Module 02

{ ‘A’, ‘r’, ‘r’, ‘a’, ‘y’, ‘s’ }

and “Strings”

Low-level array operations

```
int[] arr1;
int[] arr2 = new int[ 17 ];
int[] arr3 = { 1, 2, 3, 4 };
```

Declaration and initialization

```
arr2[15] = arr3[2];
```

Reading and writing elements

```
int els = arr2.length;
```

Array size

Arrays are just values...

```
int[] arr1 = { 1, 2, 3, 4 };
int[] arr2 = arr1;
```

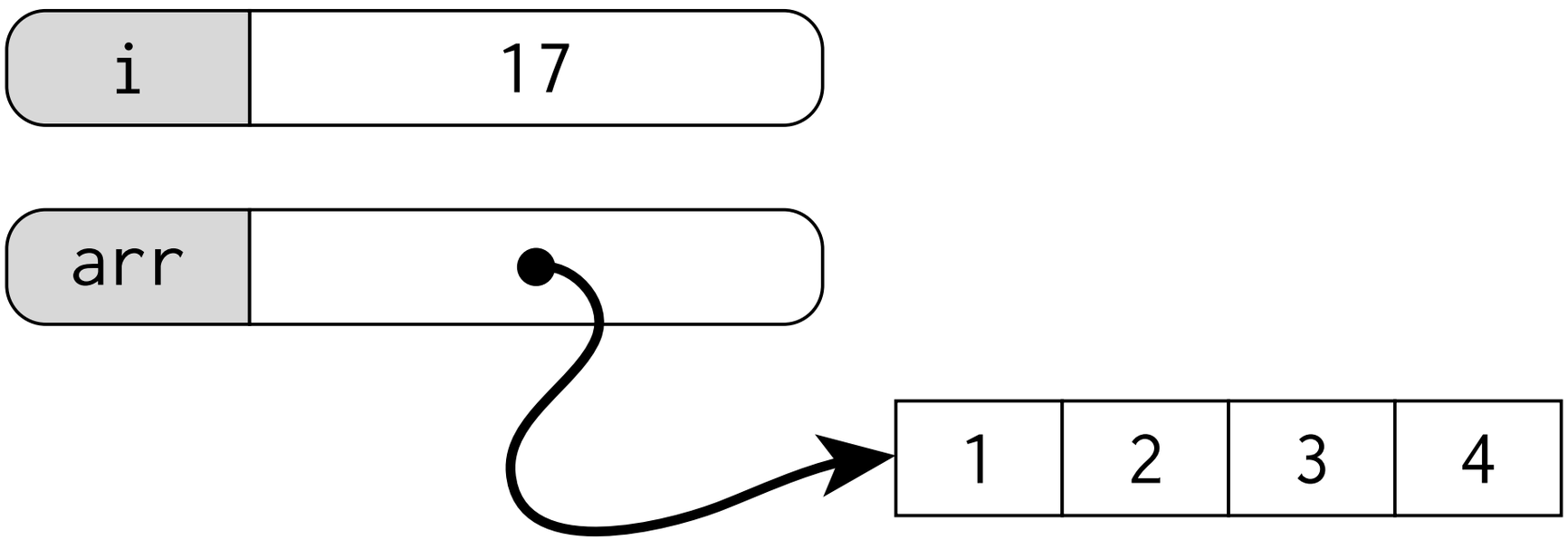
```
int[] processArray( int[] arr, float val )
{
   ...
}

int[] arr3 = processArray( arr1, 3.14 );
```

...aren't they?

An array value is really an arrow pointing to the place in memory where all the array elements are stored. We say that an array variable is a *reference*.

```
int i = 17;
int[] arr = { 1, 2, 3, 4 };
```



```
int a = 1;
```

```
int b = 2;
```

```
a = b;
```

```
b = 3;
```

```
int a = 1;
```

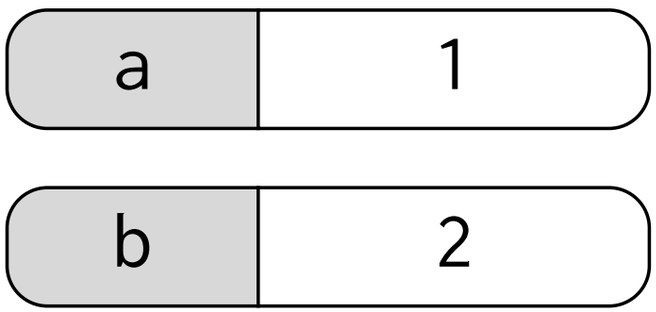
```
int b = 2;
```

```
a = b;
```

```
b = 3;
```

```
int a = 1;
```

```
int b = 2;
```

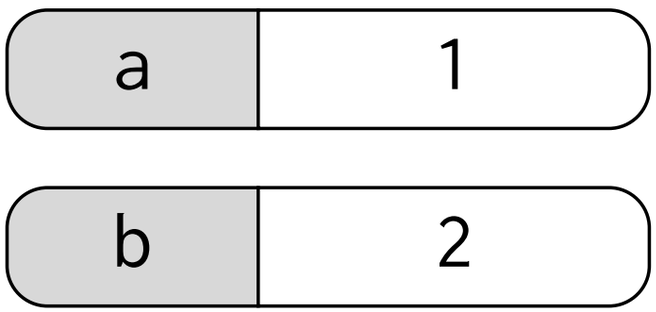


```
a = b;
```

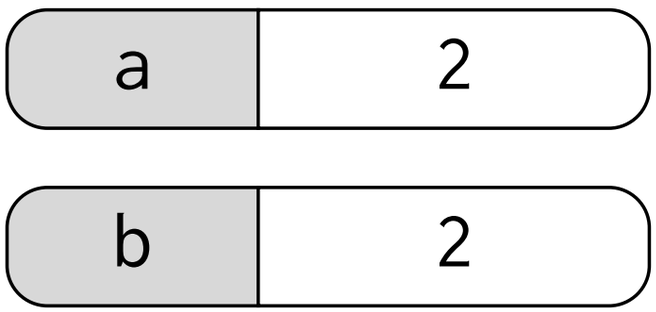
```
b = 3;
```

```
int a = 1;
```

```
int b = 2;
```



