You can remove multiple elements this way, too:

```
> years[c("Carter","Clinton")] <- NULL     # Remove two elements
> years
$Kennedy
[1] 1960
```

5.11 Flatten a List into a Vector

Problem

You want to flatten all the elements of a list into a vector.

Solution

Use the `unlist` function.

Discussion

There are many contexts that require a vector. Basic statistical functions work on vectors but not on lists, for example. If `iq.scores` is a list of numbers, then we cannot directly compute their mean:

```
> mean(iq.scores)
[1] NA
Warning message:
In mean.default(iq.scores) :
  argument is not numeric or logical: returning NA
```

Instead, we must flatten the list into a vector using `unlist` and then compute the mean of the result:

```
> mean(unlist(iq.scores))
[1] 106.4452
```

Here is another example. We can `cat` scalars and vectors, but we cannot `cat` a list:

```
> cat(iq.scores, "\n")
Error in cat(list(...), file, sep, fill, labels, append) :
  argument 1 (type 'list') cannot be handled by 'cat'
```

One solution is to flatten the list into a vector before printing:

```
> cat("IQ Scores:", unlist(iq.scores), "\n")
IQ Scores: 89.73383 116.5565 113.0454
```

See Also

Conversions such as this are discussed more fully in Recipe 5.33.

5.12 Removing NULL Elements from a List

Problem

Your list contains NULL values. You want to remove them.

Solution

Suppose lst is a list some of whose elements are NULL. This expression will remove the NULL elements:

```
> lst[sapply(lst, is.null)] <- NULL
```

Discussion

Finding and removing NULL elements from a list is surprisingly tricky. I wrote the following expression after trying several other ways, including the obvious ones, and failing. Here's how it works:

1. R calls sapply to apply the is.null function to every element of the list.
2. sapply returns a vector of logical values that are TRUE wherever the corresponding list element is NULL.
3. R selects values from the list according to that vector.
4. R assigns NULL to the selected items, removing them from the list.

The curious reader may be wondering how a list can contain NULL elements, given that we remove elements by setting them to NULL (Recipe 5.10). The answer is that we can create a list containing NULL elements:

```
> lst <- list("Moe", NULL, "Curly")          # Create list with NULL element
> lst
[[1]]
[1] "Moe"

[[2]]
NULL

[[3]]
[1] "Curly"

> lst[sapply(lst, is.null)] <- NULL          # Remove NULL element from list
> lst
[[1]]
[1] "Moe"

[[2]]
[1] "Curly"
```

See Also

See Recipe 5.10 for how to remove list elements.

5.13 Removing List Elements Using a Condition

Problem

You want to remove elements from a list according to a conditional test, such as removing elements that are negative or smaller than some threshold.

Solution

Build a logical vector based on the condition. Use the vector to select list elements and then assign `NULL` to those elements. This assignment, for example, removes all negative value from `lst`:

```
> lst[lst < 0] <- NULL
```

Discussion

This recipe is based on two useful features of R. First, a list can be indexed by a logical vector. Wherever the vector element is `TRUE`, the corresponding list element is selected. Second, you can remove a list element by assigning `NULL` to it.

Suppose we want to remove elements from `lst` whose value is zero. We construct a logical vector which identifies the unwanted values (`lst == 0`). Then we select those elements from the list and assign `NULL` to them:

```
> lst[lst == 0] <- NULL
```

This expression will remove NA values from the list:

```
> lst[is.na(lst)] <- NULL
```

So far, so good. The problems arise when you cannot easily build the logical vector. That often happens when you want to use a function that cannot handle a list. Suppose you want to remove list elements whose absolute value is less than 1. The `abs` function will not handle a list, unfortunately:

```
> lst[abs(lst) < 1] <- NULL
Error in abs(lst) : non-numeric argument to function
```

The simplest solution is flattening the list into a vector by calling `unlist` and then testing the vector:

```
> lst[abs(unlist(lst)) < 1] <- NULL
```

A more elegant solution uses `lapply` to apply the function to every element of the list:

```
> lst[lapply(lst,abs) < 1] <- NULL
```

Lists can hold complex objects, too, not just atomic values. Suppose that `mods` is a list of linear models created by the `lm` function. This expression will remove any model whose R^2 value is less than 0.30:

```
> mods[sapply(mods, function(m) summary(m)$r.squared < 0.3)] <- NULL
```

See Also

See Recipes 5.7, 5.10, 5.11, 6.2, and 11.1.

5.14 Initializing a Matrix

Problem

You want to create a matrix and initialize it from given values.

Solution

Capture the data in a vector or list, and then use the `matrix` function to shape the data into a matrix. This example shapes a vector into a 2 × 3 matrix (i.e., two rows and three columns):

```
> matrix(vec, 2, 3)
```

Discussion

Suppose we want to create and initialize a 2 × 3 matrix. We can capture the initial data inside a vector and then shape it using the `matrix` function:

```
> theData <- c(1.1, 1.2, 2.1, 2.2, 3.1, 3.2)
> mat <- matrix(theData, 2, 3)
> mat
     [,1] [,2] [,3]
[1,]  1.1  2.1  3.1
[2,]  1.2  2.2  3.2
```

The first argument of `matrix` is the data, the second argument is the number of rows, and the third argument is the number of columns. Observe that the matrix was filled column by column, not row by row.

It's common to initialize an entire matrix to one value such as zero or NA. If the first argument of `matrix` is a single value, then R will apply the Recycling Rule and automatically replicate the value to fill the entire matrix:

```
> matrix(0, 2, 3)          # Create an all-zeros matrix
     [,1] [,2] [,3]
[1,]    0    0    0
[2,]    0    0    0
> matrix(NA, 2, 3)         # Create a matrix populated with NA
     [,1] [,2] [,3]
```

```
[1,]   NA   NA   NA
[2,]   NA   NA   NA
```

You can create a matrix with a one-liner, of course, but it becomes difficult to read:

```
> mat <- matrix(c(1.1, 1.2, 1.3, 2.1, 2.2, 2.3), 2, 3)
```

A common idiom in R is typing the data itself in a rectangular shape that reveals the matrix structure:

```
> theData <- c(1.1, 1.2, 1.3,
+              2.1, 2.2, 2.3)
> mat <- matrix(theData, 2, 3, byrow=TRUE)
```

Setting `byrow=TRUE` tells `matrix` that the data is row-by-row and not column-by-column (which is the default). In condensed form, that becomes:

```
> mat <- matrix(c(1.1, 1.2, 1.3,
+                 2.1, 2.2, 2.3),
+               2, 3, byrow=TRUE)
```

Expressed this way, the reader quickly sees the two rows and three columns of data.

There is a quick-and-dirty way to turn a vector into a matrix: just assign dimensions to the vector. This was discussed in the "Introduction". The following example creates a vanilla vector and then shapes it into a 2 × 3 matrix:

```
> v <- c(1.1, 1.2, 1.3, 2.1, 2.2, 2.3)
> dim(v) <- c(2,3)
> v
     [,1] [,2] [,3]
[1,]  1.1  1.3  2.2
[2,]  1.2  2.1  2.3
```

Personally, I find this more opaque than using `matrix`, especially since there is no `byrow` option here.

See Also

See Recipe 5.3.

5.15 Performing Matrix Operations

Problem

You want to perform matrix operations such as transpose, matrix inversion, matrix multiplication, or constructing an identity matrix.

Solution

`t(A)`
: Matrix transposition of A

`solve(A)`
: Matrix inverse of A

`A %*% B`
: Matrix multiplication of A and B

`diag(n)`
: An *n*-by-*n* diagonal (identity) matrix

Discussion

Recall that `A*B` is element-wise multiplication whereas `A %*% B` is matrix multiplication.

All these functions return a matrix. Their arguments can be either matrices or data frames. If they are data frames then R will first convert them to matrices (although this is useful only if the data frame contains exclusively numeric values).

5.16 Giving Descriptive Names to the Rows and Columns of a Matrix

Problem

You want to assign descriptive names to the rows or columns of a matrix.

Solution

Every matrix has a `rownames` attribute and a `colnames` attribute. Assign a vector of character strings to the appropriate attribute:

```
> rownames(mat) <- c("rowname_1", "rowname_2", ..., "rowname_m")
> colnames(mat) <- c("colname_1", "colname_2", ..., "colname_n")
```

Discussion

R lets you assign names to the rows and columns of a matrix, which is useful for printing the matrix. R will display the names if they are defined, enhancing the readability of your output. Consider this matrix of correlations between the prices of IBM, Microsoft, and Google stock:

```
> print(tech.corr)
      [,1]  [,2]  [,3]
[1,] 1.000 0.556 0.390
[2,] 0.556 1.000 0.444
[3,] 0.390 0.444 1.000
```

In this form, the matrix output's interpretation is not self-evident. Yet if we define names for the rows and columns, then R will annotate the matrix output with the names:

```
> colnames(tech.corr) <- c("IBM","MSFT","GOOG")
> rownames(tech.corr) <- c("IBM","MSFT","GOOG")
> print(tech.corr)
       IBM  MSFT  GOOG
IBM  1.000 0.556 0.390
MSFT 0.556 1.000 0.444
GOOG 0.390 0.444 1.000
```

Now the reader knows at a glance which rows and columns apply to which stocks.

Another advantage of naming rows and columns is that you can refer to matrix elements by those names:

```
> tech.corr["IBM","GOOG"]     # What is the correlation between IBM and GOOG?
[1] 0.39
```

5.17 Selecting One Row or Column from a Matrix

Problem

You want to select a single row or a single column from a matrix.

Solution

The solution depends on what you want. If you want the result to be a simple vector, just use normal indexing:

```
> vec <- mat[1,]          # First row
> vec <- mat[,3]          # Third column
```

If you want the result to be a one-row matrix or a one-column matrix, then include the `drop=FALSE` argument:

```
> row <- mat[1,,drop=FALSE]          # First row in a one-row matrix
> col <- mat[,3,drop=FALSE]          # Third column in a one-column matrix
```

Discussion

Normally, when you select one row or column from a matrix, R strips off the dimensions. The result is a dimensionless vector:

```
> mat[1,]
[1]  1  4  7 10
> mat[,3]
[1] 7 8 9
```

When you include the `drop=FALSE` argument, however, R retains the dimensions. In that case, selecting a row returns a row vector (a $1 \times n$ matrix):

```
> mat[1,,drop=FALSE]
     [,1] [,2] [,3] [,4]
[1,]    1    4    7   10
```

Likewise, selecting a column with `drop=FALSE` returns a column vector (an $n \times 1$ matrix):

```
> mat[,3,drop=FALSE]
     [,1]
[1,]    7
[2,]    8
[3,]    9
```

5.18 Initializing a Data Frame from Column Data

Problem

Your data is organized by columns, and you want to assemble it into a data frame.

Solution

If your data is captured in several vectors and/or factors, use the `data.frame` function to assemble them into a data frame:

```
> dfrm <- data.frame(v1, v2, v3, f1, f2)
```

If your data is captured in a *list* that contains vectors and/or factors, use instead `as.data.frame`:

```
> dfrm <- as.data.frame(list.of.vectors)
```

Discussion

A data frame is a collection of columns, each of which corresponds to an observed variable (in the statistical sense, not the programming sense). If your data is already organized into columns, then it's easy to build a data frame.

The `data.frame` function can construct a data frame from vectors, where each vector is one observed variable. Suppose you have two numeric predictor variables, one categorical predictor variable, and one response variable. The `data.frame` function can create a data frame from your vectors:

```
> dfrm <- data.frame(pred1, pred2, pred3, resp)
> dfrm
        pred1       pred2 pred3     resp
1  -2.7528917 -1.40784130    AM 12.57715
2  -0.3626909  0.31286963    AM 21.02418
3  -1.0416039 -0.69685664    PM 18.94694
4   1.2666820 -1.27511434    PM 18.98153
5   0.7806372 -0.27292745    AM 19.59455
6  -1.0832624  0.73383339    AM 20.71605
7  -2.0883305  0.96816822    PM 22.70062
8  -0.7063653 -0.84476203    PM 18.40691
9  -0.8394022  0.31530793    PM 21.00930
10 -0.4966884 -0.08030948    AM 19.31253
```

Notice that `data.frame` takes the column names from your program variables. You can override that default by supplying explicit column names:

```
> dfrm <- data.frame(p1=pred1, p2=pred2, p3=pred3, r=resp)
> dfrm
          p1          p2 p3        r
1  -2.7528917 -1.40784130 AM 12.57715
2  -0.3626909  0.31286963 AM 21.02418
3  -1.0416039 -0.69685664 PM 18.94694
.
. (etc.)
.
```

Alternatively, your data may be organized into vectors but those vectors are held in a list, not individual program variables, like this:

```
> lst <- list(p1=pred1, p2=pred2, p3=pred3, r=resp)
```

No problem. Use the `as.data.frame` function to create a data frame from the list of vectors:

```
> as.data.frame(lst)
          p1          p2 p3        r
1  -2.7528917 -1.40784130 AM 12.57715
2  -0.3626909  0.31286963 AM 21.02418
3  -1.0416039 -0.69685664 PM 18.94694
.
. (etc.)
.
```

5.19 Initializing a Data Frame from Row Data

Problem

Your data is organized by rows, and you want to assemble it into a data frame.

