Workshop 2.4: Data manipulation

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1. Data manipulation

1.1. 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**

1.2. Important data manipulation libraries

Task	Function	Package
Transformations	`transform()`, `within()`	base
	`mutate()`	**dplyr**
Adding columns	`within()`	base
	`mutate()`	**dplyr**
Reshaping data	`gather()`, `spread()`	**tidyr**
	`melt()`, `cast()`	reshape2

Task	Function	Package
Aggregating	`tapply()`	base
	`group_by()`	**dplyr**
	`cast()`	reshape2
	`summaryBy()`	doBy
Merging/joining	`merge()`	base
	`*_join()`	**dplyr**

1.3. The grammar of data manipulation

1.3.1. Verbs

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

1.4. The grammar of data manipulation

1.4.1. Tidying verbs

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

1.4.2. multi data.frame verbs

- `*_join()` - merging data

1.5. The grammar of data manipulation

1.5.1. Piping

- %>%

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

1.6. 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))

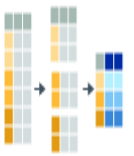
count(x, ..., wt = NULL, sort = FALSE)
Count number of rows in each group defined by the variables in ... Also **tally**().
count(iris, Species)

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))

group_by(.data, ..., add = FALSE)
Returns copy of table grouped by ...
g_iris <- group_by(iris, Species)

ungroup(x, ...)
Returns ungrouped copy of table.
ungroup(g_iris)

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()

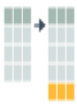
<	<=	is.na()	%in%	|	xor()
>	>=	!is.na()	!	&	

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))

ADD CASES



add_row(.data, ..., .before = NULL, .after = NULL) Add one or more rows to a table.
add_row(faithful, eruptions = 1, waiting = 1)

Manipulate Variables

EXTRACT VARIABLES

Column functions return a set of columns as a new vector or table.

pull(.data, var = -1) Extract column values as a vector. Choose by name or index.
pull(iris, Sepal.Length)

select(.data, ...)
Extract columns as a table. Also **select_if()**.
select(iris, Sepal.Length, Species)

Use these helpers with select ( ),
e.g. select(iris, starts_with("Sepal"))

contains(match)	**num_range**(prefix, range)	:, e.g. mpg:cyl
ends_with(match)	**one_of**(...)	-, e.g. -Species
matches(match)	**starts_with**(match)	

MAKE NEW VARIABLES

These apply **vectorized functions** to columns. Vectorized funs take vectors as input and return vectors of the same length as output (see back).

vectorized function

mutate(.data, ...)
Compute new column(s).
mutate(mtcars, gpm = 1/mpg)

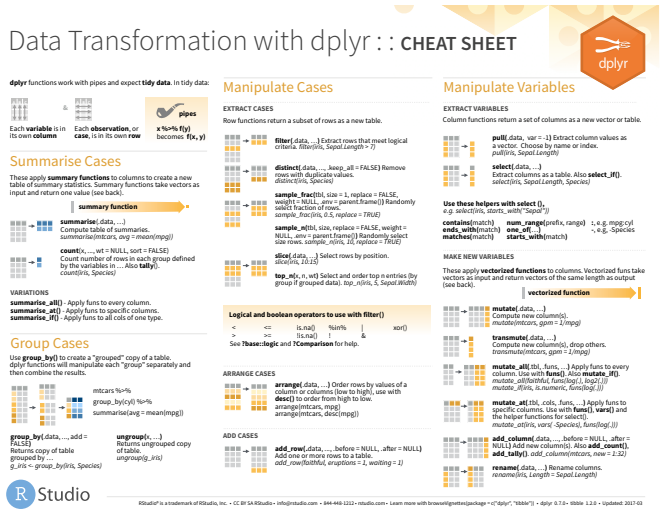
transmute(.data, ...)
Compute new column(s), drop others.
transmute(mtcars, gpm = 1/mpg)

mutate_all(.tbl, .funs, ...) Apply funs to every column. Use with **funs()**. Also **mutate_if()**.
mutate_all(faithful, funs(log(.), log2(.)))
mutate_if(iris, is.numeric, funs(log(.)))

mutate_at(.tbl, .cols, .funs, ...) Apply funs to specific columns. Use with **funs()**, **vars()** and the helper functions for select().
mutate_at(iris, vars(-Species), funs(log(.)))

add_column(.data, ..., .before = NULL, .after = NULL) Add new column(s). Also **add_count()**, **add_tally()**. *add_column(mtcars, new = 1:32)*

rename(.data, ...) Rename columns.
rename(iris, Length = Sepal.Length)



<img src="figure/data-transformation.pdf", width=0cm">

1.7. 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

1.8. Data manipulation packages

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

1.9. 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
```

1.10. 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
```

1.11. 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
```

1.12. 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"
```

1.13. 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, 26.87429,...
$ LAT     <dbl> 17.25752, 14.07060, 20.74986, 18.41013, 18.46762, 20.38767, 20.14244,...
$ LONG    <dbl> 146.2397, 144.8877, 144.6884, 142.0585, 144.0437, 145.8359, 147.7174,...
```

2. Sorting data

2.1. 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
```

2.2. 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
```

2.3. 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
```

2.4. 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
```

2.5. 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

2.6. 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
```

2.7. 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

2.8. 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
10      A2   P3    M    4 29.38325 19.68780 144.7944
11      A1   P1    M    2 23.83643 14.07060 144.8877
12      A2   P4    M    3 37.11781 18.64913 142.2459
```

3. Manipulating factors

3.1. 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)

3.2. 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
```

3.3. 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
```

3.4. 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
```

3.5. 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
```

3.6. Re-levelling & labelling

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

3.7. Re-levelling & labelling

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

4. Subset columns

4.1. 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
```

4.2. 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
```

4.3. Selecting columns (select)

4.3.1. helper functions

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

must evaluate to indices

4.4. Selecting columns (select)

4.4.1. 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
10   P4 20.06427 144.8924
11   P4 18.64913 142.2459
12   P4 14.52130 144.1700
```

4.5. Selecting columns (`select`)

4.5.1. 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
10 20.06427 144.8924
11 18.64913 142.2459
12 14.52130 144.1700
```

4.6. Selecting columns (`select`)

4.6.1. 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
10   P4 20.06427
11   P4 18.64913
12   P4 14.52130
```

4.7. Selecting columns (*select*)

4.7.1. 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
10    2 18.94612
11    3 37.11781
12    4 25.89843
```

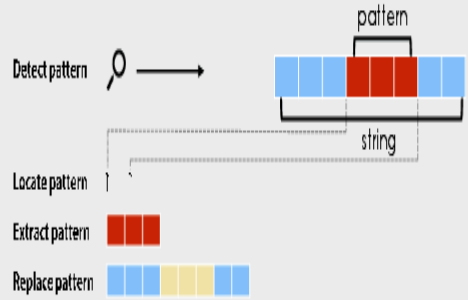
4.8. Regular expressions (regexp)

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

Basic Regular Expressions in R

Cheat Sheet

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 Patterns

regmatches(string, regexpr(pattern, string))
extract first match
```
[1] "tam" "tim"
```

regmatches(string, gregexpr(pattern, string))
extract all matches, outputs a list
```
[[1]] "tam" [[2]] character(0) [[3]] "tim" "tom"
```

stringr::**str_extract(string, pattern)**
extract first match
```
[1] "tam" NA  "tim"
```

stringr::**str_extract_all(string, pattern)**
extract all matches, outputs a list

stringr::**str_extract_all(string, pattern, simplify = TRUE)**
extract all matches, outputs a matrix

stringr::**str_match(string, pattern)**
extract first match + individual character groups

stringr::**str_match_all(string, pattern)**
extract all matches + individual character groups

Replace Patterns

sub(pattern, replacement, string)
replace first match

gsub(pattern, replacement, string)
replace all matches

stringr::**str_replace(string, pattern, replacement)**
replace first match

stringr::**str_replace_all(string, pattern, replacement)**
replace all matches

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

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 \\N where N 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

Quantifiers

*	Matches at least 0 times
+	Matches at least 1 time
?	Matches at most 1 time; optional string
{n}	Matches exactly n times
{n,}	Matches at least n times
{n,m}	Matches between n and m times

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'
(?<!)	Negative lookbehind (PERL = TRUE); position NOT following pattern
?(if)then	If-then-condition (PERL = TRUE); use lookaheads, optional char. etc in if-clause
?(if)then|else	If-then-else-condition (PERL = TRUE)

*see, e.g. http://www.regular-expressions.info/lookaround.html
http://www.regular-expressions.info/conditional.html

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.

All functions can be used with literal searches using `fixed = TRUE` for base or by wrapping patterns with `fixed()` for stringr.

All base functions can be made case insensitive by specifying `ignore.cases = TRUE`.

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.

Case Conversions

Regular expressions can be made case insensitive using (?i). In backreferences, the strings can be converted to lower or upper case using \\L or \\U (e.g. \\L\\1). This requires `PERL = TRUE`.

Greedy Matching

By default the asterisk * is greedy, i.e. it always matches the longest possible string. It can be used in lazy mode by adding ?, i.e. *?.

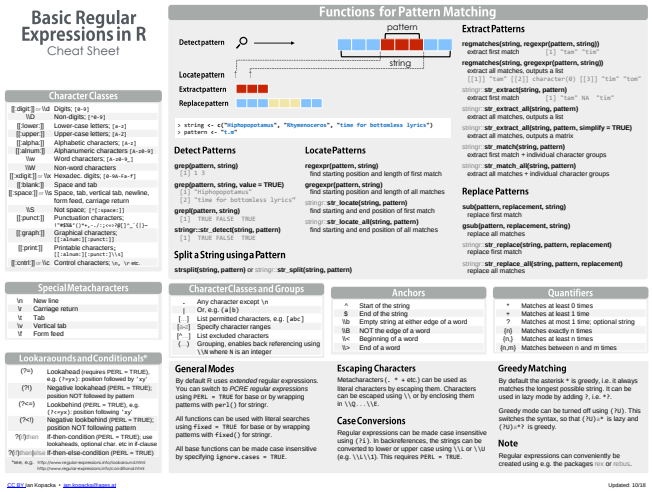
Greedy mode can be turned off using (?U). This switches the syntax, so that (?U)a* is lazy and (?U)a*? is greedy.

Note

Regular expressions can conveniently be created using e.g. the packages rex or rebus.

 · ian.kopacka@ages.at

Updated: 10/18



<img src="figure/regex.pdf", width=0cm">

4.9. Selecting columns (`select`)

4.9.1. 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
10      A2   P4    H    2 18.94612
11      A2   P4    M    3 37.11781
12      A2   P4    L    4 25.89843
```

4.10. 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

4.11. Your turn

```
> head(nasa)
```

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

```
> 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
```

4.12. 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`

4.13. 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'))
```

4.14. 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
V23                      0
V24                      0
V25                      0
V26                      0
V27                      0
V28                      0
V29                      0
V30                      0
V31                      0
V32                      0
V33                      0
V34                      0
V35                      0
V36                      0
V37                      0
V38                      0
V39                      0
V40                      0
V41                     18
V42                      0
V43                      0
V44                      0
V45                      0
V46                      0
V47                      0
V48                      0
V49                      0
V50                      0
V51                      0
```

```
V52                     0
V53                     0
V54                     0
V55                     0
V56                     0
V57                    10
V58                     0
V59                    30
V60                     0
```

4.15. 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
```

5. Filtering

5.1. 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
8      A2   P4    M    3 37.11781 18.64913 142.2459
```

5.2. 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
```

5.3. 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

5.4. 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
```

