

# Lecture 6. Tidy Data Using tidyr

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# Introduction

*“Happy families are all alike; every unhappy family is unhappy in its own way.” — Leo Tolstoy*

*“Tidy datasets are all alike, but every messy dataset is messy in its own way.” — Hadley Wickham*

In this chapter, you will learn a consistent way to organise your data in R, an organisation called **tidy data**. Getting your data into this format requires some upfront work, but that work pays off in the long term. Once you have tidy data and the tidy tools provided by packages in the tidyverse, you will spend much less time munging data from one representation to another, allowing you to spend more time on the analytic questions at hand.

This chapter will give you a practical introduction to tidy data and the accompanying tools in the **tidyr** package. If you’d like to learn more about the underlying theory, you might enjoy the *Tidy Data* paper published in the Journal of Statistical Software, <http://www.jstatsoft.org/v59/i10/paper>.

## Prerequisites

In this chapter we’ll focus on **tidyr**, a package that provides a bunch of tools to help tidy up your messy datasets. **tidyr** is a member of the core tidyverse.

```
library(tidyverse)
```

```
## Warning: package 'tidyverse' was built under R version 3.4.3
```

```
## Warning: package 'ggplot2' was built under R version 3.4.3
```

```
## Warning: package 'tibble' was built under R version 3.4.3
```

```
## Warning: package 'tidyr' was built under R version 3.4.3
```

```
## Warning: package 'readr' was built under R version 3.4.3
```

```
## Warning: package 'purrr' was built under R version 3.4.3
```

```
## Warning: package 'dplyr' was built under R version 3.4.3
```

```
## Warning: package 'forcats' was built under R version 3.4.3
```

# Example: represent the same underlying data in multiple ways

The example below shows the same data organised in four different ways. Each dataset shows the same values of four variables *country*, *year*, *population*, and *cases*, but each dataset organises the values in a different way.

table1

```
## # A tibble: 6 x 4
##   country    year cases population
##   <chr>      <int> <int>      <int>
## 1 Afghanistan 1999     745  19987071
## 2 Afghanistan 2000    2666  20595360
## 3 Brazil      1999   37737  172006362
## 4 Brazil      2000   80488  174504898
## 5 China       1999  212258 1272915272
## 6 China       2000  213766 1280428583
```

table2

```
## # A tibble: 12 x 4
##   country    year type      count
##   <chr>      <int> <chr>      <int>
## 1 Afghanistan 1999 cases         745
## 2 Afghanistan 1999 population 19987071
## 3 Afghanistan 2000 cases         2666
## 4 Afghanistan 2000 population 20595360
## 5 Brazil      1999 cases         37737
## 6 Brazil      1999 population 172006362
## 7 Brazil      2000 cases         80488
## 8 Brazil      2000 population 174504898
## 9 China       1999 cases        212258
## 10 China      1999 population 1272915272
## 11 China      2000 cases        213766
## 12 China      2000 population 1280428583
```

table3

```
## # A tibble: 6 x 3
##   country    year rate
##   * <chr>      <int> <chr>
## 1 Afghanistan 1999 745/19987071
## 2 Afghanistan 2000 2666/20595360
## 3 Brazil      1999 37737/172006362
## 4 Brazil      2000 80488/174504898
## 5 China       1999 212258/1272915272
## 6 China       2000 213766/1280428583
```

# Spread across two tibbles

table4a # cases

```
## # A tibble: 3 x 3
##   country    `1999` `2000`
##   * <chr>      <int> <int>
## 1 Afghanistan     745    2666
## 2 Brazil          37737  80488
## 3 China          212258  213766
```

table4b # population

```
## # A tibble: 3 x 3
##   country    `1999`    `2000`
## * <chr>      <int>      <int>
## 1 Afghanistan 19987071  20595360
## 2 Brazil      172006362 174504898
## 3 China       1272915272 1280428583
```

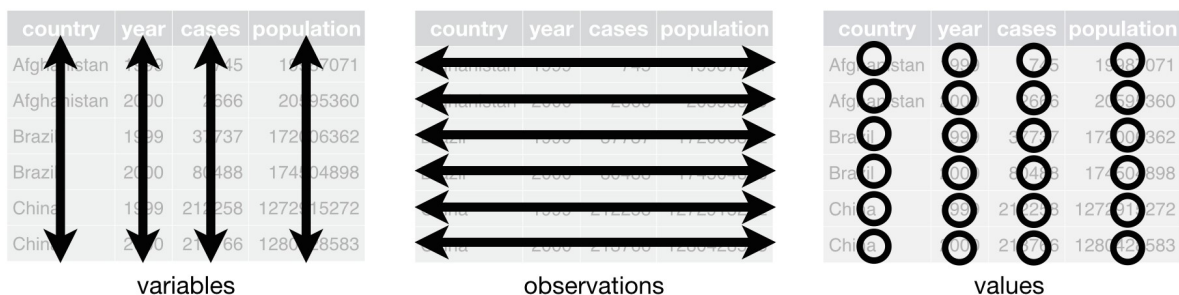
These are all representations of the same underlying data, but they are not equally easy to use. One dataset, the tidy dataset, will be much easier to work with inside the tidyverse.

# What Tidy Data Means

- There are **THREE** interrelated rules which make a dataset tidy:

- Each variable must have its own column.
- Each observation must have its own row.
- Each value must have its own cell.

Figure @ref(fig:tidy-structure) shows the rules visually.



Following three rules makes a dataset tidy: variables are in columns, observations are in rows, and values are in cells.

These three rules are interrelated because it's impossible to only satisfy two of the three.

- That interrelationship leads to an even simpler set of practical instructions:

- Put each dataset in a tibble.
- Put each variable in a column.

In this example, only `table1` is tidy. It's the only representation where each column is a variable.

# Two main advantages of Tidy Data

- Why ensure that your data is tidy? There are two main advantages of Tidy Data:
  1. There's a general advantage to picking one **consistent way** of storing data. If you have a consistent data structure, it's easier to learn the tools that work with it because they have an underlying uniformity.
  2. There's a specific advantage to placing variables in columns because it allows R's **vectorised** nature to shine. As you learned in [mutate](#) and [summary functions](#), most built-in R functions work with vectors of values. That makes transforming tidy data feel particularly natural.

`dplyr`, `ggplot2`, and all the other packages in the tidyverse are designed to work with tidy data. Here are a couple of small examples showing how you might work with `table1`.

```
# Compute rate per 10,000
table1 %>%
  mutate(rate = cases / population * 10000)
```

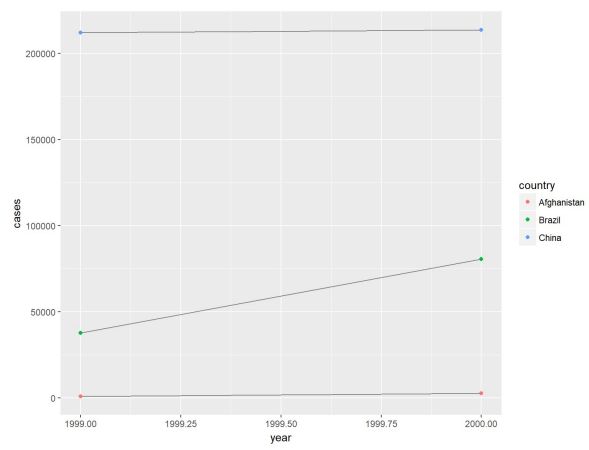
```
## Warning: package 'bindrcpp' was built under R version 3.4.3
```

```
## # A tibble: 6 x 5
##   country    year  cases population  rate
##   <chr>    <int> <int>    <int> <dbl>
## 1 Afghanistan 1999     745  19987071 0.373
## 2 Afghanistan 2000    2666  20595360 1.29
## 3 Brazil      1999   37737  172006362 2.19
## 4 Brazil      2000   80488  174504898 4.61
## 5 China       1999  212258  1272915272 1.67
## 6 China       2000  213766  1280428583 1.67
```

```
# Compute cases per year
table1 %>%
  count(year, wt = cases)
```

```
## # A tibble: 2 x 2
##   year      n
##   <int> <int>
## 1 1999 250740
## 2 2000 296920
```

```
# Visualise changes over time
library(ggplot2)
ggplot(table1, aes(year, cases)) +
  geom_line(aes(group = country), colour = "grey50") +
  geom_point(aes(colour = country))
```



## Exercises (Optional)

1. Using prose, describe how the variables and observations are organised in each of the sample tables.
2. Compute the rate for table2, and table4a + table4b. You will need to perform four operations:

*1. Extract the number of TB cases per country per year.*

*2. Extract the matching population per country per year.*

*3. Divide cases by population, and multiply by 10000.*

*4. Store back in the appropriate place.*

Which representation is easiest to work with? Which is hardest? Why?

3. Recreate the plot showing change in cases over time using table2 instead of table1. What do you need to do first?



# Spreading and gathering

The principles of tidy data seem so obvious that you might wonder if you'll ever encounter a dataset that isn't tidy.

- **Unfortunately, however, most data that you will encounter will be untidy. There are two main reasons:**
  1. Most people aren't familiar with the principles of tidy data, and it's hard to derive them yourself unless you spend a **lot** of time working with data.
  2. Data is often organised to facilitate some use other than analysis. For example, data is often organised to make entry as easy as possible.

This means for most real analyses, you'll need to do some tidying.

- **The first step is always to figure out what the variables and observations are.**

Sometimes this is easy; other times you'll need to consult with the people who originally generated the data.

- **The second step is to resolve one of two common problems:**
  1. **One variable** might be spread across **multiple columns**.
  2. **One observation** might be scattered across **multiple rows**.

Typically a dataset will only suffer from one of these problems; it'll only suffer from both if you're really unlucky! To fix these problems, you'll need the two most important functions in tidyr: `gather()` and `spread()`.

# Gathering: from Wide form to Long form

- A common problem is a dataset where some of the **column names are not names of variables, but values of a variable**.