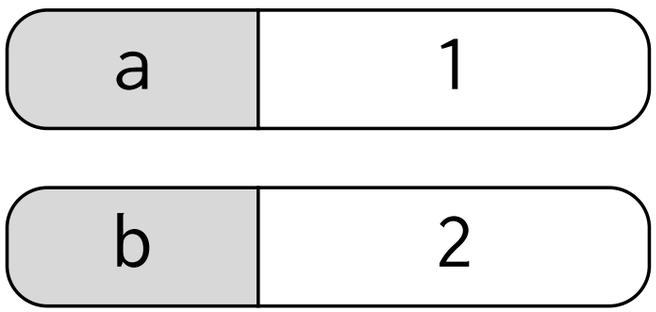
```
a = b;
```



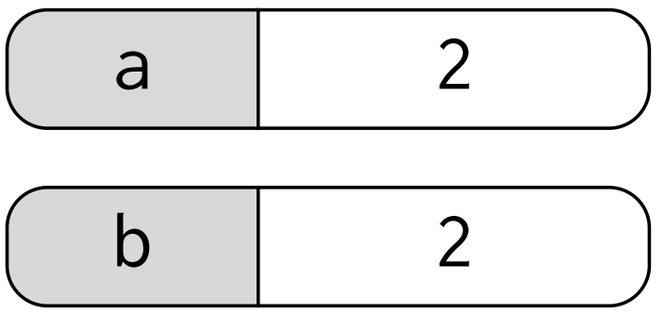
```
b = 3;
```

```
int a = 1;
```

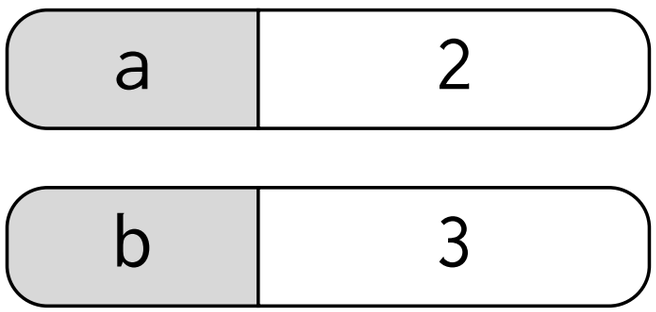
```
int b = 2;
```



```
a = b;
```

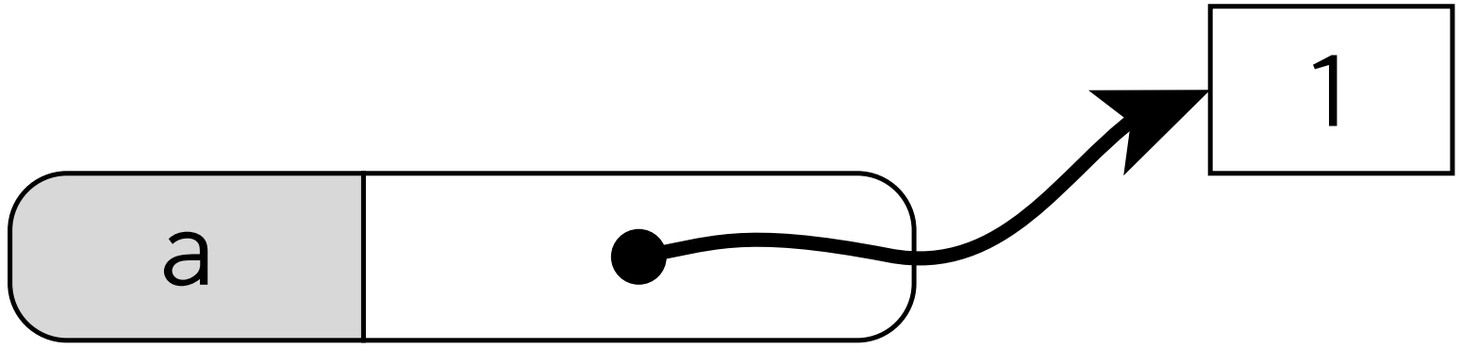


```
