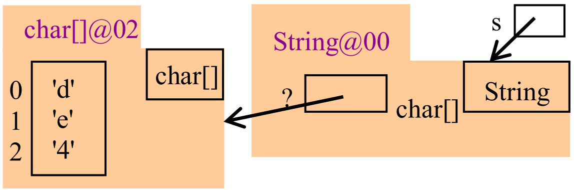
String catenation is not a basic step!

The example treated in this document illustrates that care must be taken in calculating the number of basic steps.

In the box to the right, with `x` a variable of type **int**, we know that the assignment to `x` is a basic step. The assignment to `String` variable `s` sure looks similar to the assignment to `x`, and the first thought is that it must also be a basic step. But it is not. In fact, we will show that the number of basic steps is proportional to the length of `s`.

```
x= x + 1;
s=  s + '$';
```

First, we must understand how strings are implemented. Variable `s` contains a pointer to a `String` object. This object contains, among other things, a pointer to an object that is an array of `char`s, which contains the characters in the string. We call this the *backing array* for the string. In the example shown to the right, the array contains three chars: 'd', 'e', and '4'.

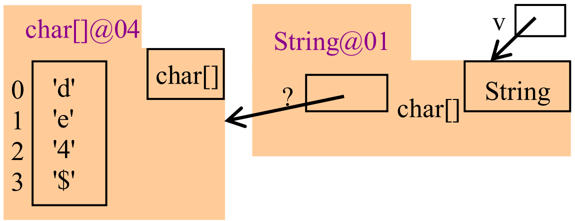


We now show how the catenation `s + '$'` is evaluated in three steps:

(1) Create a second String object and a second `char[]` object, the latter with space for 1 more character, and create a pointer `v` to the new String object;

(2) Copy the 3 chars 'd', 'e', and '4' from object `char[]@02` to object `char[]@04`; and

(3) Place the catenated character '$' into the array object `char[]@04`, producing the new objects shown to the right.



The assignment `s= s + '$';` is then completed by assigning `v` to `s`, so `s` finally points to string object `String@01`.

Figuring out the basic steps in evaluating s= s + '$';

The first step in evaluating `s + '$'` is to create the new String object *and* the `char[]` object to which it points. We can consider this to be *one* basic step. Of course, it takes a lot of time, perhaps 1000 times more than just evaluating `x+y`, but the time *is* independent of all values, including the char array in `char[]@0`. Remember that the compiler figures out where each variable and method goes in the String and char[] objects, so space allocation costs just contant time when the objects are being created. So we consider it to be *one* big basic step.

The second step is to copy the characters in the original char array (in object `char[]@02`) to the new char array (in object `char[]@04`). This takes, `s.length()` basic steps, because `s.length()` chars have to be copied into the new array.

Then, the catenated character '$', has to be placed in the new array. This is one basic step.

Finally, the assignment `s= v;` has to be executed. This is one basic step.

Therefore the number of basic steps is `s.length()` + 3.

Therefore, the number of basic steps taken in executing `s= s + '$';` is proportional to the number of characters in string `s`.