Solution

Store each row in a one-row data frame. Store the one-row data frames in a list. Use `rbind` and `do.call` to bind the rows into one, large data frame:

```
> dfrm <- do.call(rbind, obs)
```

Here, `obs` is a list of one-row data frames.

Discussion

Data often arrives as a collection of observations. Each *observation* is a record or tuple that contains several values, one for each observed variable. The lines of a flat file are usually like that: each line is one record, each record contains several columns, and each column is a different variable (see Recipe 4.12). Such data is organized by *observation*, not by *variable*. In other words, you are given rows one at a time rather than columns one at a time.

Each such row might be stored in several ways. One obvious way is as a vector. If you have purely numerical data, use a vector.

However, many datasets are a mixture of numeric, character, and categorical data, in which case a vector won't work. I recommend storing each such heterogeneous row in a one-row data frame. (You could store each row in a list, but this recipe gets a little more complicated.)

For concreteness, let's assume that you have ten rows with four variables per observation: `pred1`, `pred2`, `pred2`, and `resp`. Each row is stored in a one-row data frame, so you have ten such data frames. Those data frames are stored in a list called `obs`. The first element of `obs` might look like this:

```
> obs[[1]]
   pred1 pred2 pred3   resp
1 -1.197  0.36    AM 18.701
```

This recipe works also if your observations are stored in vectors rather than one-row data frames.

We need to bind together those rows into a data frame. That's what the `rbind` function does. It binds its arguments in such a way that each argument becomes one row in the result. If we `rbind` the first two observations, for example, we get a two-row data frame:

```
> rbind(obs[[1]], obs[[2]])
   pred1 pred2 pred3   resp
1 -1.197  0.36    AM 18.701
2 -0.952  1.23    PM 25.709
```

We want to bind together every observation, not just the first two, so we tap into the vector processing of R. The `do.call` function will expand `obs` into one, long argument list and call `rbind` with that long argument list:

```
> do.call(rbind,obs)
    pred1  pred2 pred3   resp
1  -1.197  0.360    AM 18.701
2  -0.952  1.230    PM 25.709
3   0.279  0.423    PM 21.572
4  -1.445 -1.846    AM 14.392
5   0.822 -0.246    AM 19.841
6   1.247  1.254    PM 25.637
7  -0.394  1.563    AM 24.585
8  -1.248 -1.264    PM 16.770
9  -0.652 -2.344    PM 14.915
10 -1.171 -0.776    PM 17.948
```

The result is a data frame built from our rows of data.

Sometimes, for reasons beyond your control, the rows of your data are stored in lists rather than one-row data frames. You may be dealing with rows returned by a database package, for example. In that case, `obs` will be a list of lists, not a list of data frames.

We first transform the rows into data frames using the Map function and then apply this recipe:

```
> dfrm <- do.call(rbind,Map(as.data.frame,obs))
```

See Also

See Recipe 5.18 if your data is organized by columns, not rows; see Recipe 12.18 to learn more about do.call.

5.20 Appending Rows to a Data Frame

Problem

You want to append one or more new rows to a data frame.

Solution

Create a second, temporary data frame containing the new rows. Then use the rbind function to append the temporary data frame to the original data frame.

Discussion

Suppose we want to append a new row to our data frame of Chicago-area cities. First, we create a one-row data frame with the new data:

```
> newRow <- data.frame(city="West Dundee", county="Kane", state="IL", pop=5428)
```

Next, we use the rbind function to append that one-row data frame to our existing data frame:

```
> suburbs <- rbind(suburbs, newRow)
> suburbs
                city   county state     pop
1            Chicago     Cook    IL 2853114
2            Kenosha  Kenosha    WI   90352
3             Aurora     Kane    IL  171782
4              Elgin     Kane    IL   94487
5               Gary Lake(IN)    IN  102746
6             Joliet  Kendall    IL  106221
7         Naperville   DuPage    IL  147779
8  Arlington Heights     Cook    IL   76031
9        Bolingbrook     Will    IL   70834
10            Cicero     Cook    IL   72616
11          Evanston     Cook    IL   74239
12           Hammond Lake(IN)    IN   83048
13          Palatine     Cook    IL   67232
14        Schaumburg     Cook    IL   75386
15            Skokie     Cook    IL   63348
16          Waukegan Lake(IL)    IL   91452
17       West Dundee     Kane    IL    5428
```

The `rbind` function tells R that we are appending a new row to `suburbs`, not a new column. It may be obvious to you that `newRow` is a row and not a column, but it is not obvious to R. (Use the `cbind` function to append a column.)

One word of caution. The new row must use the same column names as the data frame. Otherwise, `rbind` will fail.

We can combine these two steps into one, of course:

```
> suburbs <- rbind(suburbs,
+                  data.frame(city="West Dundee", county="Kane", state="IL", pop=5428))
```

We can even extend this technique to multiple new rows because `rbind` allows multiple arguments:

```
> suburbs <- rbind(suburbs,
+                  data.frame(city="West Dundee", county="Kane", state="IL", pop=5428),
+                  data.frame(city="East Dundee", county="Kane", state="IL", pop=2955))
```

Do not use this recipe to append many rows to a large data frame. That would force R to reallocate a large data structure repeatedly, which is a very slow process. Build your data frame using more efficient means, such as those in Recipes 5.19 or 5.21.

5.21 Preallocating a Data Frame

Problem

You are building a data frame, row by row. You want to preallocate the space instead of appending rows incrementally.

Solution

Create a data frame from generic vectors and factors using the functions `numeric(`*n*`)`, `character(`*n*`)`, and `factor(`*n*`)`:

```
> dfrm <- data.frame(colname1=numeric(n), colname2=character(n), ... etc. ... )
```

Here, *n* is the number of rows needed for the data frame.

Discussion

Theoretically, you can build a data frame by appending new rows, one by one. That's OK for small data frames, but building a large data frame in that way can be tortuous. The memory manager in R works poorly when one new row is repeatedly appended to a large data structure. Hence your R code will run very slowly.

One solution is to preallocate the data frame—assuming you know the required number of rows. By preallocating the data frame once and for all, you sidestep problems with the memory manager.

Suppose you want to create a data frame with 1,000,000 rows and three columns: two numeric and one character. Use the `numeric` and `character` functions to preallocate the columns; then join them together using `data.frame`:

```
> N <- 1000000
> dfrm <- data.frame(dosage=numeric(N), lab=character(N), response=numeric(N))
```

Now you have a data frame with the correct dimensions, 1,000,000 × 3, waiting to receive its contents.

Data frames can contain factors, but preallocating a factor is a little trickier. You can't simply call `factor(`*n*`)`. You need to specify the factor's levels because you are creating it. Continuing our example, suppose you want the `lab` column to be a factor, not a character string, and that the possible levels are `NJ`, `IL`, and `CA`. Include the levels in the column specification, like this:

```
> N <- 1000000
> dfrm <- data.frame(dosage=numeric(N),
+                    lab=factor(N, levels=c("NJ", "IL", "CA")),
+                    response=numeric(N) )
```

5.22 Selecting Data Frame Columns by Position

Problem

You want to select columns from a data frame according to their position.

Solution

To select a single column, use this list operator:

`dfrm[[`*n*`]]`
: Returns *one column*—specifically, the *n*th column of `dfrm`.

To select one or more columns and package them in a data frame, use the following sublist expressions:

`dfrm[`*n*`]`
: Returns a *data frame* consisting solely of the *n*th column of `dfrm`.

`dfrm[c(`n_1`, `n_2`, ..., `n_k`)]`
: Returns a *data frame* built from the columns in positions n_1, n_2, ..., n_k of `dfrm`.

You can use matrix-style subscripting to select one or more columns:

`dfrm[, `*n*`]`
: Returns the *n*th column (assuming that *n* contains exactly one value).

`dfrm[, c(`n_1`, `n_2`, ..., `n_k`)]`
: Returns a *data frame* built from the columns in positions n_1, n_2, ..., n_k.

Note that the matrix-style subscripting can return two different data types (either column or data frame) depending upon whether you select one column or multiple columns.

Discussion

There are a bewildering number of ways to select columns from a data frame. The choices can be confusing until you understand the logic behind the alternatives. As you read this explanation, notice how a slight change in syntax—a comma here, a double-bracket there—changes the meaning of the expression.

Let's play with the population data for the 16 largest cities in the Chicago metropolitan area:

```
> suburbs
                city    county state     pop
1            Chicago      Cook    IL 2853114
2            Kenosha   Kenosha    WI   90352
3             Aurora      Kane    IL  171782
4              Elgin      Kane    IL   94487
5               Gary  Lake(IN)    IN  102746
6             Joliet   Kendall    IL  106221
7         Naperville    DuPage    IL  147779
8  Arlington Heights      Cook    IL   76031
9         Bolingbrook      Will    IL   70834
10            Cicero      Cook    IL   72616
11          Evanston      Cook    IL   74239
12           Hammond  Lake(IN)    IN   83048
13          Palatine      Cook    IL   67232
14        Schaumburg      Cook    IL   75386
15            Skokie      Cook    IL   63348
16          Waukegan  Lake(IL)    IL   91452
```

Use simple list notation to select exactly one column, such as the first column:

```
> suburbs[[1]]
 [1] "Chicago"           "Kenosha"           "Aurora"            "Elgin"
 [5] "Gary"              "Joliet"            "Naperville"        "Arlington Heights"
 [9] "Bolingbrook"       "Cicero"            "Evanston"          "Hammond"
[13] "Palatine"          "Schaumburg"        "Skokie"            "Waukegan"
```

The first column of suburbs is a vector, so that's what `suburbs[[1]]` returns: a vector. If the first column were a factor, we'd get a factor.

The result differs when you use the single-bracket notation, as in `suburbs[1]` or `suburbs[c(1,3)]`. You still get the requested columns, but R wraps them in a data frame. This example returns the first column wrapped in a data frame:

```
> suburbs[1]
                city
1            Chicago
2            Kenosha
3             Aurora
4              Elgin
```

```
5                Gary
6              Joliet
7          Naperville
8   Arlington Heights
9         Bolingbrook
10             Cicero
11           Evanston
12            Hammond
13           Palatine
14         Schaumburg
15             Skokie
16           Waukegan
```

The next example returns the first and third columns wrapped in a data frame:

```
> suburbs[c(1,3)]
                 city     pop
1             Chicago 2853114
2             Kenosha   90352
3              Aurora  171782
4               Elgin   94487
5                Gary  102746
6              Joliet  106221
7          Naperville  147779
8   Arlington Heights   76031
9         Bolingbrook   70834
10             Cicero   72616
11           Evanston   74239
12            Hammond   83048
13           Palatine   67232
14         Schaumburg   75386
15             Skokie   63348
16           Waukegan   91452
```

A major source of confusion is that `suburbs[[1]]` and `suburbs[1]` look similar but produce very different results:

`suburbs[[1]]`
: This returns one column.

`suburbs[1]`
: This returns a data frame, and the data frame contains exactly one column. This is a special case of `dfrm[c(`n_1`,`n_2`, ...,` n_k`)]`. We don't need the `c(...)` construct because there is only one *n*.

The point here is that "one column" is different from "a data frame that contains one column." The first expression returns a column, so it's a vector or a factor. The second expression returns a data frame, which is different.

R lets you use matrix notation to select columns, as shown in the Solution. But an odd quirk can bite you: you might get a column or you might get a data frame, depending upon many subscripts you use. In the simple case of one index you get a column, like this:

```
> suburbs[,1]
 [1] "Chicago"           "Kenosha"           "Aurora"            "Elgin"
 [5] "Gary"              "Joliet"            "Naperville"        "Arlington Heights"
 [9] "Bolingbrook"       "Cicero"            "Evanston"          "Hammond"
[13] "Palatine"          "Schaumburg"        "Skokie"            "Waukegan"
```

But using the same matrix-style syntax with multiple indexes returns a data frame:

```
> suburbs[,c(1,4)]
                city     pop
1            Chicago 2853114
2            Kenosha   90352
3             Aurora  171782
4              Elgin   94487
5               Gary  102746
6             Joliet  106221
7         Naperville  147779
8  Arlington Heights   76031
9        Bolingbrook   70834
10            Cicero   72616
11          Evanston   74239
12           Hammond   83048
13          Palatine   67232
14        Schaumburg   75386
15            Skokie   63348
16          Waukegan   91452
```

This creates a problem. Suppose you see this expression in some old R script:

```
dfrm[,vec]
```

Quick, does that return a column or a data frame? Well, it depends. If `vec` contains one value then you get a column; otherwise, you get a data frame. You cannot tell from the syntax alone.

To avoid this problem, you can include `drop=FALSE` in the subscripts; this forces R to return a data frame:

```
dfrm[,vec,drop=FALSE]
```

Now there is no ambiguity about the returned data structure. It's a data frame.

When all is said and done, using matrix notation to select columns from data frames is not the best procedure. I recommend that you instead use the list operators described previously. They just seem clearer.

See Also

See Recipe 5.17 for more about using `drop=FALSE`.

5.23 Selecting Data Frame Columns by Name

Problem

You want to select columns from a data frame according to their name.