b = 3;
```

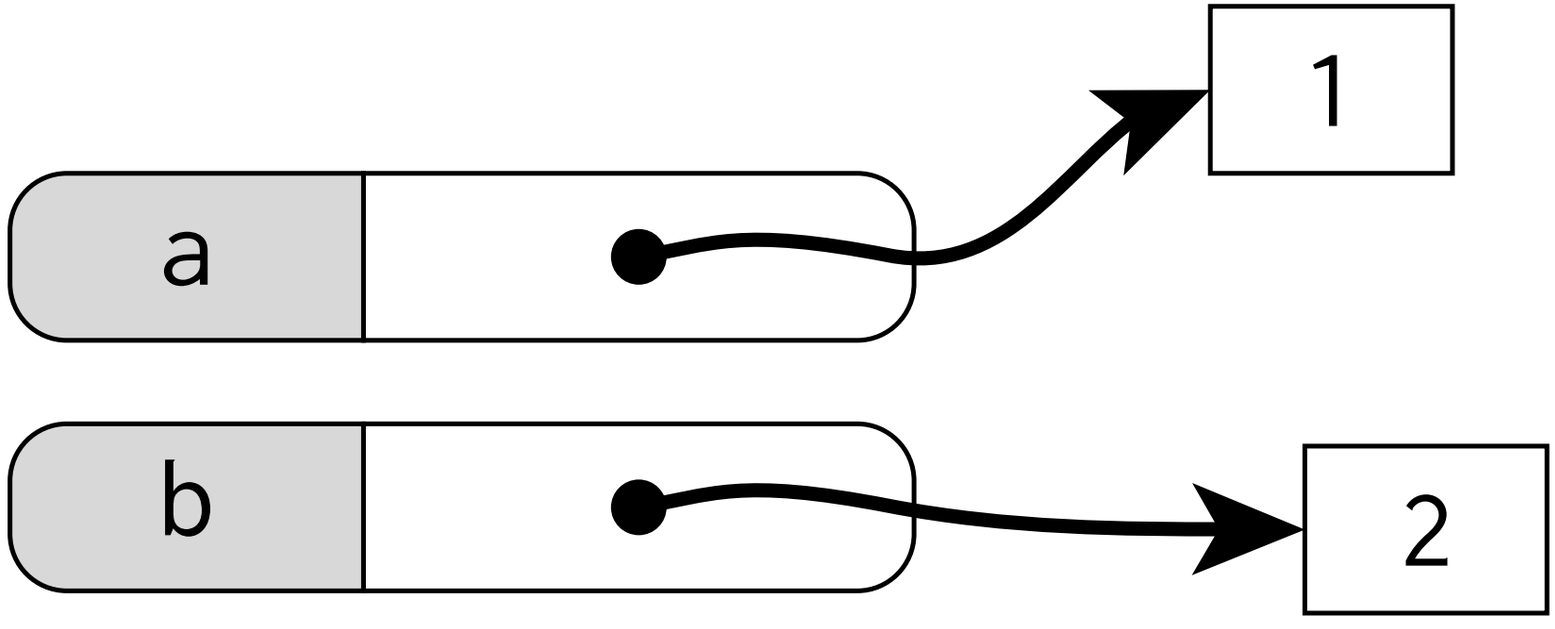


```
int[] a = { 1 };
int[] b = { 2 };
a = b;
b[0] = 3;
println( a[0] + b[0] );
```

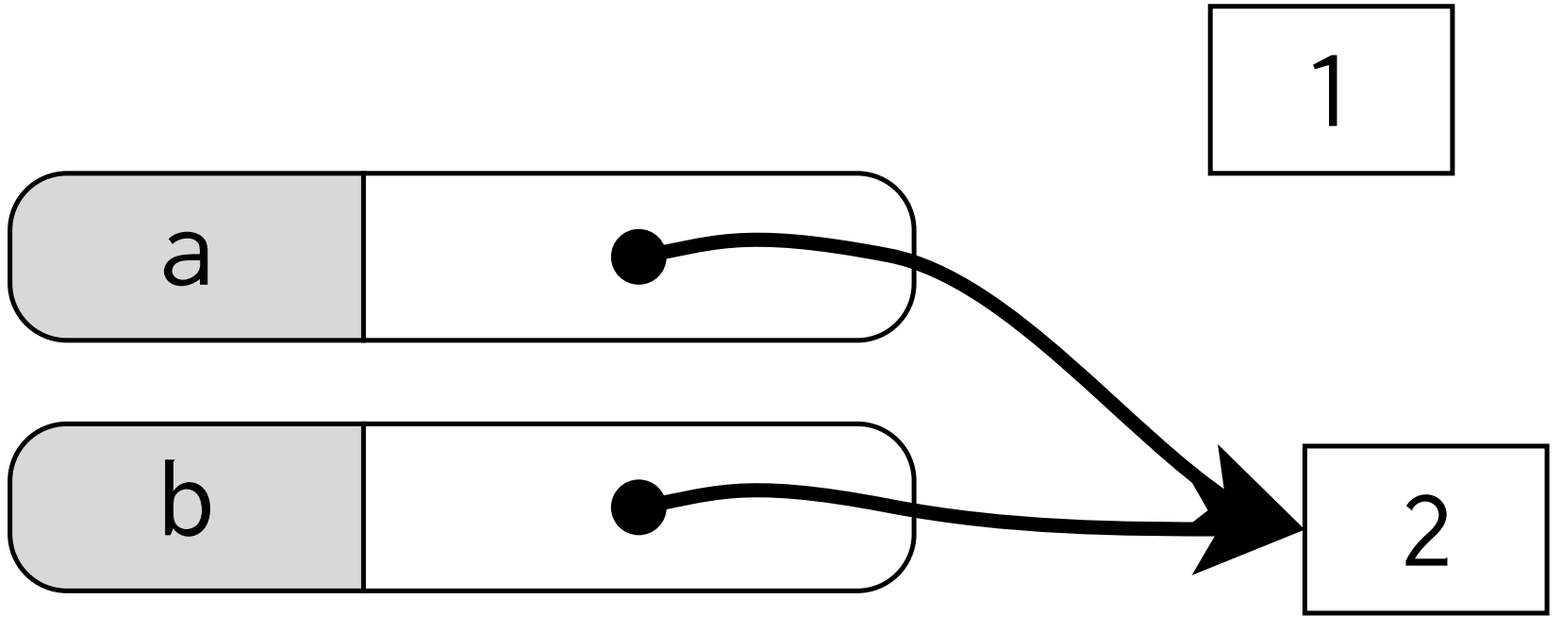
```
int[] a = { 1 };
int[] b = { 2 };
a = b;
b[0] = 3;
println( a[0] + b[0] );
```