5.5. Your turn

```
> glimpse(nasa)
```

```
Observations: 41,472
Variables: 11
$ lat         <dbl> 36.200000, 33.704348, 31.208696, 28.713043, 26.217391, 23.721739,...
$ long        <dbl> -113.8000, -113.8000, -113.8000, -113.8000, -113.8000, -113.8000,...
$ month       <int> 1, 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, 1995,...
$ cloudhigh   <dbl> 26.0, 20.0, 16.0, 13.0, 7.5, 8.0, 14.5, 19.5, 22.5, 21.0, 19.0, 1...
$ cloudlow    <dbl> 7.5, 11.5, 16.5, 20.5, 26.0, 30.0, 29.5, 26.5, 27.5, 26.0, 28.5, ...
$ cloudmid    <dbl> 34.5, 32.5, 26.0, 14.5, 10.5, 9.5, 11.0, 17.5, 18.5, 16.5, 12.5, ...
$ 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, 100...
$ surftemp    <dbl> 272.7, 279.5, 284.7, 289.3, 292.2, 294.1, 295.0, 298.3, 300.1, 30...
$ temperature <dbl> 272.1, 282.2, 285.2, 290.7, 292.7, 293.6, 294.6, 296.9, 297.8, 29...
```

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

5.6. 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)
```

5.7. 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, 23.721739,...
$ long        <dbl> -113.8000, -113.8000, -113.8000, -113.8000, -113.8000, -113.8000,...
$ month       <int> 1, 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, 1995,...
$ cloudhigh   <dbl> 26.0, 20.0, 16.0, 13.0, 7.5, 8.0, 14.5, 19.5, 22.5, 21.0, 19.0, 1...
$ cloudlow    <dbl> 7.5, 11.5, 16.5, 20.5, 26.0, 30.0, 29.5, 26.5, 27.5, 26.0, 28.5, ...
$ cloudmid    <dbl> 34.5, 32.5, 26.0, 14.5, 10.5, 9.5, 11.0, 17.5, 18.5, 16.5, 12.5, ...
$ 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, 100...
$ surftemp    <dbl> 272.7, 279.5, 284.7, 289.3, 292.2, 294.1, 295.0, 298.3, 300.1, 30...
$ temperature <dbl> 272.1, 282.2, 285.2, 290.7, 292.7, 293.6, 294.6, 296.9, 297.8, 29...
```

5.8. 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))
```

5.9. Slicing

5.9.1. 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))
```

```
  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      A2   P3    H    3 26.87429 20.14244 147.7174
```

5.10. 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
```

5.11. 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
```

5.12. 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"
```

5.13. 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"
```

5.14. Effects of filtering

5.14.1. 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"
```

5.15. Effects of filtering

5.15.1. 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)
```

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

6. Adding columns

6.1. 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
```

6.2. 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
```

6.3. 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
```

6.4. Mutate

6.4.1. 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
10      A2    P4    H    2 18.94612 20.06427 144.8924 37.11781 27.75781
11      A2    P4    M    3 37.11781 18.64913 142.2459 25.89843 18.94612
12      A2    P4    L    4 25.89843 14.52130 144.1700       NA 37.11781
```

6.5. Mutate

6.5.1. 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
10      A2    P4     H     2 18.94612 20.06427 144.8924         4              2
11      A2    P4     M     3 37.11781 18.64913 142.2459         7              3
12      A2    P4     L     4 25.89843 14.52130 144.1700        10              4
```

6.6. Mutate

6.6.1. 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
10      A2   P4    H    2 18.94612 20.06427 144.8924       4       6
11      A2   P4    M    3 37.11781 18.64913 142.2459      11       9
12      A2   P4    L    4 25.89843 14.52130 144.1700       7      12
```

6.7. Mutate

6.7.1. 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
10      A2   P4    H    2 18.94612 20.06427 144.8924              2
11      A2   P4    M    3 37.11781 18.64913 142.2459              4
12      A2   P4    L    4 25.89843 14.52130 144.1700              3
```

6.8. Mutate

6.8.1. 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
10      A2   P4    H    2 18.94612 20.06427 144.8924                 FALSE
11      A2   P4    M    3 37.11781 18.64913 142.2459                 FALSE
12      A2   P4    L    4 25.89843 14.52130 144.1700                  TRUE
```

6.9. Mutate

6.9.1. 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
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
9       A2    P3    L    1 27.75781 20.33795 145.7753 Medium
10      A2    P4    H    2 18.94612 20.06427 144.8924    Low
11      A2    P4    M    3 37.11781 18.64913 142.2459   High
12      A2    P4    L    4 25.89843 14.52130 144.1700 Medium
   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
9       A2    P3    L    1 27.75781 20.33795 145.7753 Medium
10      A2    P4    H    2 18.94612 20.06427 144.8924    Low
11      A2    P4    M    3 37.11781 18.64913 142.2459   High
12      A2    P4    L    4 25.89843 14.52130 144.1700 Medium
```

6.10. Mutate

6.10.1. 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
9       A2    P3    L    1 27.75781 20.33795 145.7753 Medium
10      A2    P4    H    2 18.94612 20.06427 144.8924    Low
11      A2    P4    M    3 37.11781 18.64913 142.2459   High
12      A2    P4    L    4 25.89843 14.52130 144.1700 Medium
```

7. Summarising (aggregating) data

7.1. 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
```

7.2. Summarise

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

```
  Between_mean Plot_mean Cond_mean Time_mean Temp_mean LAT_mean LONG_mean Between_var
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
```

7.3. 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
```

8. Piping

8.1. 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
```

9. Grouping (=aggregating)

9.1. 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
```

9.2. 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
```

9.3. 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
 4 A1      P2    H         4  38.0  18.4  142.  25.7
 5 A1      P2    M         1  25.3  18.5  144.  25.7
 6 A1      P2    L         2  13.8  20.4  146.  25.7
 7 A2      P3    H         3  26.9  20.1  148.  28.0
 8 A2      P3    M         4  29.4  19.7  145.  28.0
 9 A2      P3    L         1  27.8  20.3  146.  28.0
10 A2      P4    H         2  18.9  20.1  145.  27.3
11 A2      P4    M         3  37.1  18.6  142.  27.3
12 A2      P4    L         4  25.9  14.5  144.  27.3
```

9.4. 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
12 A2      P4    L         4  25.9  14.5  144.  27.3  -1.42
```

9.5. 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.
```

9.6. 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.
```

9.7. 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) %>%
+     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
```

9.8. 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
```

9.9. 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
```

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

9.11. 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.
```

10. Reshaping data

10.1. Reshaping data frames

10.1.1. 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

10.1.2. 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
1       A1   P1 Time.0     8
2       A1   P2 Time.0    10
3       A2   P3 Time.0     7
4       A2   P4 Time.0    11
5       A1   P1 Time.1    14
6       A1   P2 Time.1    12
7       A2   P3 Time.1    11
8       A2   P4 Time.1     9
9       A1   P1 Time.2    14
10      A1   P2 Time.2    11
11      A2   P3 Time.2     8
12      A2   P4 Time.2     2
   Between Plot   Time Count
1       A1   P1 Time.0     8
2       A1   P2 Time.0    10
3       A2   P3 Time.0     7
4       A2   P4 Time.0    11
5       A1   P1 Time.1    14
6       A1   P2 Time.1    12
7       A2   P3 Time.1    11
8       A2   P4 Time.1     9
9       A1   P1 Time.2    14
10      A1   P2 Time.2    11
11      A2   P3 Time.2     8
12      A2   P4 Time.2     2
```

10.2. Reshaping data frames

10.2.1. 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
10	22	A1	P4	S7	B2
7	16	A1	P4	S8	B1
12	13	A1	P4	S8	B2
11	23	A2	P5	S9	B1

Resp1	Resp2	Between	Plot	Subplot	Within
12	19	A2	P5	S9	B2
12	23	A2	P5	S10	B1
10	21	A2	P5	S10	B2
3	17	A3	P6	S11	B1
11	16	A3	P6	S11	B2
13	26	A3	P6	S12	B1
7	28	A3	P6	S12	B2

10.3. 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
```

10.3.1. 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
9       A3   P3      S5 14 11
10      A3   P3      S6  8  2
11      A3   P6     S11  3 11
12      A3   P6     S12 13  7
```

```
> #reshape2:::cast(data,Between+Plot+Subplot~Within,value="Resp1")
```

10.4. 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
14	A1	P4	S7	B2	Resp1	10
15	A1	P4	S8	B1	Resp1	7
16	A1	P4	S8	B2	Resp1	12
17	A2	P5	S9	B1	Resp1	11
18	A2	P5	S9	B2	Resp1	12
19	A2	P5	S10	B1	Resp1	12
20	A2	P5	S10	B2	Resp1	10
21	A3	P6	S11	B1	Resp1	3
22	A3	P6	S11	B2	Resp1	11
23	A3	P6	S12	B1	Resp1	13
24	A3	P6	S12	B2	Resp1	7
25	A1	P1	S1	B1	Resp2	17
26	A1	P1	S1	B2	Resp2	18
27	A1	P1	S2	B1	Resp2	17
28	A1	P1	S2	B2	Resp2	21
29	A2	P2	S3	B1	Resp2	19
30	A2	P2	S3	B2	Resp2	13
31	A2	P2	S4	B1	Resp2	24
32	A2	P2	S4	B2	Resp2	18
33	A3	P3	S5	B1	Resp2	25
34	A3	P3	S5	B2	Resp2	18
35	A3	P3	S6	B1	Resp2	27
36	A3	P3	S6	B2	Resp2	22
37	A1	P4	S7	B1	Resp2	17
38	A1	P4	S7	B2	Resp2	22
39	A1	P4	S8	B1	Resp2	16
40	A1	P4	S8	B2	Resp2	13
41	A2	P5	S9	B1	Resp2	23
42	A2	P5	S9	B2	Resp2	19
43	A2	P5	S10	B1	Resp2	23
44	A2	P5	S10	B2	Resp2	21
45	A3	P6	S11	B1	Resp2	17
46	A3	P6	S11	B2	Resp2	16
47	A3	P6	S12	B1	Resp2	26
48	A3	P6	S12	B2	Resp2	28

10.5. 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
14      A1   P4      S7 B2_Resp1    10
15      A1   P4      S8 B1_Resp1     7
16      A1   P4      S8 B2_Resp1    12
17      A2   P5      S9 B1_Resp1    11
18      A2   P5      S9 B2_Resp1    12
19      A2   P5     S10 B1_Resp1    12
20      A2   P5     S10 B2_Resp1    10
21      A3   P6     S11 B1_Resp1     3
22      A3   P6     S11 B2_Resp1    11
23      A3   P6     S12 B1_Resp1    13
24      A3   P6     S12 B2_Resp1     7
25      A1   P1      S1 B1_Resp2    17
26      A1   P1      S1 B2_Resp2    18
27      A1   P1      S2 B1_Resp2    17
28      A1   P1      S2 B2_Resp2    21
29      A2   P2      S3 B1_Resp2    19
30      A2   P2      S3 B2_Resp2    13
31      A2   P2      S4 B1_Resp2    24
32      A2   P2      S4 B2_Resp2    18
33      A3   P3      S5 B1_Resp2    25
34      A3   P3      S5 B2_Resp2    18
35      A3   P3      S6 B1_Resp2    27
36      A3   P3      S6 B2_Resp2    22
37      A1   P4      S7 B1_Resp2    17
38      A1   P4      S7 B2_Resp2    22
39      A1   P4      S8 B1_Resp2    16
40      A1   P4      S8 B2_Resp2    13
41      A2   P5      S9 B1_Resp2    23
42      A2   P5      S9 B2_Resp2    19
43      A2   P5     S10 B1_Resp2    23
44      A2   P5     S10 B2_Resp2    21
45      A3   P6     S11 B1_Resp2    17
46      A3   P6     S11 B2_Resp2    16
47      A3   P6     S12 B1_Resp2    26
48      A3   P6     S12 B2_Resp2    28
```

10.6. 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
```