Solution

To select a single column, use one of these list expressions:

`dfrm[["name"]]`
: Returns *one column*, the column called ***name***.

`dfrm$name`
: Same as previous, just different syntax.

To select one or more columns and package them in a data frame, use these list expressions:

`dfrm["name"]`
: Selects one column and packages it inside a data frame object.

`dfrm[c("name1", "name2", ..., "namek")]`
: Selects several columns and packages them in a data frame.

You can use matrix-style subscripting to select one or more columns:

`dfrm[, "name"]`
: Returns the named column.

`dfrm[, c("name1", "name2", ..., "namek")]`
: Selects several columns and packages in a data frame.

Once again, the matrix-style subscripting can return two different data types (column or data frame) depending upon whether you select one column or multiple columns.

Discussion

All columns in a data frame must have names. If you know the name, it's usually more convenient and readable to select by name, not by position.

The solutions just described are similar to those for Recipe 5.22, where we selected columns by position. The only difference is that here we use column names instead of column numbers. All the observations made in Recipe 5.22 apply here:

- `dfrm[["name"]]` returns one column, not a data frame.
- `dfrm[c("name1", "name2", ..., "namek")]` returns a data frame, not a column.
- `dfrm["name"]` is a special case of the previous expression and so returns a data frame, not a column.

- The matrix-style subscripting can return either a column or a data frame, so be careful how many names you supply. See Recipe 5.22 for a discussion of this "gotcha" and using `drop=FALSE`.

There is one new addition:

```
dfrm$name
```

This is identical in effect to `dfrm[["name"]]`, but it's easier to type and to read.

See Also

See Recipe 5.22 to understand these ways to select columns.

5.24 Selecting Rows and Columns More Easily

Problem

You want an easier way to select rows and columns from a data frame or matrix.

Solution

Use the `subset` function. The `select` argument is a column name, or a vector of column names, to be selected:

```
> subset(dfrm, select=colname)
> subset(dfrm, select=c(colname1, ..., colnameN))
```

Note that you do *not* quote the column names.

The `subset` argument is a logical expression that selects rows. Inside the expression, you can refer to the column names as part of the logical expression. In this example, `response` is a column in the data frame, and we are selecting rows with a positive `response`:

```
> subset(dfrm, subset=(response > 0))
```

`subset` is most useful when you combine the `select` and `subset` arguments:

```
> subset(dfrm, select=c(predictor,response), subset=(response > 0))
```

Discussion

Indexing is the "official" way to select rows and columns from a data frame, as described in Recipes 5.22 and 5.23. However, indexing is cumbersome when the index expressions become complicated.

The `subset` function provides a more convenient and readable way to select rows and columns. It's beauty is that you can refer to the columns of the data frame right inside the expressions for selecting columns and rows.

Here are some examples using the `Cars93` dataset in the `MASS` package. Recall that the dataset includes columns for `Manufacturer`, `Model`, `MPG.city`, `MPG.highway`, `Min.Price`, and `Max.Price`:

Select the model name for cars that can exceed 30 miles per gallon (MPG) in the city

```
> subset(Cars93, select=Model, subset=(MPG.city > 30))
     Model
31 Festiva
39   Metro
42   Civic
.
. (etc.)
.
```

Select the model name and price range for four-cylinder cars made in the United States

```
> subset(Cars93, select=c(Model,Min.Price,Max.Price),
+        subset=(Cylinders == 4 & Origin == "USA"))
          Model Min.Price Max.Price
6       Century      14.2      17.3
12     Cavalier       8.5      18.3
13      Corsica      11.4      11.4
.
. (etc.)
.
```

Select the manufacturer's name and the model name for all cars whose highway MPG value is above the median

```
> subset(Cars93, select=c(Manufacturer,Model),
+        subset=c(MPG.highway > median(MPG.highway)))
   Manufacturer          Model
1         Acura        Integra
5           BMW           535i
6         Buick        Century
.
. (etc.)
.
```

The `subset` function is actually more powerful than this recipe implies. It can select from lists and vectors, too. See the help page for details.

5.25 Changing the Names of Data Frame Columns

Problem

You converted a matrix or list into a data frame. R gave names to the columns, but the names are at best uninformative and at worst bizarre.

Solution

Data frames have a `colnames` attribute that is a vector of column names. You can update individual names or the entire vector:

```
> colnames(dfrm) <- newnames          # newnames is a vector of character strings
```

Discussion

The columns of data frames must have names. If you convert a vanilla matrix into a data frame, R will synthesize names that are reasonable but boring—for example, `V1`, `V2`, `V3`, and so forth:

```
> mat
       [,1]   [,2]   [,3]
[1,] -0.818 -0.667 -0.494
[2,] -0.819 -0.946 -0.205
[3,]  0.385  1.531 -0.611
[4,] -2.155 -0.535 -0.316
> as.data.frame(mat)
      V1     V2     V3
1 -0.818 -0.667 -0.494
2 -0.819 -0.946 -0.205
3  0.385  1.531 -0.611
4 -2.155 -0.535 -0.316
```

If the matrix had column names defined, R would have used those names instead of synthesizing new ones.

However, converting a list into a data frame produces some strange synthetic names:

```
> lst
[[1]]
[1] -0.284 -1.114 -1.097 -0.873

[[2]]
[1] -1.673  0.929  0.306  0.778

[[3]]
[1]  0.323  0.368  0.067 -0.080

> as.data.frame(lst)
  c..0.284...1.114...1.097...0.873. c..1.673..0.929..0.306..0.778.
1                            -0.284                         -1.673
2                            -1.114                          0.929
3                            -1.097                          0.306
4                            -0.873                          0.778
  c.0.323..0.368..0.067...0.08.
1                         0.323
2                         0.368
3                         0.067
4                        -0.080
```

Again, if the list elements had names then R would have used them.

Fortunately, you can overwrite the synthetic names with names of your own by setting the `colnames` attribute:

```
> dfrm <- as.data.frame(lst)
> colnames(dfrm) <- c("before","treatment","after")
> dfrm
  before treatment  after
1 -0.284    -1.673  0.323
2 -1.114     0.929  0.368
3 -1.097     0.306  0.067
4 -0.873     0.778 -0.080
```

See Also

See Recipe 5.33.

5.26 Editing a Data Frame

Problem

Data in a data frame are incorrect or missing. You want a convenient way to edit the data frame contents.

Solution

R includes a data editor that displays your data frame in a spreadsheet-like window. Invoke the editor using the `edit` function:

```
> temp <- edit(dfrm)
> dfrm <- temp               # Overwrite only if you're happy with the changes!
```

Make your changes and then close the editor window. The edit function will return the updated data, which here are assigned to `temp`. If you are happy with the changes, overwrite your data frame with the results.

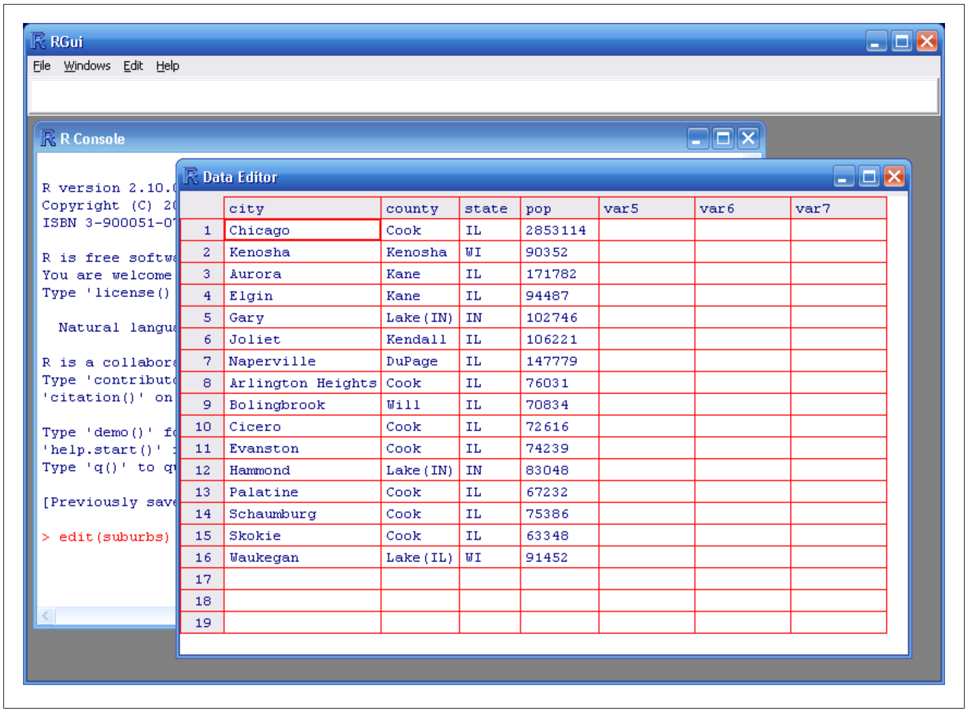
If you are feeling brave, the `fix` function invokes the editor and overwrites your variable with the result. There is no "undo", however:

```
> fix(dfrm)
```

Discussion

Figure 5-1 is a screenshot of the data editor on Windows during the editing of data from Recipe 5.22.

As of this writing, the editor is quite primitive. It does not include the common features of a modern editor—not even an "undo" command, for instance. I cannot recommend the data editor for regular use, but it's OK for emergency touch-ups.



```
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[Previously sav

> edit(suburbs)
```

	city	county	state	pop	var5	var6	var7
1	Chicago	Cook	IL	2853114			
2	Kenosha	Kenosha	WI	90352			
3	Aurora	Kane	IL	171782			
4	Elgin	Kane	IL	94487			
5	Gary	Lake(IN)	IN	102746			
6	Joliet	Kendall	IL	106221			
7	Naperville	DuPage	IL	147779			
8	Arlington Heights	Cook	IL	76031			
9	Bolingbrook	Will	IL	70834			
10	Cicero	Cook	IL	72616			
11	Evanston	Cook	IL	74239			
12	Hammond	Lake(IN)	IN	83048			
13	Palatine	Cook	IL	67232			
14	Schaumburg	Cook	IL	75386			
15	Skokie	Cook	IL	63348			
16	Waukegan	Lake(IL)	WI	91452			
17							
18							
19							

Figure 5-1. Editing a data frame

Since there is no undo, take note of the solution that assigns the edited result to a temporary, intermediate variable. If you mess up your data, you can just delete the temporary variable without affecting the original data.

See Also

Several of the add-on GUI frontends provide data editors that are better than the native editor.

5.27 Removing NAs from a Data Frame

Problem

Your data frame contains NA values, which is creating problems for you.

Solution

Use `na.omit` to remove rows that contain any NA values.

```
> clean <- na.omit(dfrm)
```

Discussion

I frequently stumble upon situations where just a few NA values in my data frame cause everything to fall apart. One solution is simply to remove all rows that contain NAs. That's what `na.omit` does.

Here we can see `cumsum` fail because the input contains NA values:

```
> dfrm
           x          y
1 -0.9714511 -0.4578746
2         NA  3.1663282
3  0.3367627         NA
4  1.7520504  0.7406335
5  0.4918786  1.4543427
> cumsum(dfrm)
          x          y
1 -0.971451 -0.4578746
2        NA  2.7084536
3        NA         NA
4        NA         NA
5        NA         NA
```

If we remove the NA values, `cumsum` can complete its summations:

```
> cumsum(na.omit(dfrm))
           x          y
1 -0.9714511 -0.4578746
4  0.7805993  0.2827589
5  1.2724779  1.7371016
```

This recipe works for vectors and matrices, too, but not for lists.

Will You Still Have Enough Data?

The obvious danger here is that simply dropping observations from your data could render the results computationally or statistically meaningless. Make sure that omitting data makes sense in your context. Remember that `na.omit` will remove entire rows, not just the NA values, which could eliminate a lot of useful information.

5.28 Excluding Columns by Name

Problem

You want to exclude a column from a data frame using its name.

Solution

Use the `subset` function with a negated argument for the `select` parameter:

```
> subset(dfrm, select = -badboy)          # All columns except badboy
```

Discussion

We can exclude a column by position (e.g., `dfrm[-1]`), but how do we exclude a column by name? The subset function can exclude columns from a data frame. The `select` parameter is a normally a list of columns to include, but prefixing a minus sign (`-`) to the name causes the column to be excluded instead.

I often encounter this problem when calculating the correlation matrix of a data frame and I want to exclude nondata columns such as labels:

```
> cor(patient.data)
            patient.id        pre     dosage        post
patient.id  1.00000000  0.02286906  0.3643084 -0.13798149
pre         0.02286906  1.00000000  0.2270821 -0.03269263
dosage      0.36430837  0.22708208  1.0000000 -0.42006280
post       -0.13798149 -0.03269263 -0.4200628  1.00000000
```

This correlation matrix includes the meaningless "correlation" between patient ID and other variables, which is annoying. We can exclude the patient ID column to clean up the output:

```
> cor(subset(patient.data, select = -patient.id))
               pre     dosage        post
pre     1.00000000  0.2270821 -0.03269264
dosage  0.22708207  1.0000000 -0.42006280
post   -0.03269264 -0.4200628  1.00000000
```

We can exclude multiple columns by giving a vector of negated names:

```
> cor(subset(patient.data, select = c(-patient.id,-dosage)))
             pre        post
pre   1.00000000 -0.03269264
post -0.03269264  1.00000000
```

See Also

See Recipe 5.24 for more about the `subset` function.

