For more information on `%prun`, as well as its available options, use the IPython help functionality (i.e., type **%prun?** at the IPython prompt).

Line-by-Line Profiling with %lprun

The function-by-function profiling of `%prun` is useful, but sometimes it's more convenient to have a line-by-line profile report. This is not built into Python or IPython, but there is a `line_profiler` package available for installation that can do this. Start by using Python's packaging tool, `pip`, to install the `line_profiler` package:

```
$ pip install line_profiler
```

Next, you can use IPython to load the `line_profiler` IPython extension, offered as part of this package:

```
In[9]: %load_ext line_profiler
```

Now the `%lprun` command will do a line-by-line profiling of any function—in this case, we need to tell it explicitly which functions we're interested in profiling:

```
In[10]: %lprun -f sum_of_lists sum_of_lists(5000)
```

As before, the notebook sends the result to the pager, but it looks something like this:

```
Timer unit: 1e-06 s

Total time: 0.009382 s
File: <ipython-input-19-fa2be176cc3e>
Function: sum_of_lists at line 1

Line #      Hits         Time  Per Hit   % Time  Line Contents
==============================================================
     1                                           def sum_of_lists(N):
     2         1            2      2.0      0.0       total = 0
     3         6            8      1.3      0.1       for i in range(5):
     4         5         9001   1800.2     95.9           L = [j ^ (j >> i) ...
     5         5          371     74.2      4.0           total += sum(L)
     6         1            0      0.0      0.0       return total
```

The information at the top gives us the key to reading the results: the time is reported in microseconds and we can see where the program is spending the most time. At this point, we may be able to use this information to modify aspects of the script and make it perform better for our desired use case.

For more information on `%lprun`, as well as its available options, use the IPython help functionality (i.e., type **%lprun?** at the IPython prompt).

Profiling Memory Use: %memit and %mprun

Another aspect of profiling is the amount of memory an operation uses. This can be evaluated with another IPython extension, the `memory_profiler`. As with the `line_profiler`, we start by `pip`-installing the extension:

```
$ pip install memory_profiler
```

Then we can use IPython to load the extension:

```
In[12]: %load_ext memory_profiler
```

The memory profiler extension contains two useful magic functions: the `%memit` magic (which offers a memory-measuring equivalent of `%timeit`) and the `%mprun` function (which offers a memory-measuring equivalent of `%lprun`). The `%memit` function can be used rather simply:

```
In[13]: %memit sum_of_lists(1000000)

peak memory: 100.08 MiB, increment: 61.36 MiB
```

We see that this function uses about 100 MB of memory.

For a line-by-line description of memory use, we can use the `%mprun` magic. Unfortunately, this magic works only for functions defined in separate modules rather than the notebook itself, so we'll start by using the `%%file` magic to create a simple module called `mprun_demo.py`, which contains our `sum_of_lists` function, with one addition that will make our memory profiling results more clear:

```
In[14]: %%file mprun_demo.py
        def sum_of_lists(N):
            total = 0
            for i in range(5):
                L = [j ^ (j >> i) for j in range(N)]
                total += sum(L)
                del L # remove reference to L
            return total

Overwriting mprun_demo.py
```

We can now import the new version of this function and run the memory line profiler:

```
In[15]: from mprun_demo import sum_of_lists
        %mprun -f sum_of_lists sum_of_lists(1000000)
```

The result, printed to the pager, gives us a summary of the memory use of the function, and looks something like this: