

Tidy Data, dplyr, and tidyr

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Tidy data

country	year	cases	population
Afghanistan	1999	745	15437071
Afghanistan	2000	2666	20495360
Brazil	1999	37737	172006362
Brazil	2000	80488	174404898
China	1999	212258	1272915272
China	2000	210766	1280428583

variables

country	year	cases	population
Afghanistan	1999	745	15437071
Afghanistan	2000	2666	20495360
Brazil	1999	37737	172006362
Brazil	2000	80488	174404898
China	1999	212258	1272915272
China	2000	210766	1280428583

observations

- One variable per column
- One observation per row
- Each type of observational unit forms a table



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Modern data frames

Hadley Wickham / RStudio have a package that modifies data frames to be more modern, or as he calls them surly and lazy.

```
library(tibble)  
class(iris)
```

```
## [1] "data.frame"
```

```
tbl_iris = as_tibble(iris)  
class(tbl_iris)
```

```
## [1] "tbl_df"      "tbl"        "data.frame"
```

Fancy Printing

```
tbl_iris
```

```
## # A tibble: 150 x 5
##   Sepal.Length Sepal.Width Petal.Length Petal.Width Species
##   <dbl>         <dbl>         <dbl>         <dbl> <fct>
## 1         5.1         3.5         1.4         0.2 setosa
## 2         4.9         3         1.4         0.2 setosa
## 3         4.7         3.2         1.3         0.2 setosa
## 4         4.6         3.1         1.5         0.2 setosa
## 5         5         3.6         1.4         0.2 setosa
## 6         5.4         3.9         1.7         0.4 setosa
## 7         4.6         3.4         1.4         0.3 setosa
## 8         5         3.4         1.5         0.2 setosa
## 9         4.4         2.9         1.4         0.2 setosa
## 10        4.9         3.1         1.5         0.1 setosa
## # ... with 140 more rows
```

```
iris
```

```
##   Sepal.Length Sepal.Width Petal.Length Petal.Width Species
## 1         5.1         3.5         1.4         0.2 setosa
## 2         4.9         3.0         1.4         0.2 setosa
## 3         4.7         3.2         1.3         0.2 setosa
## 4         4.6         3.1         1.5         0.2 setosa
## 5         5.0         3.6         1.4         0.2 setosa
## 6         5.4         3.9         1.7         0.4 setosa
## 7         4.6         3.4         1.4         0.3 setosa
## 8         5.0         3.4         1.5         0.2 setosa
## 9         4.4         2.9         1.4         0.2 setosa
## 10        4.9         3.1         1.5         0.1 setosa
## 11        5.4         3.7         1.5         0.2 setosa
## 12        4.8         3.4         1.6         0.2 setosa
```

```
df = data.frame(x = rnorm(10,sd=5), y = rnorm(10), z = runif(10))
```

```
as_tibble(df)
```

```
## # A tibble: 10 x 3
##       x         y         z
##   <dbl>   <dbl> <dbl>
## 1 -5.36    2.78    0.458
## 2 -5.74   -0.132   0.287
## 3 -6.91    0.369   0.686
## 4  4.91    0.0153  0.987
## 5 -3.10   -0.740   0.384
## 6 -2.14   -1.02    0.271
## 7  5.35   -0.386   0.504
## 8  1.56   -1.24    0.729
## 9  2.83    1.40    0.531
## 10 -0.930 -0.358   0.161
```

```
df
```

```
##       x         y         z
## 1 -5.3643821  2.77713413 0.4579635
## 2 -5.7379364 -0.13153354 0.2874075
## 3 -6.9123161  0.36929147 0.6859301
## 4  4.9130146  0.01534519 0.9871974
## 5 -3.1025007 -0.73996282 0.3839141
## 6 -2.1377957 -1.02413642 0.2707454
## 7  5.3489623 -0.38550940 0.5044308
## 8  1.5579705 -1.24219038 0.7285012
## 9  2.8279844  1.39631887 0.5305590
## 10 -0.9303533 -0.35796097 0.1611061
```

Tibbles are lazy

```
tbl_iris[1,]
```

```
## # A tibble: 1 x 5  
##   Sepal.Length Sepal.Width Petal.Length Petal.Width Species  
##           <dbl>         <dbl>         <dbl>         <dbl> <fct>  
## 1           5.1           3.5           1.4           0.2 setosa
```


Tibbles are lazy

```
tbl_iris[1,]
```

```
## # A tibble: 1 x 5
##   Sepal.Length Sepal.Width Petal.Length Petal.Width Species
##         <dbl>         <dbl>         <dbl>         <dbl> <fct>
## 1         5.1         3.5         1.4         0.2 setosa
```

```
tbl_iris[,"Species"]
```

```
## # A tibble: 150 x 1
##   Species
##   <fct>
## 1 setosa
## 2 setosa
## 3 setosa
## 4 setosa
## 5 setosa
## 6 setosa
## 7 setosa
## 8 setosa
## 9 setosa
## 10 setosa
## # ... with 140 more rows
```

Tibbles are lazy

```
tbl_iris[1,]
```

```
## # A tibble: 1 x 5
##   Sepal.Length Sepal.Width Petal.Length Petal.Width Species
##         <dbl>         <dbl>         <dbl>         <dbl> <fct>
## 1         5.1         3.5         1.4         0.2 setosa
```

```
tbl_iris[,"Species"]
```

```
## # A tibble: 150 x 1
##   Species
##   <fct>
## 1 setosa
## 2 setosa
## 3 setosa
## 4 setosa
## 5 setosa
## 6 setosa
## 7 setosa
## 8 setosa
## 9 setosa
## 10 setosa
## # ... with 140 more rows
```

```
tibble(
  x = 1:3,
  y = c("A", "B", "C")
)
```

```
## # A tibble: 3 x 2
##       x y
##   <int> <chr>
## 1     1 A
## 2     2 B
## 3     3 C
```

More laziness

```
head( tbl_iris[1] )
```

```
## # A tibble: 6 x 1
##   Sepal.Length
##   <dbl>
## 1         5.1
## 2         4.9
## 3         4.7
## 4         4.6
## 5         5
## 6         5.4
```

More laziness

```
head( tbl_iris[1] )
```

```
## # A tibble: 6 x 1
##   Sepal.Length
##   <dbl>
## 1         5.1
## 2         4.9
## 3         4.7
## 4         4.6
## 5         5
## 6         5.4
```

```
head( tbl_iris[[1]] )
```

```
## [1] 5.1 4.9 4.7 4.6 5.0 5.4
```

More laziness

```
head( tbl_iris[1] )
```

```
## # A tibble: 6 x 1
##   Sepal.Length
##   <dbl>
## 1         5.1
## 2         4.9
## 3         4.7
## 4         4.6
## 5         5
## 6         5.4
```

```
head( tbl_iris[[1]] )
```

```
## [1] 5.1 4.9 4.7 4.6 5.0 5.4
```

```
head( iris$Sp )
```

```
## [1] setosa setosa setosa setosa setosa setosa
## Levels: setosa versicolor virginica
```

```
tbl_iris$Sp
```

```
## Warning: Unknown or uninitialised column: 'Sp'.
## NULL
```

```
head( tbl_iris$Species )
```

```
## [1] setosa setosa setosa setosa setosa setosa
## Levels: setosa versicolor virginica
```

Tibbles and length coercion

```
tibble(x = 1:4, y = 1)
```

```
## # A tibble: 4 x 2
##       x     y
##   <int> <dbl>
## 1     1     1
## 2     2     1
## 3     3     1
## 4     4     1
```

Tibbles and length coercion

```
tibble(x = 1:4, y = 1)
```

```
## # A tibble: 4 x 2
##       x     y
##   <int> <dbl>
## 1     1     1
## 2     2     1
## 3     3     1
## 4     4     1
```

```
tibble(x = 1:4, y = 1:2)
```

```
## Tibble columns must have consistent lengths, only values of length one are recycled:
## * Length 2: Column `y`
## * Length 4: Column `x`
```

Tibbles and length coercion

```
tibble(x = 1:4, y = 1)
```

```
## # A tibble: 4 x 2
##       x     y
##   <int> <dbl>
## 1     1     1
## 2     2     1
## 3     3     1
## 4     4     1
```

```
tibble(x = 1:4, y = 1:2)
```

```
## Tibble columns must have consistent lengths, only values of length one are recycled:
## * Length 2: Column `y`
## * Length 4: Column `x`
```

```
tibble(x = 1:4, y = 1:3)
```

```
## Tibble columns must have consistent lengths, only values of length one are recycled:
## * Length 3: Column `y`
## * Length 4: Column `x`
```


Tibbles and S3

```
d = tibble(  
  x = 1:3,  
  y = c("A", "B", "C")  
)
```

```
class(d)
```

```
## [1] "tbl_df"      "tbl"        "data.frame"
```

Tibbles and S3

```
d = tibble(  
  x = 1:3,  
  y = c("A", "B", "C")  
)
```

```
class(d)
```

```
## [1] "tbl_df"      "tbl"        "data.frame"
```

```
class(d) = rev(class(d))  
class(d)
```

```
## [1] "data.frame" "tbl"        "tbl_df"
```

```
d
```

```
##    x y  
## 1 1 A  
## 2 2 B  
## 3 3 C
```



magrittr

Pipes in R

You can think about the following sequence of actions - find key, unlock car, start car, drive to school, park.

Expressed as a set of nested functions in R pseudocode this would look like:

```
park(drive(start_car(find("keys")), to="campus"))
```

Writing it out using pipes give it a more natural (and easier to read) structure:

```
find("keys") %>%  
  start_car() %>%  
  drive(to="campus") %>%  
  park()
```

Approaches

All of the following are fine, it comes down to personal preference:

Nested:

```
h( g( f(x), y=1), z=1 )
```

Piped:

```
f(x) %>% g(y=1) %>% h(z=1)
```

Intermediate:

```
res = f(x)  
res = g(res, y=1)  
res = h(res, z=1)
```

What about other arguments?

Sometimes we want to send our results to a function argument other than the first one or we want to use the previous result for multiple arguments. In these cases we can refer to the previous result using `..`.

What about other arguments?

Sometimes we want to send our results to an function argument other than first one or we want to use the previous result for multiple arguments. In these cases we can refer to the previous result using `..`.

```
data.frame(a = 1:3, b = 3:1) %>% lm(a~b, data=..)
```

```
##  
## Call:  
## lm(formula = a ~ b, data = ..)  
##  
## Coefficients:  
## (Intercept)          b  
##           4          -1
```

What about other arguments?

Sometimes we want to send our results to an function argument other than first one or we want to use the previous result for multiple arguments. In these cases we can refer to the previous result using ..

```
data.frame(a = 1:3, b = 3:1) %>% lm(a~b, data=.)
```

```
##  
## Call:  
## lm(formula = a ~ b, data = .)  
##  
## Coefficients:  
## (Intercept)          b  
##           4          -1
```

```
data.frame(a = 1:3, b = 3:1) %>% .[[1]]
```

```
## [1] 1 2 3
```


What about other arguments?

Sometimes we want to send our results to an function argument other than first one or we want to use the previous result for multiple arguments. In these cases we can refer to the previous result using `..`.

```
data.frame(a = 1:3, b = 3:1) %>% lm(a~b, data=.)
```

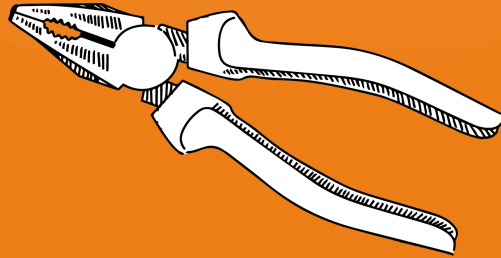
```
##  
## Call:  
## lm(formula = a ~ b, data = .)  
##  
## Coefficients:  
## (Intercept)          b  
##           4          -1
```

```
data.frame(a = 1:3, b = 3:1) %>% .[[1]]
```

```
## [1] 1 2 3
```

```
data.frame(a = 1:3, b = 3:1) %>% .[[length(.)]]
```

```
## [1] 3 2 1
```



dplyr

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A Grammar of Data Manipulation

dplyr is based on the concepts of functions as verbs that manipulate data frames.