11. Combining data

11.1. 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
1	1.453	0.8858	A1	P1	S1
2	3.266	0.18	A1	P1	S2
3	1.179	5.078	A1	P2	S3
4	13.4	1.576	A1	P2	S4

	Chem1	Chem2	Between	Plot	Subplot
5	3.779	1.622	A2	P3	S5
6	1.197	4.237	A2	P3	S6
8	5.688	2.986	A2	P4	S8
9	4.835	4.133	A3	P5	S9
10	2.003	3.604	A3	P5	S10
11	12.33	1.776	A3	P6	S11
12	4.014	0.2255	A3	P6	S12

11.2. 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

11.3. 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

11.4. 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
```

11.5. 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
```

12. VLOOKUP

12.1. 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
```

12.2. 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
```

13. Applied examples

13.1. 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...
$ ‘Acropera aspera‘        <int> 17, 18, 9, 8, 23, 0, 17, 13, 16,...
$ ‘Acropora hyacinthus‘    <int> 141, 34, 55, 54, 0, 0, 0, 0, 0, ...
$ ‘Acropora palifera‘      <int> 32, 0, 44, 0, 17, 0, 0, 0, 0, 0,...
$ ‘Acropora cytherea‘      <int> 108, 33, 14, 122, 0, 0, 0, 8, 0,...
$ ‘Acropora tenuis‘        <int> 0, 25, 0, 0, 0, 22, 28, 0, 0, 0,...
$ ‘Acropora pulchra‘       <int> 0, 0, 15, 52, 62, 33, 0, 0, 24, ...
$ ‘Acropora nasuta‘        <int> 43, 21, 19, 0, 0, 0, 10, 0, 0, 0...
$ ‘Acropora humilis‘       <int> 31, 25, 0, 19, 0, 0, 0, 0, 0, 0,...
$ ‘Acropora diversa‘       <int> 22, 19, 20, 13, 23, 14, 0, 12, 1...
$ ‘Acropora digitifera‘    <int> 30, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0...
$ ‘Acropora divaricata‘    <int> 0, 32, 55, 0, 0, 0, 0, 0, 0, 0, ...
$ ‘Acropora subglabra‘     <int> 51, 0, 0, 44, 15, 0, 0, 25, 0, 0...
$ ‘Acropora cerealis‘      <int> 0, 75, 0, 0, 0, 0, 0, 0, 0, 0, 0...
$ ‘Acropora valida‘        <int> 0, 0, 0, 30, 0, 0, 0, 0, 0, 0, 0...
$ ‘Acropora acuminata‘     <int> 20, 0, 71, 0, 15, 0, 25, 25, 0, ...
$ ‘Acropora elsevi‘        <int> 30, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0...
$ ‘Acropora millepora‘     <int> 17, 14, 0, 20, 0, 0, 0, 0, 0, 0,...
$ ‘Montipora monasteriata‘ <int> 60, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0...
$ ‘Montipora tuberculosa‘  <int> 0, 15, 15, 0, 0, 0, 0, 0, 0, 0, ...
$ ‘Montipora hispida‘      <int> 0, 0, 0, 32, 40, 24, 0, 0, 0, 0,...
$ ‘Montipora digitata‘     <int> 0, 0, 0, 0, 0, 77, 84, 53, 71, 3...
$ ‘Montipora foliosa‘      <int> 0, 0, 0, 0, 50, 71, 62, 81, 24, ...
$ ‘Montipora verrucosa‘    <int> 0, 0, 30, 0, 0, 0, 0, 0, 0, 0, 0...
$ ‘Fungia fungites‘        <int> 0, 0, 18, 17, 0, 0, 0, 0, 0, 0, ...
$ ‘Fungia paumotensis‘     <int> 0, 33, 0, 0, 0, 0, 0, 0, 0, 0, 1...
$ ‘Fungia concina‘         <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...
$ ‘Fungia scutaria‘        <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...
$ ‘Halomitra limax‘        <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...
$ ‘Pavona varians‘         <int> 30, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3...
$ ‘Pavona venosa‘          <int> 0, 24, 0, 0, 0, 0, 0, 0, 0, 0, 0...
$ ‘Pavona cactus‘          <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...
$ ‘Coeloseris mayeri‘      <int> 20, 0, 15, 0, 9, 19, 0, 0, 25, 0...
$ ‘Galaxea fascicularis‘   <int> 51, 27, 31, 24, 0, 13, 0, 0, 0, ...
$ ‘Symphyllia radians‘     <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...
$ ‘Lobophyllia corymbosa‘  <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...
$ ‘Lobophyllia hemprichii‘ <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...
$ ‘Porites cylindrica‘     <int> 61, 24, 0, 20, 0, 0, 0, 0, 0, 0,...
$ ‘Porites lichen‘         <int> 0, 47, 49, 0, 0, 0, 0, 0, 0, 0, ...
$ ‘Porites lobata‘         <int> 36, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0...
$ ‘Porites lutea‘          <int> 30, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0...
$ ‘Porites nigrescens‘     <int> 0, 0, 0, 21, 0, 9, 25, 0, 45, 26...
$ ‘Porites solida‘         <int> 0, 0, 10, 0, 17, 0, 31, 41, 0, 0...
$ ‘Porites stephensoni‘    <int> 0, 0, 0, 0, 0, 0, 0, 30, 0, 0, 0...
$ ‘Goniopora lobata‘       <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...
$ ‘Favia pallida‘          <int> 10, 20, 0, 0, 0, 0, 0, 0, 0, 0, ...
$ ‘Favia speciosa‘         <int> 0, 0, 30, 0, 0, 0, 0, 0, 0, 0, 0...
$ ‘Favia stelligera‘       <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...
$ ‘Favia rotumana‘         <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...
$ ‘Favites abdita‘         <int> 33, 41, 23, 27, 91, 63, 72, 48, ...
$ ‘Favites chinensis‘      <int> 0, 44, 78, 61, 44, 0, 55, 30, 30...
$ ‘Goniastrea rectiformis‘ <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 6,...
$ ‘Goniastrea pectinata‘   <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...
$ ‘Goniastrea sp‘          <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...
```