5.29 Combining Two Data Frames

Problem

You want to combine the contents of two data frames into one data frame.

Solution

To combine the columns of two data frames side by side, use `cbind`:

```
> all.cols <- cbind(dfrm1,dfrm2)
```

To "stack" the rows of two data frames, use `rbind`:

```
> all.rows <- rbind(dfrm1,dfrm2)
```

Discussion

You can combine data frames in one of two ways: either by putting the columns side by side to create a wider data frame; or by "stacking" the rows to create a taller data frame. The `cbind` function will combine data frames side by side, as shown here when combining `stooges` and `birth`:

```
> stooges
   name n.marry n.child
1   Moe       1       2
2 Larry       1       2
3 Curly       4       2
> birth
  birth.year  birth.place
1       1887  Bensonhurst
2       1902 Philadelphia
3       1903     Brooklyn
> cbind(stooges,birth)
   name n.marry n.child birth.year  birth.place
1   Moe       1       2       1887  Bensonhurst
2 Larry       1       2       1902 Philadelphia
3 Curly       4       2       1903     Brooklyn
```

You would normally combine columns with the same height (number of rows). Technically speaking, however, `cbind` does not require matching heights. If one data frame is short, it will invoke the Recycling Rule to extend the short columns as necessary (Recipe 5.3), which may or may not be what you want.

The `rbind` function will "stack" the rows of two data frames, as shown here when combining `stooges` and `guys`:

```
> stooges
   name n.marry n.child
1   Moe       1       2
2 Larry       1       2
3 Curly       4       2
> guys
   name n.marry n.child
1   Tom       4       2
2  Dick       1       4
3 Harry       1       1
> rbind(stooges,guys)
   name n.marry n.child
1   Moe       1       2
2 Larry       1       2
3 Curly       4       2
4   Tom       4       2
5  Dick       1       4
6 Harry       1       1
```

The `rbind` function requires that the data frames have the same width: same number of columns and same column names. The columns need not be in the same *order*, however; `rbind` will sort that out.

Finally, this recipe is slightly more general than the title implies. First, you can combine more than two data frames because both `rbind` and `cbind` accept multiple arguments. Second, you can apply this recipe to other data types because `rbind` and `cbind` work also with vectors, lists, and matrices.

See Also

The `merge` function can combine data frames that are otherwise incompatible owing to missing or different columns. The `reshape2` and `plyr` packages, available on CRAN, include some powerful functions for slicing, dicing, and recombining data frames.

5.30 Merging Data Frames by Common Column

Problem

You have two data frames that share a common column. You want to merge their rows into one data frame by matching on the common column.

Solution

Use the `merge` function to join the data frames into one new data frame based on the common column:

```
> m <- merge(df1, df2, by="name")
```

Here *`name`* is the name of the column that is common to data frames *`df1`* and *`df2`*.

Discussion

Suppose you have two data frames, `born` and `died`, that each contain a column called `name`:

```
> born
   name year.born   place.born
1   Moe      1887  Bensonhurst
2 Larry      1902 Philadelphia
3 Curly      1903     Brooklyn
4 Harry      1964       Moscow
> died
   name year.died
1 Curly      1952
2   Moe      1975
3 Larry      1975
```

We can merge them into one data frame by using `name` to combine matched rows:

```
> merge(born, died, by="name")
   name year.born   place.born year.died
1 Curly      1903     Brooklyn      1952
2 Larry      1902 Philadelphia      1975
3   Moe      1887  Bensonhurst      1975
```

Notice that `merge` does not require the rows to be sorted or even to occur in the same order. It found the matching rows for Curly even though they occur in different positions. It also discards rows that appear in only one data frame or the other.

In SQL terms, the `merge` function essentially performs a join operation on the two data frames. It has many options for controlling that join operation, all of which are described on the help page for `merge`.

See Also

See Recipe 5.29 for other ways to combine data frames.

5.31 Accessing Data Frame Contents More Easily

Problem

Your data is stored in a data frame. You are getting tired of repeatedly typing the data frame name and want to access the columns more easily.

Solution

For quick, one-off expressions, use the `with` function to expose the column names:

```
> with(dataframe, expr)
```

Inside *`expr`*, you can refer to the columns of *`dataframe`* by their names—as if they were simple variables.

For repetitive access, use the `attach` function to insert the data frame into your search list. You can then refer to the data frame columns by name without mentioning the data frame:

```
> attach(dataframe)
```

Use the `detach` function to remove the data frame from your search list.

Discussion

A data frame is a great way to store your data, but accessing individual columns can become tedious. For a data frame called `suburbs` that contains a column called `pop`, here is the naïve way to calculate the *z*-scores of `pop`:

```
> z <- (suburbs$pop - mean(suburbs$pop)) / sd(suburbs$pop)
```

Call me a whiner, but all that typing gets tedious. The `with` function lets you expose the columns of a data frame as distinct variables. It takes two arguments, a data frame and an expression to be evaluated. Inside the expression, you can refer to the data frame columns by their names:

```
> z <- with(suburbs, (pop - mean(pop)) / sd(pop))
```

That is useful for one-liners. If you will be working repeatedly with columns in your data frame, attach the data frame to your search list and the columns will become available as variables:

```
> attach(suburbs)
```

After the `attach`, the second item in the search list is the `suburbs` data frame:

```
> search()
 [1] ".GlobalEnv"        "suburbs"           "package:stats"
 [4] "package:graphics"  "package:grDevices" "package:utils"
 [7] "package:datasets"  "package:methods"   "Autoloads"
[10] "package:base"
```

Now we can refer to the columns of the data frame as if they were variables:

```
> z <- (pop - mean(pop)) / sd(pop)
```

When you are done, use a `detach` (with no arguments) to remove the second location in the search list:

```
> detach()
> search()
[1] ".GlobalEnv"        "package:stats"     "package:graphics"
[4] "package:grDevices" "package:utils"     "package:datasets"
[7] "package:methods"   "Autoloads"         "package:base"
```

Observe that `suburbs` is no longer in the search list.