Take table4a: the column names 1999 and 2000 represent values of the year variable, and each row represents two observations, not one.

table4a

```
## # A tibble: 3 x 3
##   country    `1999` `2000`
## * <chr>      <int> <int>
## 1 Afghanistan    745   2666
## 2 Brazil        37737  80488
## 3 China         212258 213766
```

- To tidy a dataset like this, we need to **gather** those columns into a new pair of variables.
- To describe the **gather** operation we need three parameters:
  1. The set of **columns that represent values**, not variables. In this example, those are the columns 1999 and 2000.
  2. The name of the variable whose values form the column names. I call that the **key**, and here it is year.
  3. The name of the variable whose values are spread over the cells. I call that **value**, and here it's the number of cases.
- Together those parameters generate the call to **gather()**:

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

```
## # A tibble: 6 x 3
##   country    year  cases
##   <chr>      <chr> <int>
## 1 Afghanistan 1999     745
## 2 Brazil      1999  37737
## 3 China       1999 212258
## 4 Afghanistan 2000     2666
## 5 Brazil      2000  80488
## 6 China       2000 213766
```

The columns to gather are specified with `dplyr::select()` style notation. Here there are only two columns, so we list them individually. Note that “1999” and “2000” are non-syntactic names (because they don’t start with a letter) so we have to surround them in backticks.

- To refresh your memory of the other ways to select columns, see [select](#).

country	year	cases
Afghanistan	1999	745
Afghanistan	2000	2666
Brazil	1999	37737
Brazil	2000	80488
China	1999	212258
China	2000	213766

country	1999	2000
Afghanistan	745	2666
Brazil	37737	80488
China	212258	213766

table4

Gathering table4 into a tidy form.

- In the final result, the gathered columns are dropped, and we get new key and value columns.

Otherwise, the relationships between the original variables are preserved. Visually, this is shown in Figure @ref(fig:tidy-gather).

- We can use `gather()` to tidy table4b in a similar fashion. The only difference is the variable stored in the cell values:

table4b

```
## # A tibble: 3 x 3
##   country    `1999`    `2000`
##   <chr>      <int>      <int>
## 1 Afghanistan 19987071 20595360
## 2 Brazil      172006362 174504898
## 3 China       1272915272 1280428583
```

```
table4b %>%
  gather(`1999`, `2000`, key = "year", value = "population")
```

```
## # A tibble: 6 x 3
##   country    year population
##   <chr>      <chr>      <int>
## 1 Afghanistan 1999    19987071
## 2 Brazil      1999    172006362
## 3 China       1999    1272915272
## 4 Afghanistan 2000    20595360
## 5 Brazil      2000    174504898
## 6 China       2000    1280428583
```

- To combine the tidied versions of table4a and table4b into a single tibble, we need to use `dplyr::left_join()`, which you'll learn about in [relational data].

```
tidy4a <- table4a %>%
  gather(`1999`, `2000`, key = "year", value = "cases")
tidy4b <- table4b %>%
```

```
gather(`1999`, `2000`, key = "year", value = "population")
left_join(tidy4a, tidy4b)
```

```
## Joining, by = c("country", "year")
```

```
## # A tibble: 6 x 4
##   country    year  cases population
##   <chr>      <chr> <int>      <int>
## 1 Afghanistan 1999     745  19987071
## 2 Brazil      1999   37737  172006362
## 3 China       1999  212258  1272915272
## 4 Afghanistan 2000    2666   20595360
## 5 Brazil      2000   80488  174504898
## 6 China       2000  213766  1280428583
```

# Spreading: from Long form to Wide form

- Spreading is the opposite of gathering. You use it when **an observation is scattered across multiple rows**.

For example, take `table2`: an observation is a country in a year, but each observation is spread across two rows.

`table2`

```
## # A tibble: 12 x 4
##   country    year type      count
##   <chr>      <int> <chr>    <int>
## 1 Afghanistan 1999 cases      745
## 2 Afghanistan 1999 population 19987071
## 3 Afghanistan 2000 cases      2666
## 4 Afghanistan 2000 population 20595360
## 5 Brazil      1999 cases      37737
## 6 Brazil      1999 population 172006362
## 7 Brazil      2000 cases      80488
## 8 Brazil      2000 population 174504898
## 9 China       1999 cases      212258
## 10 China      1999 population 1272915272
## 11 China      2000 cases      213766
## 12 China      2000 population 1280428583
```

- To tidy this up, we first analyse the representation in similar way to `gather()`. This time, however, we only need two parameters:
  1. The column that contains variable names, the **key** column. Here, it's `type`.
  2. The column that contains values forms multiple variables, the **value** column. Here it's `count`.

Once we've figured that out, we can use `spread()`, as shown programmatically below, and visually in Figure [@ref\(fig:tidy-spread\)](#).

```
spread(table2, key = type, value = count)
```

```
## # A tibble: 6 x 4
##   country    year cases population
##   <chr>      <int> <int>    <int>
## 1 Afghanistan 1999     745  19987071
## 2 Afghanistan 2000    2666  20595360
## 3 Brazil      1999   37737  172006362
## 4 Brazil      2000   80488  174504898
## 5 China       1999 212258 1272915272
## 6 China       2000 213766 1280428583
```

country	year	key	value		country	year	cases	population
Afghanistan	1999	cases	745	→	Afghanistan	1999	745	19987071
Afghanistan	1999	population	19987071	→	Afghanistan	2000	2666	20595360
Afghanistan	2000	cases	2666	→	Brazil	1999	37737	172006362
Afghanistan	2000	population	20595360	→	Brazil	2000	80488	174504898
Brazil	1999	cases	37737	→	China	1999	212258	1272915272
Brazil	1999	population	172006362	→	China	2000	213766	1280428583
Brazil	2000	cases	80488	→				
Brazil	2000	population	174504898	→				
China	1999	cases	212258	→				
China	1999	population	1272915272	→				
China	2000	cases	213766	→				
China	2000	population	1280428583	→				

table2

Spreading table2 makes it tidy

As you might have guessed from the common key and value arguments, `spread()` and `gather()` are complements. `gather()` makes wide tables narrower and longer; `spread()` makes long tables shorter and wider.

## Exercises

- I. **(Optional)** Why are `gather()` and `spread()` not perfectly symmetrical?

Carefully consider the following example:

```
stocks <- tibble(
  year   = c(2015, 2015, 2016, 2016),
  half   = c( 1,    2,    1,    2),
  return = c(1.88, 0.59, 0.92, 0.17)
)

stocks %>%
  spread(year, return) %>%
  gather("year", "return", `2015`:`2016`)
```

(Hint: look at the variable types and think about column *names*.)

Both `spread()` and `gather()` have a `convert` argument. What does it do?

2. **(Optional)** Why does this code fail?

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

```
## Error in inds_combine(.vars, ind_list): Position must be between 0 and n
```

3. Why does spreading this tibble fail? How could you add a new column to fix the problem?

```
people <- tribble(
  ~name,           ~key,    ~value,
  #-----/-----/-----
  "Phillip Woods", "age",    45,
  "Phillip Woods", "height",  186,
  "Phillip Woods", "age",    50,
  "Jessica Cordero", "age",    37,
  "Jessica Cordero", "height",  156
)
```

4. Tidy the simple tibble below. Do you need to spread or gather it? What are the variables?

Note: This is a example of crosstab you may learn in Statitics course.  
(10, 20, 12) indicates number of observations.

```
preg <- tribble(
  ~pregnant, ~male, ~female,
  "yes",      NA,      10,
```

```
"no", 20, 12
)
```



# Separating and uniting

So far you've learned how to tidy `table2` and `table4`, but not `table3`.

`table3` has a different problem: we have one column (`rate`) that contains two variables (`cases` and `population`).

To fix this problem, we'll need the `separate()` function. You'll also learn about the complement of `separate()`: `unite()`, which you use if a single variable is spread across multiple columns.

## Separate

`separate()` pulls apart one column into multiple columns, by splitting wherever a separator character appears. Take `table3`:

`table3`

```
## # A tibble: 6 x 3
##   country      year rate
## * <chr>      <int> <chr>
## 1 Afghanistan 1999 745/19987071
## 2 Afghanistan 2000 2666/20595360
## 3 Brazil      1999 37737/172006362
## 4 Brazil      2000 80488/174504898
## 5 China       1999 212258/1272915272
## 6 China       2000 213766/1280428583
```

The `rate` column contains both `cases` and `population` variables, and we need to split it into two variables.

- `separate()` takes the name of the column to separate, and the names of the columns to separate into, as shown in Figure @ref(fig:tidy-separate) and the code below.

```
table3 %>%
  separate(rate, into = c("cases", "population"))
```

```
## # A tibble: 6 x 4
##   country      year cases population
## * <chr>      <int> <chr>      <chr>
## 1 Afghanistan 1999 745      19987071
## 2 Afghanistan 2000 2666     20595360
## 3 Brazil      1999 37737    172006362
## 4 Brazil      2000 80488    174504898
## 5 China       1999 212258   1272915272
## 6 China       2000 213766   1280428583
```

country	year	rate
Afghanistan	1999	745 / 19987071
Afghanistan	2000	2666 / 20595360
Brazil	1999	37737 / 172006362
Brazil	2000	80488 / 174504898
China	1999	212258 / 1272915272
China	2000	213766 / 1280428583

table3

country	year	cases	population
Afghanistan	1999	745	19987071
Afghanistan	2000	2666	20595360
Brazil	1999	37737	172006362
Brazil	2000	80488	174504898
China	1999	212258	1272915272
China	2000	213766	1280428583

Separating table3 makes it tidy

- By default, `separate()` will split values wherever it sees a *non-alphanumeric character* (i.e. a character that isn't a number or letter).

For example, in the code above, `separate()` split the values of `rate` at the forward slash characters. If you wish to use a specific character to separate a column, you can pass the character to the *sep* argument of `separate()`. For example, we could rewrite the code above as:

```
table3 %>%
  separate(rate, into = c("cases", "population"), sep = "/")
```

(Formally, `sep` is a regular expression, which you'll learn more about in [strings].)

Look carefully at the column types: you'll notice that `cases` and `population` are character columns. This is the default behaviour in `separate()`: it leaves the type of the column as is. Here, however, it's not very useful as those really are numbers.