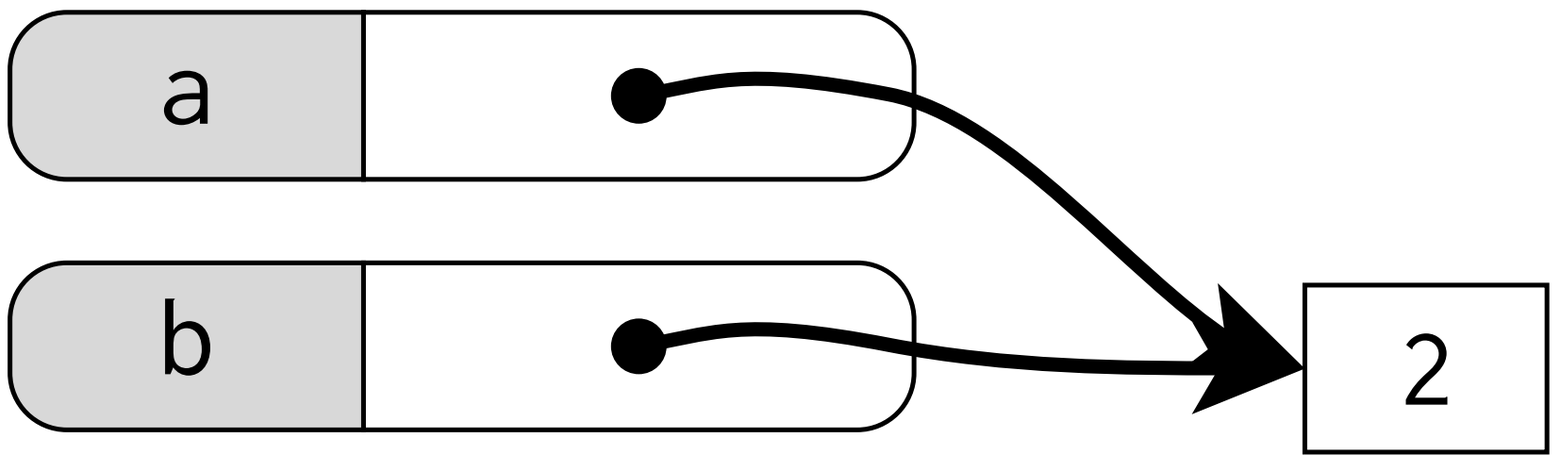
```
int[] a = { 1 };
int[] b = { 2 };
a = b;
b[0] = 3;
println( a[0] + b[0] );
```



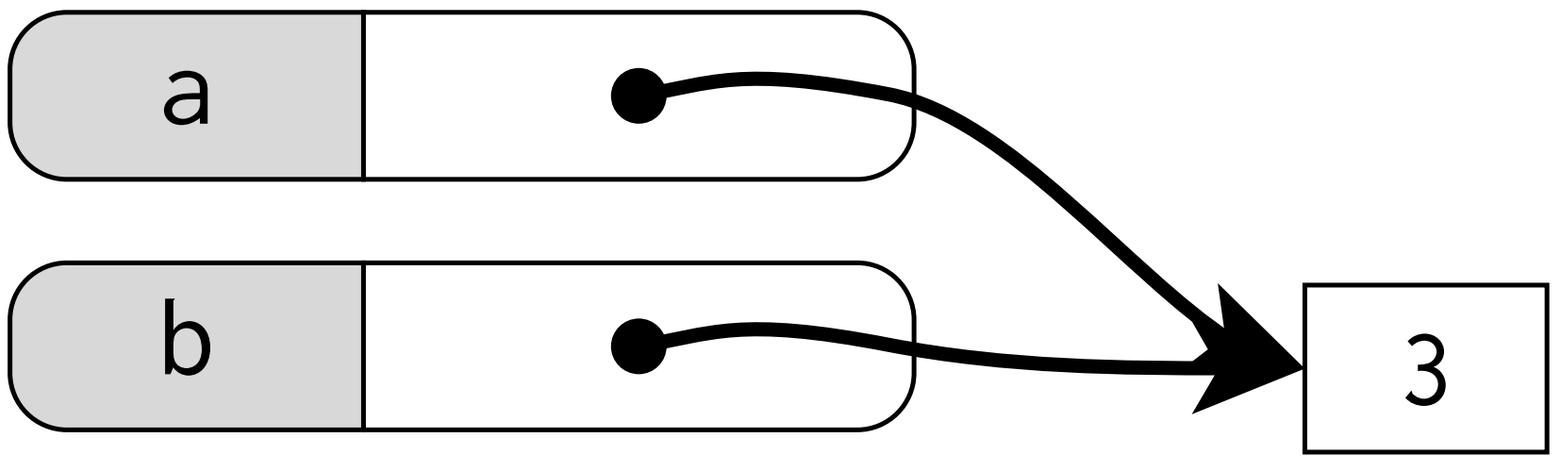
```
int[] a = { 1 };
int[] b = { 2 };
a = b;
b[0] = 3;
println( a[0] + b[0] );
```



```
int[] a = { 1 };
int[] b = { 2 };
a = b;
b[0] = 3;
println( a[0] + b[0] );
```



```
int[] a = { 1 };
int[] b = { 2 };
a = b;
b[0] = 3;
println( a[0] + b[0] );
```



References

The base types `int`, `float`, `boolean`, and `char` are "primitive": their values are "naked" and copied around directly.