Attaching a data frame has a big quirk: R attaches a *temporary copy* of the data frame, which means that changes to the original data frame are hidden. In this session fragment, notice how changing the data frame does not change our view of the attached data:

```
> attach(suburbs)
> pop
 [1] 2853114   90352  171782   94487  102746  106221  147779   76031   70834
[10]   72616   74239   83048   67232   75386   63348   91452
> suburbs$pop <- 0          # Overwrite data frame contents
> pop                       # Hey! It seems nothing changed
 [1] 2853114   90352  171782   94487  102746  106221  147779   76031   70834
[10]   72616   74239   83048   67232   75386   63348   91452
> suburbs$pop               # Contents of data frame did indeed change
 [1] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

Another source of confusion is that assigning values to the exposed names does not work as you might expect. In the following fragment, you might think we are scaling `pop` by 1,000 but we are actually creating a new local variable:

```
> attach(suburbs)
> pop
 [1] 2853114   90352  171782   94487  102746  106221  147779   76031   70834
[10]   72616   74239   83048   67232   75386   63348   91452
> pop <- pop / 1000         # Achtung! This is creating a local variable called "pop"
> ls()                      # We can see the new variable in our workspace
[1] "pop"     "suburbs"
```

```
> suburbs$pop               # Original data is unchanged
 [1] 2853114   90352  171782   94487  102746  106221  147779   76031   70834
[10]   72616   74239   83048   67232   75386   63348   91452
```

5.32 Converting One Atomic Value into Another

Problem

You have a data value which has an atomic data type: character, complex, double, integer, or logical. You want to convert this value into one of the other atomic data types.

Solution

For each atomic data type, there is a function for converting values to that type. The conversion functions for atomic types include:

- `as.character(x)`
- `as.complex(x)`
- `as.numeric(x)` or `as.double(x)`
- `as.integer(x)`
- `as.logical(x)`

Discussion

Converting one atomic type into another is usually pretty simple. If the conversion works, you get what you would expect. If it does not work, you get NA:

```
> as.numeric(" 3.14 ")
[1] 3.14
> as.integer(3.14)
[1] 3
> as.numeric("foo")
[1] NA
Warning message:
NAs introduced by coercion
> as.character(101)
[1] "101"
```

If you have a vector of atomic types, these functions apply themselves to every value. So the preceding examples of converting scalars generalize easily to converting entire vectors:

```
> as.numeric(c("1","2.718","7.389","20.086"))
[1]  1.000  2.718  7.389 20.086
> as.numeric(c("1","2.718","7.389","20.086", "etc."))
[1]  1.000  2.718  7.389 20.086     NA
Warning message:
NAs introduced by coercion
```

```
> as.character(101:105)
[1] "101" "102" "103" "104" "105"
```

When converting logical values into numeric values, R converts `FALSE` to `0` and `TRUE` to `1`:

```
> as.numeric(FALSE)
[1] 0
> as.numeric(TRUE)
[1] 1
```

This behavior is useful when you are counting occurrences of `TRUE` in vectors of logical values. If `logvec` is a vector of logical values, then `sum(logvec)` does an implicit conversion from logical to integer and returns the number of `TRUE`s.

5.33 Converting One Structured Data Type into Another

Problem

You want to convert a variable from one structured data type to another—for example, converting a vector into a list or a matrix into a data frame.

Solution

These functions convert their argument into the corresponding structured data type:

- `as.data.frame(x)`
- `as.list(x)`
- `as.matrix(x)`
- `as.vector(x)`

Some of these conversions may surprise you, however. I suggest you review Table 5-1.

Discussion

Converting between structured data types can be tricky. Some conversions behave as you'd expect. If you convert a matrix into a data frame, for instance, the rows and columns of the matrix become the rows and columns of the data frame. No sweat.

Table 5-1. Data conversions

Conversion	How	Notes
Vector→List	`as.list(vec)`	Don't use `list(vec)`; that creates a 1-element list whose only element is a copy of `vec`.
Vector→Matrix	To create a 1-column matrix: `cbind(vec)` *or* `as.matrix(vec)` To create a 1-row matrix: `rbind(vec)`	See Recipe 5.14.

Conversion	How	Notes
	To create an $n \times m$ matrix: `matrix(vec,n,m)`	
Vector→Data frame	To create a 1-column data frame: `as.data.frame(vec)`	
	To create a 1-row data frame: `as.data.frame(rbind(vec))`	
List→Vector	`unlist(lst)`	Use `unlist` rather than `as.vector`; see Note 1 and Recipe 5.11.
List→Matrix	To create a 1-column matrix: `as.matrix(lst)`	
	To create a 1-row matrix: `as.matrix(rbind(lst))`	
	To create an $n \times m$ matrix: `matrix(lst,n,m)`	
List→Data frame	If the list elements are columns of data: `as.data.frame(lst)`	
	If the list elements are rows of data: Recipe 5.19	
Matrix→Vector	`as.vector(mat)`	Returns all matrix elements in a vector.
Matrix→List	`as.list(mat)`	Returns all matrix elements in a list.
Matrix→Data frame	`as.data.frame(mat)`	
Data frame→Vector	To convert a 1-row data frame: `dfrm[1,]`	See Note 2.
	To convert a 1-column data frame: `dfrm[,1]` or `dfrm[[1]]`	
Data frame→List	`as.list(dfrm)`	See Note 3.
Data frame→Matrix	`as.matrix(dfrm)`	See Note 4.

In other cases, the results might surprise you. Table 5-1 summarizes some noteworthy examples. The following Notes are cited in that table:

1. When you convert a list into a vector, the conversion works cleanly if your list contains atomic values that are all of the same mode. Things become complicated if either (a) your list contains mixed modes (e.g., numeric and character), in which case everything is converted to characters; or (b) your list contains other structured data types, such as sublists or data frames—in which case very odd things happen, so don't do that.
2. Converting a data frame into a vector makes sense only if the data frame contains one row or one column. To extract all its elements into one, long vector, use `as.vector(as.matrix(dfrm))`. But even that makes sense only if the data frame is all-numeric or all-character; if not, everything is first converted to character strings.
3. Converting a data frame into a list may seem odd in that a data frame is already a list (i.e., a list of columns). Using `as.list` essentially removes the class (`data.frame`) and thereby exposes the underlying list. That is useful when you want R to treat your data structure as a list—say, for printing.

4. Be careful when converting a data frame into a matrix. If the data frame contains only numeric values then you get a numeric matrix. If it contains only character values, you get a character matrix. But if the data frame is a mix of numbers, characters, and/or factors, then all values are first converted to characters. The result is a matrix of character strings.

Problems with matrices

The matrix conversions detailed here assume that your matrix is homogeneous: all elements have the same mode (e.g, all numeric or all character). A matrix can to be heterogeneous, too, when the matrix is built from a list. If so, conversions become messy. For example, when you convert a mixed-mode matrix to a data frame, the data frame's columns are actually lists (to accommodate the mixed data).

See Also

See Recipe 5.32 for converting atomic data types; see the "Introduction" to this chapter for remarks on problematic conversions.