- We can ask `separate()` to try and convert to better types using `convert = TRUE`:

```
table3 %>%
  separate(rate, into = c("cases", "population"), convert = TRUE)
```

```
## # A tibble: 6 x 4
##   country    year cases population
##   <chr>    <int> <int>    <int>
## 1 Afghanistan 1999     745   19987071
## 2 Afghanistan 2000    2666   20595360
## 3 Brazil      1999   37737   172006362
## 4 Brazil      2000   80488   174504898
## 5 China       1999  212258  1272915272
## 6 China       2000  213766  1280428583
```

- You can also pass a vector of integers to `sep`. `separate()` will interpret the integers as *positions* to split at.

Positive values start at 1 on the far-left of the strings; negative value start at -1 on the far-right of the strings. When using integers to separate strings, the length of sep should be one less than the number of names in into.

You can use this arrangement to separate the last two digits of each year. This makes this data less tidy, but is useful in other cases, as you'll see in a little bit.

```
table3 %>%  
  separate(year, into = c("century", "year"), sep = 2)
```

```
## # A tibble: 6 x 4  
##   country    century year   rate  
## * <chr>      <chr>   <chr> <chr>  
## 1 Afghanistan 19      99    745/19987071  
## 2 Afghanistan 20      00    2666/20595360  
## 3 Brazil      19      99    37737/172006362  
## 4 Brazil      20      00    80488/174504898  
## 5 China       19      99    212258/1272915272  
## 6 China       20      00    213766/1280428583
```

# Unite

- `unite()` is the inverse of `separate()`: it **combines multiple columns into a single column**.

You'll need it much less frequently than `separate()`, but it's still a useful tool to have in your back pocket.

country	year	rate
Afghanistan	1999	745 / 19987071
Afghanistan	2000	2666 / 20595360
Brazil	1999	37737 / 172006362
Brazil	2000	80488 / 174504898
China	1999	212258 / 1272915272
China	2000	213766 / 1280428583

country	century	year	rate
Afghanistan	19	99	745 / 19987071
Afghanistan	20	0	2666 / 20595360
Brazil	19	99	37737 / 172006362
Brazil	20	0	80488 / 174504898
China	19	99	212258 / 1272915272
China	20	0	213766 / 1280428583

table6

Uniting table5 makes it tidy

We can use `unite()` to rejoin the *century* and *year* columns that we created in the last example. That data is saved as `tidyr::table5`. `unite()` takes a data frame, the name of the new variable to create, and a set of columns to combine, again specified in `dplyr::select()` style:

```
table5 %>%  
  unite(new, century, year)
```

```
## # A tibble: 6 x 3  
##   country    new    rate  
##   <chr>      <chr> <chr>  
## 1 Afghanistan 19_99 745/19987071  
## 2 Afghanistan 20_00 2666/20595360  
## 3 Brazil      19_99 37737/172006362  
## 4 Brazil      20_00 80488/174504898  
## 5 China       19_99 212258/1272915272  
## 6 China       20_00 213766/1280428583
```

In this case we also need to use the `sep` argument. The default will place an underscore (`_`) between the values from different columns. Here we don't want any separator so we use `""`:

```
table5 %>%  
  unite(new, century, year, sep = "")
```

```
## # A tibble: 6 x 3  
##   country    new    rate  
##   <chr>      <chr> <chr>  
## 1 Afghanistan 1999 745/19987071  
## 2 Afghanistan 2000 2666/20595360  
## 3 Brazil      1999 37737/172006362  
## 4 Brazil      2000 80488/174504898
```

## 5 China	1999	212258/1272915272
## 6 China	2000	213766/1280428583

## Exercises (Optional)

1. What do the extra and fill arguments do in separate()? Experiment with the various options for the following two toy datasets.

```
tibble(x = c("a,b,c", "d,e,f,g", "h,i,j")) %>%  
  separate(x, c("one", "two", "three"))  
  
tibble(x = c("a,b,c", "d,e", "f,g,i")) %>%  
  separate(x, c("one", "two", "three"))
```

2. Both unite() and separate() have a remove argument. What does it do? Why would you set it to FALSE?
3. Compare and contrast separate() and extract(). Why are there three variations of separation (by position, by separator, and with groups), but only one unite?

# Missing values

Changing the representation of a dataset brings up an important subtlety of missing values. Surprisingly, a value can be missing in one of two possible ways:

- **Explicitly**, i.e. flagged with NA.
- **Implicitly**, i.e. simply not present in the data.

Let's illustrate this idea with a very simple data set:

```
stocks <- tibble(  
  year = c(2015, 2015, 2015, 2015, 2016, 2016, 2016),  
  qtr = c( 1, 2, 3, 4, 2, 3, 4),  
  return = c(1.88, 0.59, 0.35, NA, 0.92, 0.17, 2.66)  
)
```

There are two missing values in this dataset:

- The return for the fourth quarter of 2015 is explicitly missing, because the cell where its value should be instead contains NA.
- The return for the first quarter of 2016 is implicitly missing, because it simply does not appear in the dataset.

One way to think about the difference is with this Zen-like koan: An explicit missing value is the presence of an absence; an implicit missing value is the absence of a presence.

The way that a dataset is represented can make implicit values explicit. For example, we can make the implicit missing value explicit by putting years in the columns:

```
stocks %>%  
  spread(year, return)
```

```
## # A tibble: 4 x 3  
##   qtr `2015` `2016`  
##   <dbl> <dbl> <dbl>  
## 1     1.  1.88    NA  
## 2     2.  0.590  0.920  
## 3     3.  0.350  0.170  
## 4     4.    NA    2.66
```

Because these explicit missing values may not be important in other representations of the data, you can set `na.rm = TRUE` in `gather()` to turn explicit missing values implicit:

```
stocks %>%  
  spread(year, return) %>%  
  gather(year, return, `2015`:`2016`, na.rm = TRUE)
```

```
## # A tibble: 6 x 3
##   qtr year return
## * <dbl> <chr> <dbl>
## 1     1. 2015  1.88
## 2     2. 2015  0.590
## 3     3. 2015  0.350
## 4     2. 2016  0.920
## 5     3. 2016  0.170
## 6     4. 2016  2.66
```

Another important tool for making missing values explicit in tidy data is `complete()`:

```
stocks %>%
  complete(year, qtr)
```

```
## # A tibble: 8 x 3
##   year qtr return
##   <dbl> <dbl> <dbl>
## 1 2015.     1.  1.88
## 2 2015.     2.  0.590
## 3 2015.     3.  0.350
## 4 2015.     4.  NA
## 5 2016.     1.  NA
## 6 2016.     2.  0.920
## 7 2016.     3.  0.170
## 8 2016.     4.  2.66
```

`complete()` takes a set of columns, and finds all unique combinations. It then ensures the original dataset contains all those values, filling in explicit NAs where necessary.

There's one other important tool that you should know for working with missing values. Sometimes when a data source has primarily been used for data entry, missing values indicate that the previous value should be carried forward:

```
treatment <- tribble(
  ~ person,      ~ treatment, ~response,
  "Derrick Whitmore", 1,      7,
  NA,                2,      10,
  NA,                3,      9,
  "Katherine Burke", 1,      4
)
```

You can fill in these missing values with `fill()`. It takes a set of columns where you want missing values to be replaced by the most recent non-missing value (sometimes called last observation carried forward).

```
treatment %>%
  fill(person)
```

```
## # A tibble: 4 x 3
##   person      treatment response
##   <chr>         <dbl>     <dbl>
## 1 Derrick Whitmore     1.         7.
## 2 Derrick Whitmore     2.        10.
## 3 Derrick Whitmore     3.         9.
## 4 Katherine Burke      1.         4.
```





## Exercises

1. Compare and contrast the `fill` arguments to `spread()` and `complete()`.
2. What does the `direction` argument to `fill()` do?

# Case Study

To finish off the chapter, let's pull together everything you've learned to tackle a realistic data tidying problem. The `tidyr::who` dataset contains tuberculosis (TB) cases broken down by year, country, age, gender, and diagnosis method. The data comes from the *2014 World Health Organization Global Tuberculosis Report*, available at <http://www.who.int/tb/country/data/download/en/>.

There's a wealth of epidemiological information in this dataset, but it's challenging to work with the data in the form that it's provided:

who

```
## # A tibble: 7,240 x 60
##   country      iso2 iso3 year new_sp_m014 new_sp_m1524 new_sp_m2534
##   <chr>      <chr> <chr> <int> <int> <int> <int>
## 1 Afghanistan AF   AFG  1980      NA      NA      NA
## 2 Afghanistan AF   AFG  1981      NA      NA      NA
## 3 Afghanistan AF   AFG  1982      NA      NA      NA
## 4 Afghanistan AF   AFG  1983      NA      NA      NA
## 5 Afghanistan AF   AFG  1984      NA      NA      NA
## 6 Afghanistan AF   AFG  1985      NA      NA      NA
## 7 Afghanistan AF   AFG  1986      NA      NA      NA
## 8 Afghanistan AF   AFG  1987      NA      NA      NA
## 9 Afghanistan AF   AFG  1988      NA      NA      NA
## 10 Afghanistan AF   AFG  1989      NA      NA      NA
## # ... with 7,230 more rows, and 53 more variables: new_sp_m3544 <int>,
## #   new_sp_m4554 <int>, new_sp_m5564 <int>, new_sp_m65 <int>,
## #   new_sp_f014 <int>, new_sp_f1524 <int>, new_sp_f2534 <int>,
## #   new_sp_f3544 <int>, new_sp_f4554 <int>, new_sp_f5564 <int>,
## #   new_sp_f65 <int>, new_sn_m014 <int>, new_sn_m1524 <int>,
## #   new_sn_m2534 <int>, new_sn_m3544 <int>, new_sn_m4554 <int>,
## #   new_sn_m5564 <int>, new_sn_m65 <int>, new_sn_f014 <int>,
## #   new_sn_f1524 <int>, new_sn_f2534 <int>, new_sn_f3544 <int>,
## #   new_sn_f4554 <int>, new_sn_f5564 <int>, new_sn_f65 <int>,
## #   new_ep_m014 <int>, new_ep_m1524 <int>, new_ep_m2534 <int>,
## #   new_ep_m3544 <int>, new_ep_m4554 <int>, new_ep_m5564 <int>,
## #   new_ep_m65 <int>, new_ep_f014 <int>, new_ep_f1524 <int>,
## #   new_ep_f2534 <int>, new_ep_f3544 <int>, new_ep_f4554 <int>,
## #   new_ep_f5564 <int>, new_ep_f65 <int>, newrel_m014 <int>,
## #   newrel_m1524 <int>, newrel_m2534 <int>, newrel_m3544 <int>,
## #   newrel_m4554 <int>, newrel_m5564 <int>, newrel_m65 <int>,
## #   newrel_f014 <int>, newrel_f1524 <int>, newrel_f2534 <int>,
## #   newrel_f3544 <int>, newrel_f4554 <int>, newrel_f5564 <int>,
## #   newrel_f65 <int>
```