Single data frame functions / verbs:

- `filter()` / `slice()`: pick rows based on criteria
- `select()` / `rename()`: select columns by name
- `pull()`: grab a column as a vector
- `arrange()`: reorder rows
- `mutate()` / `transmute()`: add new variables
- `distinct()`: filter for unique rows
- `sample_n()` / `sample_frac()`: randomly sample rows
- `summarise()` / `count()`: reduce variables to values
- `group_by()` / `ungroup()`: modify other verbs to act on subsets
- ... (many more)

dplyr rules

1. First argument is *always* a data frame
2. Subsequent arguments say what to do with that data frame
3. *Always* return a data frame
4. Don't modify in place
5. Lazy evaluation magic

Example Data

We will demonstrate dplyr's functionality using the nycflights13 data.

```
library(dplyr)
library(nycflights13)
```

```
flights
```

```
## # A tibble: 336,776 x 19
##   year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##   <int> <int> <int>   <int>         <int>         <dbl>   <int>         <int>
## 1  2013     1     1     517             515           2     830             819
## 2  2013     1     1     533             529           4     850             830
## 3  2013     1     1     542             540           2     923             850
## 4  2013     1     1     544             545          -1    1004            1022
## 5  2013     1     1     554             600          -6     812             837
## 6  2013     1     1     554             558          -4     740             728
## 7  2013     1     1     555             600          -5     913             854
## 8  2013     1     1     557             600          -3     709             723
## 9  2013     1     1     557             600          -3     838             846
## 10 2013     1     1     558             600          -2     753             745
## # ... with 336,766 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dtm>
```

filter() - March flights

```
flights %>% filter(month == 3)
```

```
## # A tibble: 28,834 x 19
##   year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##   <int> <int> <int>   <int>         <int>         <dbl>   <int>         <int>
## 1  2013     3     1         4           2159          125     318           56
## 2  2013     3     1        50           2358           52     526          438
## 3  2013     3     1       117           2245          152     223          2354
## 4  2013     3     1      454           500           -6     633          648
## 5  2013     3     1     505           515          -10     746          810
## 6  2013     3     1     521           530           -9     813          827
## 7  2013     3     1     537           540           -3     856          850
## 8  2013     3     1     541           545           -4    1014         1023
## 9  2013     3     1     549           600          -11     639          703
## 10 2013     3     1     550           600          -10     747          801
## # ... with 28,824 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dtm>
```

filter() - Flights in the first 7 days of March

```
flights %>% filter(month == 3, day <= 7)
```

```
## # A tibble: 6,530 x 19
##   year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##   <int> <int> <int>   <int>         <int>         <dbl>   <int>         <int>
## 1  2013     3     1         4           2159          125     318           56
## 2  2013     3     1        50           2358           52     526          438
## 3  2013     3     1       117           2245          152     223          2354
## 4  2013     3     1       454           500           -6     633          648
## 5  2013     3     1      505           515          -10     746          810
## 6  2013     3     1      521           530           -9     813          827
## 7  2013     3     1      537           540           -3     856          850
## 8  2013     3     1      541           545           -4    1014         1023
## 9  2013     3     1      549           600          -11     639          703
## 10 2013     3     1      550           600          -10     747          801
## # ... with 6,520 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dtm>
```

filter() - Flights to LAX or JFK in March

```
flights %>% filter(dest == "LAX" | dest == "JFK", month==3)
```

```
## # A tibble: 1,178 x 19
##   year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##   <int> <int> <int>   <int>         <int>         <dbl>   <int>         <int>
## 1  2013     3     1     607           610          -3     832           925
## 2  2013     3     1     629           632          -3     844           952
## 3  2013     3     1     657           700          -3     953          1034
## 4  2013     3     1     714           715          -1     939          1037
## 5  2013     3     1     716           710           6     958          1035
## 6  2013     3     1     727           730          -3    1007          1100
## 7  2013     3     1     836           840          -4    1111          1157
## 8  2013     3     1     857           900          -3    1202          1221
## 9  2013     3     1     903           900           3    1157          1220
## 10 2013     3     1     904           831          33    1150          1151
## # ... with 1,168 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dtm>
```


slice() - First 10 flights

```
flights %>% slice(1:10)
```

```
## # A tibble: 10 x 19
##   year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##   <int> <int> <int>   <int>         <int>         <dbl>   <int>         <int>
## 1  2013     1     1     517           515           2     830           819
## 2  2013     1     1     533           529           4     850           830
## 3  2013     1     1     542           540           2     923           850
## 4  2013     1     1     544           545          -1    1004          1022
## 5  2013     1     1     554           600          -6     812           837
## 6  2013     1     1     554           558          -4     740           728
## 7  2013     1     1     555           600          -5     913           854
## 8  2013     1     1     557           600          -3     709           723
## 9  2013     1     1     557           600          -3     838           846
## 10 2013     1     1     558           600          -2     753           745
## # ... with 11 more variables: arr_delay <dbl>, carrier <chr>, flight <int>,
## #   tailnum <chr>, origin <chr>, dest <chr>, air_time <dbl>, distance <dbl>,
## #   hour <dbl>, minute <dbl>, time_hour <dtm>
```

slice() - Last 5 flights

```
flights %>% slice((n()-4):n())
```

```
## # A tibble: 5 x 19
##   year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##   <int> <int> <int>   <int>         <int>         <dbl>   <int>         <int>
## 1  2013     9    30      NA             1455          NA       NA             1634
## 2  2013     9    30      NA             2200          NA       NA             2312
## 3  2013     9    30      NA             1210          NA       NA             1330
## 4  2013     9    30      NA             1159          NA       NA             1344
## 5  2013     9    30      NA             840           NA       NA             1020
## # ... with 11 more variables: arr_delay <dbl>, carrier <chr>, flight <int>,
## #   tailnum <chr>, origin <chr>, dest <chr>, air_time <dbl>, distance <dbl>,
## #   hour <dbl>, minute <dbl>, time_hour <dtm>
```