All other types (arrays and objects, including `String`) are passed around by reference (arrows).

Array idioms

An idiom is not a single algorithm or line of code. It's a rough template that can be customized to a specific situation.

```
for( int idx = 0; idx < arr.length; ++idx ) {
    // something with arr[idx]
}
```

Processing arrays

1. Distillation

There are many natural operations on arrays that involve “reducing” the array down to a single value:

- Largest element
- Smallest element
- Is X in the array?
- Find the index of X
- Sum of elements
- Average of elements
- Number of positive elements

```
float distill( float[] arr )
{
  float result =
  for( int idx = 0; idx < arr.length; ++idx ) {
    result =                    arr[idx]      result
  }

  return result;
}
```

Initial value for result

```
float distill( float[] arr )
{
  float result =
  for( int idx = 0; idx < arr.length; ++idx ) {
    result =                    arr[idx]      result
  }

  return result;
}
```

```
float distill( float[] arr )
{
  float result =
  for( int idx = 0; idx < arr.length; ++idx ) {
    result =                    arr[idx]      result
  }

  return result;
}
```

Combine what you know with another array element to get a slightly better answer

```
float distill( float[] arr )
{
  float result =
  for( int idx = 0; idx < arr.length; ++idx ) {
    result =                    arr[idx]      result
  }

  return result;
}
```

We've seen the whole array, so this is the final answer.

```
float largestElement( float[] arr )
{
  float result = arr[0];
  for( int idx = 0; idx < arr.length; ++idx ) {
    if( arr[idx] > result ) {
      result = arr[idx];
    }
  }

  return result;
}
```

```
float largestElement( float[] arr )
{
  float result = arr[0];
  for( int idx = 1; idx < arr.length; ++idx ) {
    if( arr[idx] > result ) {
      result = arr[idx];
    }
  }

  return result;
}
```

This is a common enough operation that `max()` and `min()` already work on arrays of numbers.

```
float[] arr = { 1.0, 4.2, -129832, PI, 2.718 };
println( max( arr ) );
println( min( arr ) );
```

Sometimes, we can stop processing an array early.

```
int getProduct( int[] arr )
{
  int total = 1;
  for( int idx = 0; idx < arr.length; ++idx ) {
    total = total * arr[idx];
  }
  return total;
}
```

What if we see a zero?

```
int getProduct( int[] arr )
{
  int total = 1;
  for( int idx = 0; idx <= arr.length; ++idx ) {
    if( arr[idx] == 0 ) {
      return 0;
    }
    total = total * arr[idx];
  }
  return total;
}
```

Processing arrays

2. Generation

Sometimes we want to conjure an array from nothing. We can do that in a function that takes values as input and returns an array.

Example: write a function that takes an integer `n` as input and produces the integer array `{0, 1, 2, …, n-1}`.

```
int[] upto( int n )
{
  int[] ret = new int[ n ];
  for ( int idx = 0; idx < n; ++idx ) {
    ret[idx] = idx;
  }
  return ret;
}
```

Processing arrays

3. Transformation

Often we want to transform an array element-by-element into a new array. Sort of a combination of distillation and generation.

```
Type2[] transform( Type1[] arr )
{
  Type2[] ret = new Type2[ arr.length ];

  for( int idx = 0; idx < arr.length; ++idx ) {
    ret[idx] = [illegible] arr[idx] [illegible]
  }

  return ret;
}
```

```
int[] badArrayClone( int[] arr )
{
  return arr;
}
```

```
int[] badArrayClone( int[] arr )
{
  return arr;
}

int[] goodArrayClone( int[] arr )
{
  int[] ret = new int[ arr.length ];

  for( int idx = 0; idx < arr.length; ++idx ) {
    ret[idx] = arr[idx];
  }

  return ret;
}
```

Growing an array

Exercise: add one new element to the end of an array.

There's no way to grow an array "in place". Instead, we have to produce a new array that has all the original elements together with the new one.

Growing an array

The built-in function append() **adds a single new element to an array, returning the enlarged array.**

```
int[] arr1 = { 1, 2, 3, 4 };
float[] arr2 = { 1.2, 3.4, 5.6, 7.8 };

arr1 = append( arr1, 5 );
arr2 = append( arr2, cos( 2.0 * PI / 5.0 ) );
```

Casting

The append() **function and other array functions tend to work fine with built-in types, but "need help" with other types.**

```
class Circle
{ … }

Circle[] circs = …
circs = append( circs, new Circle( 10, 20, 30 ) );
```

Casting

The append() **function and other array functions tend to work fine with built-in types, but "need help" with other types.**

```
class Circle
{ … }

Circle[] circs = …
circs = append( circs, new Circle( 10, 20, 30 ) );
```

Type mismatch, "java.lang.Object" does not match with "sketch_170108c.Circle[]"

Casting

A “casting operator” is a way to remind Processing of what type you’re working with in cases where it forgets.

```
Circle[] circs = …
circs =
  (Circle[])append( circs, new Circle( 10, 20, 30 ) );
```

Casting

A “casting operator” is a way to remind Processing of what type you’re working with in cases where it forgets.

```
Circle[] circs = …
circs =
  (Circle[])append( circs, new Circle( 10, 20, 30 ) );
```

Force the expression that follows to be treated as an array of `Circle`s.