This is a very typical real-life example dataset. It contains redundant columns, odd variable codes, and many missing values. In short, `who` is messy, and we'll need multiple steps to tidy it. Like `dplyr`, `tidyr` is designed so that each function does one thing well. That means in real-life situations you'll usually need to string together multiple verbs into a pipeline.

The best place to start is almost always to gather together the columns that are not variables. Let's have a look at what we've got:

- It looks like `country`, `iso2`, and `iso3` are three variables that redundantly specify the country.

- year is clearly also a variable.
- We don't know what all the other columns are yet, but given the structure in the variable names (e.g. new\_sp\_m014, new\_ep\_m014, new\_ep\_f014) these are likely to be values, not variables.

So we need to gather together all the columns from new\_sp\_m014 to newrel\_f65. We don't know what those values represent yet, so we'll give them the generic name "key". We know the cells represent the count of cases, so we'll use the variable cases. There are a lot of missing values in the current representation, so for now we'll use na.rm just so we can focus on the values that are present.

```
who1 <- who %>%
  gather(new_sp_m014:newrel_f65, key = "key", value = "cases", na.rm = TRUE)
who1
```

```
## # A tibble: 76,046 x 6
##   country iso2 iso3 year key cases
##   <chr>   <chr> <chr> <int> <chr> <int>
## 1 Afghanistan AF AFG 1997 new_sp_m014 0
## 2 Afghanistan AF AFG 1998 new_sp_m014 30
## 3 Afghanistan AF AFG 1999 new_sp_m014 8
## 4 Afghanistan AF AFG 2000 new_sp_m014 52
## 5 Afghanistan AF AFG 2001 new_sp_m014 129
## 6 Afghanistan AF AFG 2002 new_sp_m014 90
## 7 Afghanistan AF AFG 2003 new_sp_m014 127
## 8 Afghanistan AF AFG 2004 new_sp_m014 139
## 9 Afghanistan AF AFG 2005 new_sp_m014 151
## 10 Afghanistan AF AFG 2006 new_sp_m014 193
## # ... with 76,036 more rows
```

We can get some hint of the structure of the values in the new key column by counting them:

```
who1 %>%
  count(key)
```

```
## # A tibble: 56 x 2
##   key n
##   <chr> <int>
## 1 new_ep_f014 1032
## 2 new_ep_f1524 1021
## 3 new_ep_f2534 1021
## 4 new_ep_f3544 1021
## 5 new_ep_f4554 1017
## 6 new_ep_f5564 1017
## 7 new_ep_f65 1014
## 8 new_ep_m014 1038
## 9 new_ep_m1524 1026
## 10 new_ep_m2534 1020
## # ... with 46 more rows
```

You might be able to parse this out by yourself with a little thought and some experimentation, but luckily we have the data dictionary handy. It tells us:

1. The first three letters of each column denote whether the column contains new or old cases of TB. In this dataset, each column contains new cases.
2. The next two letters describe the type of TB:
  - *rel* stands for cases of relapse
  - *ep* stands for cases of extrapulmonary TB
  - *sn* stands for cases of pulmonary TB that could not be diagnosed by a pulmonary smear (smear negative)
  - *sp* stands for cases of pulmonary TB that could be diagnosed by a pulmonary smear (smear positive)
3. The sixth letter gives the sex of TB patients. The dataset groups cases by males (m) and females (f).
4. The remaining numbers gives the age group. The dataset groups cases into seven age groups:
  - 014 = 0 – 14 years old
  - 1524 = 15 – 24 years old
  - 2534 = 25 – 34 years old
  - 3544 = 35 – 44 years old
  - 4554 = 45 – 54 years old
  - 5564 = 55 – 64 years old
  - 65 = 65 or older