select() - Individual Columns

```
flights %>% select(year, month, day)
```

```
## # A tibble: 336,776 x 3
##   year month   day
##   <int> <int> <int>
## 1  2013     1     1
## 2  2013     1     1
## 3  2013     1     1
## 4  2013     1     1
## 5  2013     1     1
## 6  2013     1     1
## 7  2013     1     1
## 8  2013     1     1
## 9  2013     1     1
## 10 2013     1     1
## # ... with 336,766 more rows
```

select() - Exclude Columns

```
flights %>% select(-year, -month, -day)
```

```
## # A tibble: 336,776 x 16
##   dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier
##   <int>      <int>      <dbl>   <int>      <int>      <dbl> <chr>
## 1      517          515         2     830          819        11 UA
## 2      533          529         4     850          830        20 UA
## 3      542          540         2     923          850        33 AA
## 4      544          545        -1    1004         1022       -18 B6
## 5      554          600        -6     812          837       -25 DL
## 6      554          558        -4     740          728        12 UA
## 7      555          600        -5     913          854        19 B6
## 8      557          600        -3     709          723       -14 EV
## 9      557          600        -3     838          846         -8 B6
## 10     558          600        -2     753          745         8 AA
## # ... with 336,766 more rows, and 9 more variables: flight <int>, tailnum <chr>,
## #   origin <chr>, dest <chr>, air_time <dbl>, distance <dbl>, hour <dbl>,
## #   minute <dbl>, time_hour <dtm>
```

select() - Ranges

```
flights %>% select(year:day)
```

```
## # A tibble: 336,776 x 3
##   year month   day
##   <int> <int> <int>
## 1  2013     1     1
## 2  2013     1     1
## 3  2013     1     1
## 4  2013     1     1
## 5  2013     1     1
## 6  2013     1     1
## 7  2013     1     1
## 8  2013     1     1
## 9  2013     1     1
## 10 2013     1     1
## # ... with 336,766 more rows
```

select() - Exclusion Ranges

```
flights %>% select(-(year:day))
```

```
## # A tibble: 336,776 x 16
##   dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier
##   <int>      <int>      <dbl>   <int>      <int>      <dbl> <chr>
## 1      517          515         2     830          819        11 UA
## 2      533          529         4     850          830        20 UA
## 3      542          540         2     923          850        33 AA
## 4      544          545        -1    1004         1022       -18 B6
## 5      554          600        -6     812          837       -25 DL
## 6      554          558        -4     740          728        12 UA
## 7      555          600        -5     913          854        19 B6
## 8      557          600        -3     709          723       -14 EV
## 9      557          600        -3     838          846         -8 B6
## 10     558          600        -2     753          745         8 AA
## # ... with 336,766 more rows, and 9 more variables: flight <int>, tailnum <chr>,
## #   origin <chr>, dest <chr>, air_time <dbl>, distance <dbl>, hour <dbl>,
## #   minute <dbl>, time_hour <dtm>
```

select() - Matching

```
flights %>% select(contains("dep"),
                  contains("arr"))
```

```
## # A tibble: 336,776 x 7
##   dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier
##   <int>      <int>      <dbl>   <int>      <int>      <dbl>   <chr>
## 1      517          515         2      830          819        11    UA
## 2      533          529         4      850          830        20    UA
## 3      542          540         2      923          850        33    AA
## 4      544          545        -1     1004         1022       -18    B6
## 5      554          600        -6      812          837       -25    DL
## 6      554          558        -4      740          728        12    UA
## 7      555          600        -5      913          854        19    B6
## 8      557          600        -3      709          723       -14    EV
## 9      557          600        -3      838          846        -8    B6
## 10     558          600        -2      753          745         8    AA
## # ... with 336,766 more rows
```

```
flights %>% select(starts_with("dep"),
                  starts_with("arr"))
```

```
## # A tibble: 336,776 x 4
##   dep_time dep_delay arr_time arr_delay
##   <int>     <dbl>   <int>   <dbl>
## 1      517         2     830      11
## 2      533         4     850      20
## 3      542         2     923      33
## 4      544        -1    1004     -18
## 5      554        -6     812     -25
## 6      554        -4     740      12
## 7      555        -5     913      19
## 8      557        -3     709     -14
## 9      557        -3     838      -8
## 10     558        -2     753       8
## # ... with 336,766 more rows
```

Some other helpers (provide by tidyselect):

starts_with, ends_with, everything, matches, num_range, one_of, everything, last_col.

select_if() - Get non-numeric columns

```
flights %>% select_if(function(x) !is.numeric(x))
```

```
## # A tibble: 336,776 x 5
##   carrier tailnum origin dest time_hour
##   <chr>    <chr>   <chr> <chr> <dtm>
## 1 UA      N14228   EWR   IAH   2013-01-01 05:00:00
## 2 UA      N24211   LGA   IAH   2013-01-01 05:00:00
## 3 AA      N619AA   JFK   MIA   2013-01-01 05:00:00
## 4 B6      N804JB   JFK   BQN   2013-01-01 05:00:00
## 5 DL      N668DN   LGA   ATL   2013-01-01 06:00:00
## 6 UA      N39463   EWR   ORD   2013-01-01 05:00:00
## 7 B6      N516JB   EWR   FLL   2013-01-01 06:00:00
## 8 EV      N829AS   LGA   IAD   2013-01-01 06:00:00
## 9 B6      N593JB   JFK   MCO   2013-01-01 06:00:00
## 10 AA     N3ALAA   LGA   ORD   2013-01-01 06:00:00
## # ... with 336,766 more rows
```