```
$ ‘Dulophyllia crispa‘     <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...
$ ‘Platygyra daedalea‘     <int> 0, 27, 55, 0, 71, 74, 55, 48, 0,...
$ ‘Platygyra sinensis‘     <int> 47, 27, 56, 26, 0, 0, 0, 0, 0, 0...
$ ‘Hydnopora rigida‘       <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...
$ ‘Leptastrea purpurea‘    <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...
$ ‘Leptastrea pruinosa‘    <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...
$ ‘Cyphastrea serailia‘    <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 19...
$ ‘Millepora platyphylla‘  <int> 30, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0...
$ ‘Millepora dichotoma‘    <int> 21, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0...
$ ‘Millepora intrincata‘   <int> 24, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0...
$ ‘Heliopora coerulea‘     <int> 461, 271, 221, 154, 0, 0, 0, 0, ...
$ time                     <fct> 81, 81, 81, 81, 81, 81, 81, 81, ...
$ rep                      <fct> 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 1...
```

13.2. Tikus Island coral data

Explore/Process data

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

13.3. 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‘)
```

13.4. 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)
```

13.5. 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)
```

13.6. 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'))
```

13.7. 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')
```

13.8. 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))
```

13.9. 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
  <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.
```

13.10. 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.
```

13.11. 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
 9 81    Goniastrea   0.      0.
10 81    Goniopora    0.      0.
# ... with 134 more rows
```

13.12. 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
 7 81    Heliopora  11.1   262.
 8 84    Montipora  11.0    70.5
 9 88    Porites     9.84   41.4
10 88    Acropora    8.55  106.
11 87    Acropora    8.01   68.5
12 87    Porites     4.49   35.8
13 84    Porites     2.94    6.65
14 85    Platygyra   2.55    8.74
15 83    Porites     1.74    2.07
```

16	84	Pavona	1.20	3.33
17	83	Fungia	1.14	3.64
18	83	Montipora	0.930	1.57