We need to make a minor fix to the format of the column names: unfortunately the names are slightly inconsistent because instead of `new_rel` we have `newrel` (it's hard to spot this here but if you don't fix it we'll get errors in subsequent steps). You'll learn about `str_replace()` in [strings], but the basic idea is pretty simple: replace the characters "newrel" with "new\_rel". This makes all variable names consistent.

```
who2 <- who1 %>%
  mutate(key = stringr::str_replace(key, "newrel", "new_rel"))
who2
```

```
## # A tibble: 76,046 x 6
##   country    iso2 iso3  year key      cases
##   <chr>      <chr> <chr> <int> <chr>   <int>
## 1 Afghanistan AF    AFG   1997 new_sp_m014    0
## 2 Afghanistan AF    AFG   1998 new_sp_m014   30
## 3 Afghanistan AF    AFG   1999 new_sp_m014    8
## 4 Afghanistan AF    AFG   2000 new_sp_m014   52
```

```
## 5 Afghanistan AF AFG 2001 new_sp_m014 129
## 6 Afghanistan AF AFG 2002 new_sp_m014 90
## 7 Afghanistan AF AFG 2003 new_sp_m014 127
## 8 Afghanistan AF AFG 2004 new_sp_m014 139
## 9 Afghanistan AF AFG 2005 new_sp_m014 151
## 10 Afghanistan AF AFG 2006 new_sp_m014 193
## # ... with 76,036 more rows
```

We can separate the values in each code with two passes of `separate()`. The first pass will split the codes at each underscore.

```
who3 <- who2 %>%
  separate(key, c("new", "type", "sexage"), sep = "_")
who3
```

```
## # A tibble: 76,046 x 8
##   country    iso2 iso3 year new type sexage cases
##   <chr>      <chr> <chr> <int> <chr> <chr> <chr> <int>
## 1 Afghanistan AF AFG 1997 new sp m014 0
## 2 Afghanistan AF AFG 1998 new sp m014 30
## 3 Afghanistan AF AFG 1999 new sp m014 8
## 4 Afghanistan AF AFG 2000 new sp m014 52
## 5 Afghanistan AF AFG 2001 new sp m014 129
## 6 Afghanistan AF AFG 2002 new sp m014 90
## 7 Afghanistan AF AFG 2003 new sp m014 127
## 8 Afghanistan AF AFG 2004 new sp m014 139
## 9 Afghanistan AF AFG 2005 new sp m014 151
## 10 Afghanistan AF AFG 2006 new sp m014 193
## # ... with 76,036 more rows
```

Then we might as well drop the new column because it's constant in this dataset. While we're dropping columns, let's also drop `iso2` and `iso3` since they're redundant.

```
who3 %>%
  count(new)
```

```
## # A tibble: 1 x 2
##   new      n
##   <chr> <int>
## 1 new  76046
```

```
who4 <- who3 %>%
  select(-new, -iso2, -iso3)
```

Next we'll separate `sexage` into `sex` and `age` by splitting after the first character:

```
who5 <- who4 %>%
  separate(sexage, c("sex", "age"), sep = 1)
who5
```

```
## # A tibble: 76,046 x 6
##   country    year type sex age cases
##   <chr>      <int> <chr> <chr> <chr> <int>
## 1 Afghanistan 1997 sp m 014 0
## 2 Afghanistan 1998 sp m 014 30
## 3 Afghanistan 1999 sp m 014 8
## 4 Afghanistan 2000 sp m 014 52
## 5 Afghanistan 2001 sp m 014 129
```

```
## 6 Afghanistan 2002 sp m 014 90
## 7 Afghanistan 2003 sp m 014 127
## 8 Afghanistan 2004 sp m 014 139
## 9 Afghanistan 2005 sp m 014 151
## 10 Afghanistan 2006 sp m 014 193
## # ... with 76,036 more rows
```

The who dataset is now tidy!

I've shown you the code a piece at a time, assigning each interim result to a new variable. This typically isn't how you'd work interactively. Instead, you'd gradually build up a complex pipe:

```
who %>%
  gather(code, value, new_sp_m014:newrel_f65, na.rm = TRUE) %>%
  mutate(code = stringr::str_replace(code, "newrel", "new_rel")) %>%
  separate(code, c("new", "var", "sexage")) %>%
  select(-new, -iso2, -iso3) %>%
  separate(sexage, c("sex", "age"), sep = 1)
```

## Exercises

1. In this case study I set `na.rm = TRUE` just to make it easier to check that we had the correct values. Is this reasonable? Think about how missing values are represented in this dataset. Are there implicit missing values? What's the difference between an NA and zero?
2. What happens if you neglect the `mutate()` step?  
`(mutate(key = stringr::str_replace(key, "newrel", "new_rel"`
3. I claimed that `iso2` and `iso3` were redundant with `country`. Confirm this claim.
4. For each country, year, and sex compute the total number of cases of TB. Make an informative visualisation of the data.



## Non-tidy data

Before we continue on to other topics, it's worth talking briefly about non-tidy data. Earlier in the chapter, I used the pejorative term “messy” to refer to non-tidy data. That's an oversimplification: there are lots of useful and well-founded data structures that are not tidy data. There are two main reasons to use other data structures:

- Alternative representations may have substantial performance or space advantages.
- Specialised fields have evolved their own conventions for storing data that may be quite different to the conventions of tidy data.

Either of these reasons means you'll need something other than a tibble (or data frame). If your data does fit naturally into a rectangular structure composed of observations and variables, I think tidy data should be your default choice. But there are good reasons to use other structures; tidy data is not the only way.

If you'd like to learn more about non-tidy data, I'd highly recommend this thoughtful blog post by Jeff Leek: <http://simplystatistics.org/2016/02/17/non-tidy-data/>