rename() - Change column names

```
flights %>% rename(tail_number = tailnum)
```

```
## # A tibble: 336,776 x 19
##   year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##   <int> <int> <int>   <int>         <int>         <dbl>   <int>         <int>
## 1  2013     1     1     517           515           2     830           819
## 2  2013     1     1     533           529           4     850           830
## 3  2013     1     1     542           540           2     923           850
## 4  2013     1     1     544           545          -1    1004          1022
## 5  2013     1     1     554           600          -6     812           837
## 6  2013     1     1     554           558          -4     740           728
## 7  2013     1     1     555           600          -5     913           854
## 8  2013     1     1     557           600          -3     709           723
## 9  2013     1     1     557           600          -3     838           846
## 10 2013     1     1     558           600          -2     753           745
## # ... with 336,766 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tail_number <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dtm>
```

select() vs. rename()

```
flights %>% select(tail_number = tailnum)
```

```
## # A tibble: 336,776 x 1
##   tail_number
##   <chr>
## 1 N14228
## 2 N24211
## 3 N619AA
## 4 N804JB
## 5 N668DN
## 6 N39463
## 7 N516JB
## 8 N829AS
## 9 N593JB
## 10 N3ALAA
## # ... with 336,766 more rows
```

```
flights %>% rename(tail_number = tailnum)
```

```
## # A tibble: 336,776 x 19
##   year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##   <int> <int> <int>   <int>         <int>         <dbl>   <int>         <int>
## 1  2013     1     1     517             515           2     830             819
## 2  2013     1     1     533             529           4     850             830
## 3  2013     1     1     542             540           2     923             850
## 4  2013     1     1     544             545          -1    1004            1022
## 5  2013     1     1     554             600          -6     812             837
## 6  2013     1     1     554             558          -4     740             728
## 7  2013     1     1     555             600          -5     913             854
## 8  2013     1     1     557             600          -3     709             723
## 9  2013     1     1     557             600          -3     838             846
## 10 2013     1     1     558             600          -2     753             745
## # ... with 336,766 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tail_number <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dtm>
```

pull()

```
names(flights)
```

```
## [1] "year"      "month"     "day"       "dep_time"
## [5] "sched_dep_time" "dep_delay" "arr_time"  "sched_arr_time"
## [9] "arr_delay"    "carrier"   "flight"    "tailnum"
## [13] "origin"       "dest"      "air_time"  "distance"
## [17] "hour"        "minute"    "time_hour"
```

```
flights %>% pull("year") %>% head()
```

```
## [1] 2013 2013 2013 2013 2013 2013
```

```
flights %>% pull(1) %>% head()
```

```
## [1] 2013 2013 2013 2013 2013 2013
```

```
flights %>% pull(-1) %>% head()
```

```
## [1] "2013-01-01 05:00:00 EST" "2013-01-01 05:00:00 EST"
## [3] "2013-01-01 05:00:00 EST" "2013-01-01 05:00:00 EST"
## [5] "2013-01-01 06:00:00 EST" "2013-01-01 05:00:00 EST"
```

arrange() - Sort data

```
flights %>% filter(month==3,day==2) %>% arrange(origin, dest)
```

```
## # A tibble: 765 x 19
##   year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##   <int> <int> <int>   <int>         <int>         <dbl>   <int>         <int>
## 1  2013     3     2    1336           1329         7     1426           1432
## 2  2013     3     2     628           629        -1      837           849
## 3  2013     3     2     637           640        -3      903           915
## 4  2013     3     2     743           745        -2      945          1010
## 5  2013     3     2     857           900        -3     1117          1126
## 6  2013     3     2    1027          1030        -3     1234          1247
## 7  2013     3     2    1134          1145       -11     1332          1359
## 8  2013     3     2    1412          1415        -3     1636          1630
## 9  2013     3     2    1633          1636        -3     1848          1908
## 10 2013     3     2    1655          1700        -5     1857          1924
## # ... with 755 more rows, and 11 more variables: arr_delay <dbl>, carrier <chr>,
## #   flight <int>, tailnum <chr>, origin <chr>, dest <chr>, air_time <dbl>,
## #   distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dtm>
```

arrange() & desc() - Descending order

```
flights %>% filter(month==3,day==2) %>% arrange(desc(origin), dest) %>% select(origin, dest, ta
```

```
## # A tibble: 765 x 3
##   origin dest  tailnum
##   <chr>  <chr> <chr>
## 1 LGA    ATL   N928AT
## 2 LGA    ATL   N623DL
## 3 LGA    ATL   N680DA
## 4 LGA    ATL   N996AT
## 5 LGA    ATL   N510MQ
## 6 LGA    ATL   N663DN
## 7 LGA    ATL   N942DL
## 8 LGA    ATL   N511MQ
## 9 LGA    ATL   N910DE
## 10 LGA   ATL   N902DE
## # ... with 755 more rows
```

mutate() - Modify columns

```
flights %>% select(year:day) %>% mutate(date = paste(year,month,day,sep="/"))
```

```
## # A tibble: 336,776 x 4
##   year month   day date
##   <int> <int> <int> <chr>
## 1  2013     1     1 2013/1/1
## 2  2013     1     1 2013/1/1
## 3  2013     1     1 2013/1/1
## 4  2013     1     1 2013/1/1
## 5  2013     1     1 2013/1/1
## 6  2013     1     1 2013/1/1
## 7  2013     1     1 2013/1/1
## 8  2013     1     1 2013/1/1
## 9  2013     1     1 2013/1/1
## 10 2013     1     1 2013/1/1
## # ... with 336,766 more rows
```

transmute() - Create new tibble from existing columns

```
flights %>% select(year:day) %>% transmute(date = paste(year,month,day,sep="/"))
```

```
## # A tibble: 336,776 x 1
##   date
##   <chr>
## 1 2013/1/1
## 2 2013/1/1
## 3 2013/1/1
## 4 2013/1/1
## 5 2013/1/1
## 6 2013/1/1
## 7 2013/1/1
## 8 2013/1/1
## 9 2013/1/1
## 10 2013/1/1
## # ... with 336,766 more rows
```


distinct() - Find unique rows

```
flights %>% select(origin, dest) %>% distinct() %>% arrange(origin,dest)
```

```
## # A tibble: 224 x 2
##   origin dest
##   <chr>  <chr>
## 1 EWR    ALB
## 2 EWR    ANC
## 3 EWR    ATL
## 4 EWR    AUS
## 5 EWR    AVL
## 6 EWR    BDL
## 7 EWR    BNA
## 8 EWR    BOS
## 9 EWR    BQN
## 10 EWR   BTV
## # ... with 214 more rows
```