Other occasionally useful array operations:

```
int[] a = { 6, 3, 4, 1, 2, 5 };
int[] b = { 5, 6, 7 };

concat( a, b ) ⇒


reverse( a ) ⇒

shorten( b ) ⇒

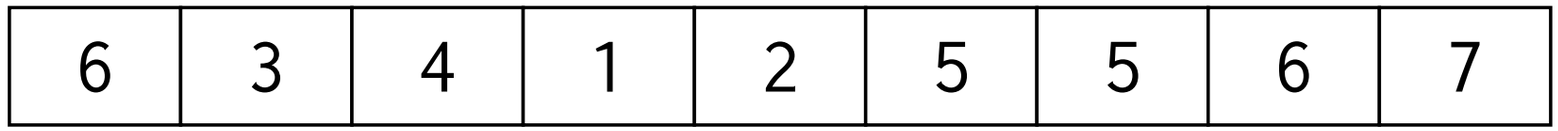
sort( a ) ⇒

subset( a, 2, 3 ) ⇒
```

Other occasionally useful array operations:

```
int[] a = { 6, 3, 4, 1, 2, 5 };
int[] b = { 5, 6, 7 };
```

concat(a, b) ⇒



reverse(a) ⇒

shorten(b) ⇒

sort(a) ⇒

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Other occasionally useful array operations:

```
int[] a = { 6, 3, 4, 1, 2, 5 };
int[] b = { 5, 6, 7 };
```

concat(a, b) ⇒

6	3	4	1	2	5	5	6	7

reverse(a) ⇒

5	2	1	4	3	6

shorten(b) ⇒

sort(a) ⇒

subset(a, 2, 3) ⇒

Other occasionally useful array operations:

```
int[] a = { 6, 3, 4, 1, 2, 5 };
int[] b = { 5, 6, 7 };
```

concat(a, b) ⇒

6	3	4	1	2	5	5	6	7

reverse(a) ⇒

5	2	1	4	3	6

shorten(b) ⇒

5	6

sort(a) ⇒

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6	3	4	1	2	5	5	6	7

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shorten(b) ⇒

5	6

sort(a) ⇒

1	2	3	4	5	6

subset(a, 2, 3) ⇒

Other occasionally useful array operations:

```
int[] a = { 6, 3, 4, 1, 2, 5 };
int[] b = { 5, 6, 7 };
```

concat(a, b) ⇒

6	3	4	1	2	5	5	6	7

reverse(a) ⇒

5	2	1	4	3	6

shorten(b) ⇒

5	6

sort(a) ⇒

1	2	3	4	5	6

subset(a, 2, 3) ⇒

4	1	2

Ian Barbour

Strings

In many programming situations, we want to deal with blocks of text.

- Text boxes in a web form
- Text drawn to the screen
- Analyzing text documents for patterns

We need a type to hold blocks of text. Processing includes the type `String`, which is inherits from Java.

Strings and characters

A *character* is one symbol or letter in a string, including whitespace and other control characters. Characters are represented using the built-in type `char`.

Literals

To give an explicit character (a *literal)*, put it in single quotes.

```
char a = 'a';
char b = 'd';
char c = ' ';
char d = '*';
```

To give an explicit string, put it in double quotes.

```
String name = “Kylo Ren”;
String title = “Star Wars: The Last Jedi”;
String line = ”The son of Han Solo and Leia Organa”;
```

```
println( "mouse is pressed" );
```

```
img = loadImage( "bird.png" );
```

```
println( "mouse is pressed" );
```

String literals

```
img = loadImage( "bird.png" );
```

Special characters

And now the leather-covered sphere came hurtling through the air,
And Casey stood a-watching it in haughty grandeur there.
Close by the sturdy batsman the ball unheeded sped—
“That ain’t my style,” said Casey. “Strike one!” the umpire said.

```
String lastline = ""That ain't my style," sai
```

Ernest Lawrence Thayer, *Casey at the Bat* (1888)

Special characters

Use the backslash \ to tell Processing about upcoming special characters.

```
char single_quote = '\'';    // Only in chars
String double_quote = "\""; // Only in strings
char newline = '\n';         // Like pressing return
char uni = '\u2603';         // 16-bit Unicode
```

