 0, 0, 0, 41, 25, 38,...
$ `Stylopora pistillata`   <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...
$ `Acropora bruegemanni`   <int> 0, 44, 0, 11, 9, 10, 0, 0, 0, 37...
$ `Acropora robusta`       <int> 0, 35, 40, 0, 0, 0, 0, 0, 0, 0, ...
$ `Acropora grandis`       <int> 0, 0, 0, 0, 0, 0, 60, 0, 0, 0, 0...
$ `Acropora intermedia`    <int> 30, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0...
$ `Acropora formosa`       <int> 75, 0, 15, 0, 125, 0, 0, 0, 10, ...
$ `Acropora splendida`     <int> 0, 22, 0, 31, 0, 9, 16, 0, 0, 20...
```

Tikus Island coral data

Explore/Process data

- Convert abundance to cover
- Mean cover of total Acropora per year
- NOTE there is a typo "Acropera"

Tikus Island coral data

Explore/Process data

- Convert abundance to cover (abundance is the length in cm of a 10m transect containing the species)
- Mean cover of total Acropora per year
- NOTE there is a typo "Acropera"

Step 1. fix typo (rename) - backticks

```
> tikus %>% rename(`Acropora aspera`=`Acropera aspera`)
```

Tikus Island coral data

Explore/Process data

- Convert abundance to cover
- Mean cover of total Acropora per year
- NOTE there is a typo "Acropera"

Step 2. melt data (gather)

```
> tikus %>% rename(`Acropora aspera`=`Acropera aspera`) %>%
+     gather(Species, Abundance,-time,-rep)
```

Tikus Island coral data

Explore/Process data

- Convert abundance to cover
- Mean cover of total Acropora per year
- NOTE there is a typo "Acropera"

Step 3. Calculate Cover (`mutate`) (Abundance/10)

```
> tikus %>% rename(`Acropora aspera`=`Acropera aspera`) %>%
+     gather(Species, Abundance,-time,-rep) %>%
+         mutate(Cover=Abundance/10)
```

Tikus Island coral data

Explore/Process data

- Convert abundance to cover
- Mean cover of total Acropora per year
- NOTE there is a typo "Acropera"

Step 4. Split species into Genera and Species (separate)

```
> tikus %>% rename(`Acropora aspera`=`Acropera aspera`) %>%
+     gather(Species, Abundance,-time,-rep) %>%
+         mutate(Cover=Abundance/10) %>%
+             separate(Species,c('Genera','Species'))
```

Tikus Island coral data

Explore/Process data

- Convert abundance to cover
- Mean cover of total Acropora per year
- NOTE there is a typo "Acropera"

Step 5. Subset just "Acropora" (`filter`)

```
> tikus %>% rename(`Acropora aspera`=`Acropera aspera`) %>%
+     gather(Species, Abundance,-time,-rep) %>%
+         mutate(Cover=Abundance/10) %>%
+             separate(Species,c('Genera','Species')) %>%
+                 filter(Genera=='Acropora')
```

Tikus Island coral data

Explore/Process data

- Convert abundance to cover
- Mean cover of total Acropora per year
- NOTE there is a typo "Acropera"

Step 6. Sum over all Species (group_by and summarise)

```
> tikus %>% rename(`Acropora aspera`=`Acropera aspera`) %>%
+     gather(Species, Abundance,-time,-rep) %>%
+         mutate(Cover=Abundance/10) %>%
+             separate(Species,c('Genera','Species')) %>%
+                 filter(Genera=='Acropora') %>%
+                     group_by(time,rep) %>%
+                         summarise(SumCover=sum(Cover))
```

Tikus Island coral data

Explore/Process data

- Convert abundance to cover
- Mean cover of total Acropora per year
- NOTE there is a typo "Acropera"

Step 7. Summarise per year

```
> tikus %>% rename(`Acropora aspera`=`Acropera aspera`) %>%
+     gather(Species, Abundance,-time,-rep) %>%
+         mutate(Cover=Abundance/10) %>%
+             separate(Species,c('Genera','Species')) %>%
+                 filter(Genera=='Acropora') %>%
+                     group_by(time,rep) %>%
+                         summarise(SumCover=sum(Cover)) %>%
+                             group_by(time) %>%
+                                 summarise(Mean=mean(SumCover),
+                                           Var=var(SumCover))
```

```
# A tibble: 6 x 3
  time    Mean    Var
```

Tikus Island coral data

```
> tikus %>% rename(`Acropora aspera`=`Acropera aspera`) %>%
+     gather(Species, Abundance,-time,-rep) %>%
+         mutate(Cover=Abundance/10) %>%
+             separate(Species,c('Genera','Species')) %>%
+                 filter(Genera=='Acropora') %>%
+                     group_by(time,rep) %>%
+                         summarise(SumCover=sum(Cover)) %>%
+                             group_by(time) %>%
+                                 summarise(Mean=mean(SumCover),
+                                           Var=var(SumCover))
```

```
# A tibble: 6 x 3
  time   Mean   Var
  <fct> <dbl> <dbl>
1 81    25.6  383.
2 83     0.     0.
3 84     0.     0.
4 85     2.43  14.2
5 87     8.01  68.5
6 88     8.55 106.
```

Tikus Island coral data

Can you modify so that we get the means and var for each Genera per year?

```
> tikus %>% rename(`Acropora aspera`=`Acropera aspera`) %>%
+     gather(Species, Abundance,-time,-rep) %>%
+         mutate(Cover=Abundance/10) %>%
+             separate(Species,c('Genera','Species')) %>%
+                     group_by(time,rep,Genera) %>%
+                         summarise(SumCover=sum(Cover)) %>%
+                             group_by(time,Genera) %>%
+                                 summarise(Mean=mean(SumCover),
+                                           Var=var(SumCover))
```

```
# A tibble: 144 x 4
# Groups:   time [?]
   time  Genera        Mean    Var
   <fct> <chr>        <dbl>  <dbl>
 1 81    Acropora    25.6   383.
 2 81    Coeloseris   0.880   1.02
 3 81    Cyphastrea   0.      0.
 4 81    Dulophyllia  0.      0.
 5 81    Favia        0.600   1.16
 6 81    Favites      8.22   14.9
 7 81    Fungia       0.680   1.38
 8 81    Galaxea      1.46    3.23
```

Tikus Island coral data

What about the means and var for the top 3 Genera per year (sorted from highest to lowest)?

```
> tikus %>% rename(`Acropora aspera`=`Acropera aspera`) %>%
+     gather(Species, Abundance,-time,-rep) %>%
+         mutate(Cover=Abundance/10) %>%
+             separate(Species,c('Genera','Species')) %>%
+                     group_by(time,rep,Genera) %>%
+                         summarise(SumCover=sum(Cover)) %>%
+                             group_by(time,Genera) %>%
+                                 summarise(Mean=mean(SumCover),
+                                           Var=var(SumCover)) %>%
+                                     top_n(3,Mean) %>%
+                                         arrange(desc(Mean))
```

```
# A tibble: 18 x 4
# Groups:   time [6]
   time  Genera      Mean    Var
   <fct> <chr>      <dbl>  <dbl>
 1 87    Montipora 27.4   966.
 2 81    Acropora  25.6   383.
 3 85    Montipora 20.5   171.
 4 85    Porites   19.0    51.3
 5 88    Montipora 11.8   644.
 6 81    Montipora 11.4    95.7
```