Sampling rows

```
flights %>% sample_n(10)
```

```
## # A tibble: 10 x 19
##   year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##   <int> <int> <int>   <int>         <int>         <dbl>   <int>         <int>
## 1  2013     7     8    1803             1759          4     2115             2058
## 2  2013    10    16     708             717         -9       759             831
## 3  2013     1    27    1810             1815         -5     2040             2026
## 4  2013    10    24    1751             1800         -9     2108             2103
## 5  2013     7     9    1653             1700         -7     1942             1845
## 6  2013     4    18    1728             1615         73     1949             1840
## 7  2013     9     6    1808             1815         -7     2038             2128
## 8  2013     9     6     849             845          4     1002             1022
## 9  2013     9    28    1639             1643         -4     1922             1955
## 10 2013    11     8    1259             1259          0     1554             1605
## # ... with 11 more variables: arr_delay <dbl>, carrier <chr>, flight <int>,
## #   tailnum <chr>, origin <chr>, dest <chr>, air_time <dbl>, distance <dbl>,
## #   hour <dbl>, minute <dbl>, time_hour <dtm>
```

```
flights %>% sample_frac(0.00003)
```

```
## # A tibble: 10 x 19
##   year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##   <int> <int> <int>   <int>         <int>         <dbl>   <int>         <int>
## 1  2013    10     7    2317             2124        113      131             2337
## 2  2013     1    27    1516             1435         41     1801             1748
## 3  2013     3     1    1854             1855         -1     2117             2142
## 4  2013     4    17     655             700         -5       922             933
## 5  2013     3     2     946             900         46     1212             1213
## 6  2013     4     5     736             740         -4       932             948
## 7  2013    10    12     959             1004         -5     1146             1203
## 8  2013     8    13    1114             1030         44     1242             1142
## 9  2013     7     9    1412             1417         -5     1602             1541
## 10 2013     6    27    1106             1110         -4     1403             1407
## # ... with 11 more variables: arr_delay <dbl>, carrier <chr>, flight <int>,
## #   tailnum <chr>, origin <chr>, dest <chr>, air_time <dbl>, distance <dbl>,
## #   hour <dbl>, minute <dbl>, time_hour <dtm>
```

summarise()

```
flights %>% summarize(n(), min(dep_delay), max(dep_delay))
```

```
## # A tibble: 1 x 3
##   `n()` `min(dep_delay)` `max(dep_delay)`
##   <int>      <dbl>      <dbl>
## 1  336776          NA          NA
```

summarise()

```
flights %>% summarize(n(), min(dep_delay), max(dep_delay))
```

```
## # A tibble: 1 x 3
##   `n()` `min(dep_delay)` `max(dep_delay)`
##   <int>      <dbl>      <dbl>
## 1  336776          NA          NA
```

```
flights %>%
  summarize(
    n = n(),
    min_dep_delay = min(dep_delay, na.rm = TRUE),
    max_dep_delay = max(dep_delay, na.rm = TRUE)
  )
```

```
## # A tibble: 1 x 3
##       n min_dep_delay max_dep_delay
##   <int>      <dbl>      <dbl>
## 1  336776      -43       1301
```

group_by()

```
flights %>% group_by(origin)
```

```
## # A tibble: 336,776 x 19
## # Groups:   origin [3]
##   year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##   <int> <int> <int>   <int>         <int>         <dbl>   <int>         <int>
## 1  2013     1     1     517           515           2     830           819
## 2  2013     1     1     533           529           4     850           830
## 3  2013     1     1     542           540           2     923           850
## 4  2013     1     1     544           545          -1    1004          1022
## 5  2013     1     1     554           600          -6     812           837
## 6  2013     1     1     554           558          -4     740           728
## 7  2013     1     1     555           600          -5     913           854
## 8  2013     1     1     557           600          -3     709           723
## 9  2013     1     1     557           600          -3     838           846
## 10 2013     1     1     558           600          -2     753           745
## # ... with 336,766 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dtm>
```

summarise() with group_by()

```
flights %>% group_by(origin) %>%  
  summarize(  
    n = n(),  
    min_dep_delay = min(dep_delay, na.rm = TRUE),  
    max_dep_delay = max(dep_delay, na.rm = TRUE)  
  )
```

```
## # A tibble: 3 x 4  
##   origin      n min_dep_delay max_dep_delay  
##   <chr>   <int>         <dbl>         <dbl>  
## 1 EWR    120835         -25           1126  
## 2 JFK    111279         -43           1301  
## 3 LGA    104662         -33            911
```

```

flights %>% group_by(origin, carrier) %>%
  summarize(
    n = n(),
    min_dep_delay = min(dep_delay, na.rm = TRUE),
    max_dep_delay = max(dep_delay, na.rm = TRUE)
  ) %>%
  filter(n > 10000)

```

```

## # A tibble: 10 x 5
## # Groups:   origin [3]
##   origin carrier      n min_dep_delay max_dep_delay
##   <chr>   <chr>   <int>         <dbl>         <dbl>
## 1 EWR     EV      43939          -25           548
## 2 EWR     UA      46087          -18           424
## 3 JFK     9E      14651          -24           747
## 4 JFK     AA      13783          -15          1014
## 5 JFK     B6      42076          -43           453
## 6 JFK     DL      20701          -18           960
## 7 LGA     AA      15459          -24           803
## 8 LGA     DL      23067          -33           911
## 9 LGA     MQ      16928          -26           366
## 10 LGA    US      13136          -18           500

```

count()

```
flights %>%  
  group_by(origin, carrier) %>%  
  summarize(n = n()) %>%  
  ungroup()
```

```
## # A tibble: 35 x 3  
##   origin carrier      n  
##   <chr>   <chr>   <int>  
## 1 EWR     9E      1268  
## 2 EWR     AA      3487  
## 3 EWR     AS       714  
## 4 EWR     B6      6557  
## 5 EWR     DL      4342  
## 6 EWR     EV     43939  
## 7 EWR     MQ      2276  
## 8 EWR     OO         6  
## 9 EWR     UA     46087  
## 10 EWR    US      4405  
## # ... with 25 more rows
```

```
flights %>% count(origin, carrier)
```

```
## # A tibble: 35 x 3  
##   origin carrier      n  
##   <chr>   <chr>   <int>  
## 1 EWR     9E      1268  
## 2 EWR     AA      3487  
## 3 EWR     AS       714  
## 4 EWR     B6      6557  
## 5 EWR     DL      4342  
## 6 EWR     EV     43939  
## 7 EWR     MQ      2276  
## 8 EWR     OO         6  
## 9 EWR     UA     46087  
## 10 EWR    US      4405  
## # ... with 25 more rows
```


mutate() with group_by()

```
flights %>% group_by(origin) %>%  
  mutate(  
    n = n(),  
  ) %>%  
  select(origin, n)
```

```
## # A tibble: 336,776 x 2  
## # Groups:   origin [3]  
##   origin      n  
##   <chr>   <int>  
## 1 EWR     120835  
## 2 LGA     104662  
## 3 JFK     111279  
## 4 JFK     111279  
## 5 LGA     104662  
## 6 EWR     120835  
## 7 EWR     120835  
## 8 LGA     104662  
## 9 JFK     111279  
## 10 LGA     104662  
## # ... with 336,766 more rows
```

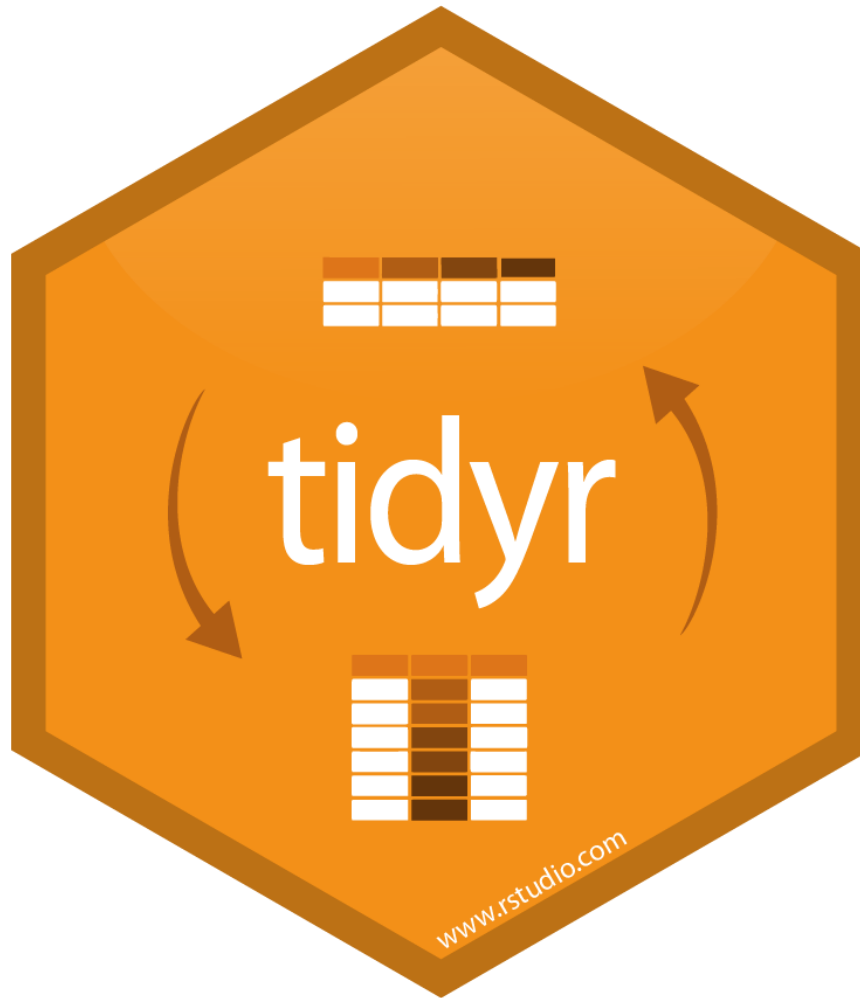
Demos

1. How many flights to Los Angeles (LAX) did each of the legacy carriers (AA, UA, DL or US) have in May from JFK, and what was their average duration?
1. What was the shortest flight out of each airport in terms of distance? In terms of duration?

Exercise 1

1. Which plane (check the tail number) flew out of each New York airport the most?

1. Which date should you fly on if you want to have the lowest possible average departure delay? What about arrival delay?



Gather

gather(data, key, value, ..., na.rm = FALSE,
convert = FALSE, factor_key = FALSE)

gather() moves column names into a **key** column, gathering the column values into a single **value** column.

table4a

country	1999	2000
A	0.7K	2K
B	37K	80K
C	212K	213K



country	year	cases
A	1999	0.7K
B	1999	37K
C	1999	212K
A	2000	2K
B	2000	80K
C	2000	213K

key value

```
gather(table4a, `1999`, `2000`,  
key = "year" value = "cases")
```


Spread

spread(data, key, value, fill = NA, convert = FALSE,
drop = TRUE, sep = NULL)

spread() moves the unique values of a **key** column into the column names, spreading the values of a **value** column across the new columns.

table2

country	year	type	count
A	1999	cases	0.7K
A	1999	pop	19M
A	2000	cases	2K
A	2000	pop	20M
B	1999	cases	37K
B	1999	pop	172M
B	2000	cases	80K
B	2000	pop	174M
C	1999	cases	212K
C	1999	pop	1T
C	2000	cases	213K
C	2000	pop	1T



country	year	cases	pop
A	1999	0.7K	19M
A	2000	2K	20M
B	1999	37K	172M
B	2000	80K	174M
C	1999	212K	1T
C	2000	213K	1T

key value

From data import cheatsheet

spread(table2, type, count)

Separate

separate(data, col, into, sep = "[^[:alnum:]]+", remove = TRUE, convert = FALSE, extra = "warn", fill = "warn", ...)