Special characters

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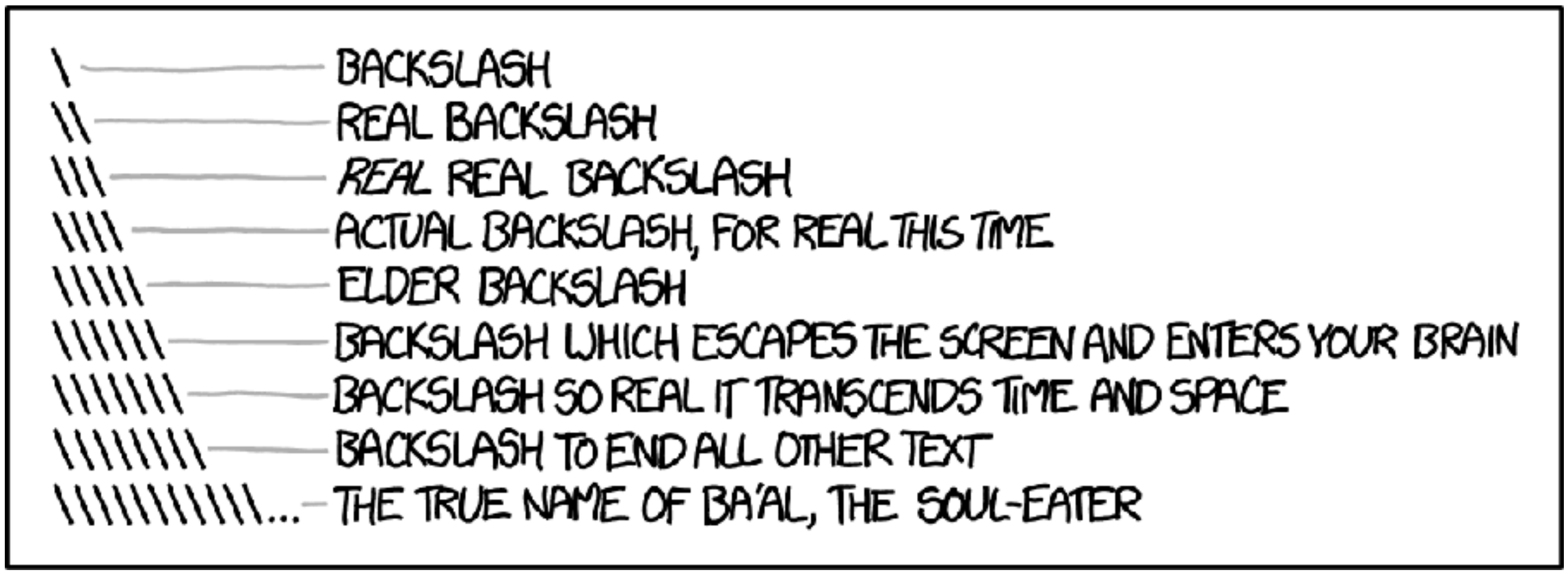
char single_quote = '\'';    // Only in chars
String double_quote = "\""; // Only in strings
char newline = '\n';         // Like pressing return
char uni = '\u2603';         // 16-bit Unicode
char backslash = '\\';
```



https://xkcd.com/1638/

```
String lines = "Close by the
    sturdy batsman the ball
    unheeded sped—\n\"That ain't my
    style,\" said Casey. \"Strike
    one!\" the umpire said.";
```

This would be one long line in your program!

Strings are just values

```
String str1 = "Hello";
String str2 = str1;

String processString( String str, float val )
{
   …
}

String str3 = processString( str1, 3.14 );

String[] columns = { "Doric", "Ionic", "Corinthian" };
```

`String` **vs.** `char[]`

Strings *wish* they were arrays of characters, but they aren't quite. Still, your knowledge of arrays will help you.

```
char[] wd = {…};
```

```
char[] wd = {'h','e','l','l','o'};
```

```
String wd = "…";
```

```
String wd = "hello";
```

`String` **vs.** `char[]`

Strings *wish* they were arrays of characters, but they aren't quite. Still, your knowledge of arrays will help you.

```
char[] wd = {…};
int len = wd.length;
char c = wd[2];
wd[4] = '!';
```

```
String wd = "…";
```

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```
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int len = wd.length;
char c = wd[2];
wd[4] = '!';
```

```
String wd = "…";
int len = wd.length();
```

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```
char[] wd = {…};
int len = wd.length;
char c = wd[2];
wd[4] = '!';
```

```
String wd = "…";
int len = wd.length();
char c = wd.charAt(2);
```

`String` **vs.** `char[]`

Strings *wish* they were arrays of characters, but they aren't quite. Still, your knowledge of arrays will help you.

```
char[] wd = {…};
int len = wd.length;
char c = wd[2];
wd[4] = '!';
```

```
String wd = "…";
int len = wd.length();
char c = wd.charAt(2);
```

NOTHING!

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```
char[] wd = {…};
int len = wd.length;
char c = wd[2];
wd[4] = '!';
```

```
String wd = "…";
int len = wd.length();
char c = wd.charAt(2);
```

NOTHING!

Strings are *immutable*: once you create one, you can't change its contents. Instead, assign the variable to hold a new, different string.

`String` **vs.** `char[]`

Strings *wish* they were arrays of characters, but they aren't quite. Still, your knowledge of arrays will help you.

```
char[] wd = {…};
int len = wd.length;
char c = wd[2];
wd[4] = '!';
```

```
String wd = "…";
int len = wd.length();
char c = wd.charAt(2);
```

NOTHING!

```
char[] wd3 = concat( wd1, wd2 );
```

`String` **vs.** `char[]`

Strings *wish* they were arrays of characters, but they aren't quite. Still, your knowledge of arrays will help you.

```
char[] wd = {…};
int len = wd.length;
char c = wd[2];
wd[4] = '!';
```

```
String wd = "…";
int len = wd.length();
char c = wd.charAt(2);
```

NOTHING!

```
char[] wd3 = concat( wd1, wd2 );
```

```
String str3 = str1 + str2;
```

Concatenating strings

The + operator on strings is very flexible.

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```
"Call me" + " " + "Ishmael."
```

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```
"Call me" + " " + "Ishmael."
"Ours go to " + 11
```

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```
"Call me" + " " + "Ishmael."
"Ours go to " + 11
"The value of PI is " + PI
```

Concatenating strings

The + operator on strings is very flexible.

```
"Call me" + " " + "Ishmael."
"Ours go to " + 11
"The value of PI is " + PI
"A " + true + " or " + false + " question"
```

Concatenating strings

The + operator on strings is very flexible.

```
"Call me" + " " + "Ishmael."
"Ours go to " + 11
"The value of PI is " + PI
"A " + true + " or " + false + " question"
float x, y;
"The point is at (" + x + ", " + y + ")"
```

Parsing strings

We often obtain “raw text” from external sources, and need to *parse* it into meaningful data.

The built-in functions `int()` and `float()` work on strings and arrays of strings.