Separate each cell in a column to make several columns.

table3

country	year	rate	country	year	cases	pop
A	1999	0.7K/19M	A	1999	0.7K	19M
A	2000	2K/20M	A	2000	2K	20M
B	1999	37K/172M	B	1999	37K	172
B	2000	80K/174M	B	2000	80K	174
C	1999	212K/1T	C	1999	212K	1T
C	2000	213K/1T	C	2000	213K	1T

*separate(table3, rate,
into = c("cases", "pop"))*


Unite

unite(data, col, ..., sep = "_", remove = TRUE)

Collapse cells across several columns to make a single column.

table5

country	century	year
Afghan	19	99
Afghan	20	0
Brazil	19	99
Brazil	20	0
China	19	99
China	20	0



country	year
Afghan	1999
Afghan	2000
Brazil	1999
Brazil	2000
China	1999
China	2000

*unite(table5, century, year,
col = "year", sep = "")*

Example 1 - Grades

Is the following data tidy?

```
(grades = tibble(  
  name = c("Alice", "Bob", "Carol", "Dave"),  
  hw_1 = c(19, 18, 18, 19),  
  hw_2 = c(19, 20, 20, 19),  
  hw_3 = c(18, 18, 18, 18),  
  hw_4 = c(20, 16, 17, 19),  
  exam_1 = c(89, 77, 96, 86),  
  exam_2 = c(95, 88, 99, 82)  
))
```

```
## # A tibble: 4 x 7  
##   name    hw_1 hw_2 hw_3 hw_4 exam_1 exam_2  
##   <chr> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>  
## 1 Alice      19     19     18     20     89     95  
## 2 Bob        18     20     18     16     77     88  
## 3 Carol      18     20     18     17     96     99  
## 4 Dave       19     19     18     19     86     82
```

Example 1 - Grades

Is the following data tidy?

```
(grades = tibble(  
  name = c("Alice", "Bob", "Carol", "Dave"),  
  hw_1 = c(19, 18, 18, 19),  
  hw_2 = c(19, 20, 20, 19),  
  hw_3 = c(18, 18, 18, 18),  
  hw_4 = c(20, 16, 17, 19),  
  exam_1 = c(89, 77, 96, 86),  
  exam_2 = c(95, 88, 99, 82)  
))
```

```
## # A tibble: 4 x 7  
##   name    hw_1 hw_2 hw_3 hw_4 exam_1 exam_2  
##   <chr> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>  
## 1 Alice     19     19     18     20     89     95  
## 2 Bob       18     20     18     16     77     88  
## 3 Carol     18     20     18     17     96     99  
## 4 Dave      19     19     18     19     86     82
```

How would we calculate a final score based on the following formula,

$$\text{score} = 0.6 \frac{\sum \text{hw}_i}{80} + 0.4 \frac{\sum \text{exam}_j}{200}$$

Semi-tidy approach

```
grades %>%
  mutate(
    hw_avg = (hw_1+hw_2+hw_3+hw_4)/4,
    exam_avg = (exam_1+exam_2)/2
  ) %>%
  mutate(
    overall = 0.4*(exam_avg/100) + 0.6*(hw_avg/20)
  )
```

```
## # A tibble: 4 x 10
```

##	name	hw_1	hw_2	hw_3	hw_4	exam_1	exam_2	hw_avg	exam_avg	overall
##	<chr>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
## 1	Alice	19	19	18	20	89	95	19	92	0.938
## 2	Bob	18	20	18	16	77	88	18	82.5	0.87
## 3	Carol	18	20	18	17	96	99	18.2	97.5	0.938
## 4	Dave	19	19	18	19	86	82	18.8	84	0.899

Wide -> Long (pivot_longer)

```
tidyr::pivot_longer(grades, cols = hw_1:exam_2,  
  names_to = "assignment",  
  values_to = "score")
```

```
## # A tibble: 24 x 3  
##   name assignment score  
##   <chr> <chr>      <dbl>  
## 1 Alice hw_1        19  
## 2 Alice hw_2        19  
## 3 Alice hw_3        18  
## 4 Alice hw_4        20  
## 5 Alice exam_1       89  
## 6 Alice exam_2       95  
## 7 Bob   hw_1        18  
## 8 Bob   hw_2        20  
## 9 Bob   hw_3        18  
## 10 Bob  hw_4        16  
## # ... with 14 more rows
```

```
tidyr::pivot_longer(grades, cols = hw_1:exam_2,  
  names_to = c("type", "id"), names_sep = "_",  
  values_to = "score")
```

```
## # A tibble: 24 x 4  
##   name type id score  
##   <chr> <chr> <chr> <dbl>  
## 1 Alice hw 1 19  
## 2 Alice hw 2 19  
## 3 Alice hw 3 18  
## 4 Alice hw 4 20  
## 5 Alice exam 1 89  
## 6 Alice exam 2 95  
## 7 Bob hw 1 18  
## 8 Bob hw 2 20  
## 9 Bob hw 3 18  
## 10 Bob hw 4 16  
## # ... with 14 more rows
```

Tidy approach

```
grades %>%
  tidyr::gather(item, score, -name) %>%
  tidyr::separate(item, c("type", "num"), sep = "_") %>%
  group_by(name, type) %>%
  summarize(avg = mean(score)) %>%
  tidyr::spread(type, avg) %>%
  mutate(overall = 0.4*(exam/100) + 0.6*(hw/20))
```

```
## # A tibble: 4 x 4
## # Groups:   name [4]
##   name    exam    hw overall
##   <chr> <dbl> <dbl>   <dbl>
## 1 Alice    92     19    0.938
## 2 Bob     82.5    18    0.87
## 3 Carol   97.5    18.2   0.938
## 4 Dave     84    18.8   0.899
```