```
int a = int( "1234" );
float b = float( "567.89" );

String[] strs = { "-81", "0", "36" };
int[] arr = int( strs );
```

String equality

We often want to compare two strings to see whether they have the same text. The `String` class has an `equals()` method for that purpose.

```
if( str1.equals( str2 ) ) {
  // The strings are equal.
}
```

String equality

We often want to compare two strings to see whether they have the same text. The `String` class has an `equals()` method for that purpose.

```
if( str1.equals( str2 ) ) {
  // The strings are equal.
}
```

WARNING! The following is legal code, but probably not what you want.

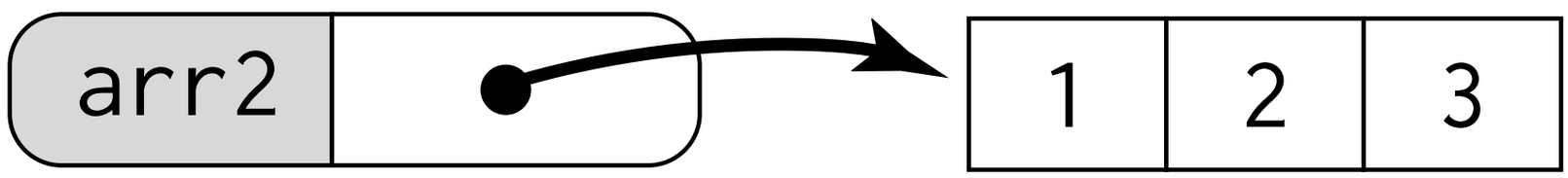
```
if( str1 == str2 ) ) {
  // What can go wrong?
}
```

```
int[] arr1 = { 1, 2, 3 };
int[] arr2 = { 1, 2, 3 };

if( arr1 == arr2 ) {
   ...
}
```

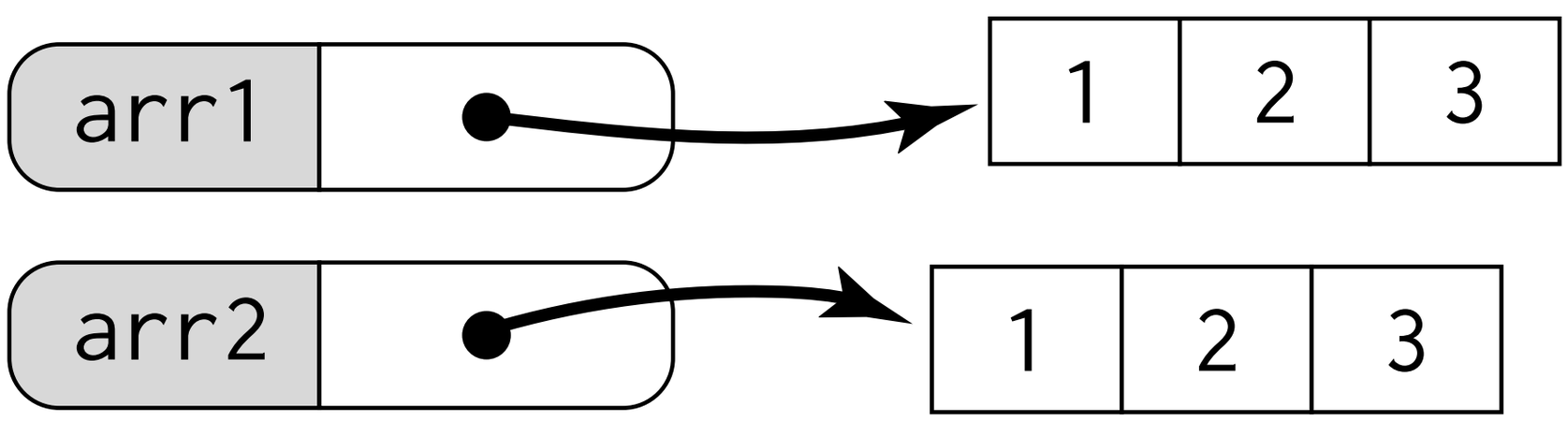
```
int[] arr1 = { 1, 2, 3 };
int[] arr2 = { 1, 2, 3 };

if( arr1 == arr2 ) {
   ...
}
```



```
int[] arr1 = { 1, 2, 3 };
int[] arr2 = { 1, 2, 3 };

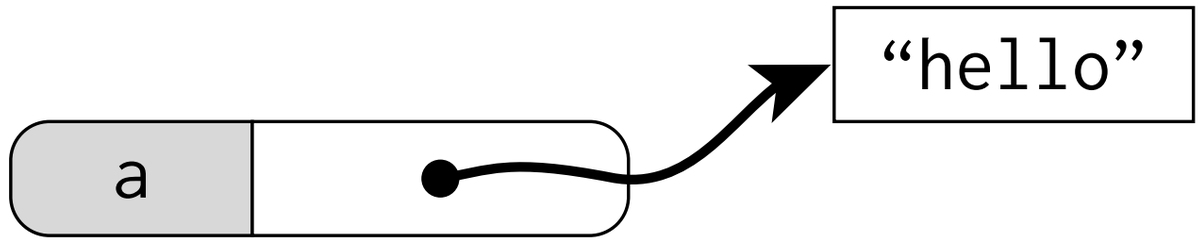
if( arr1 == arr2 ) {
   ...
}
```



Processing compares the *arrows*, not the arrays themselves.

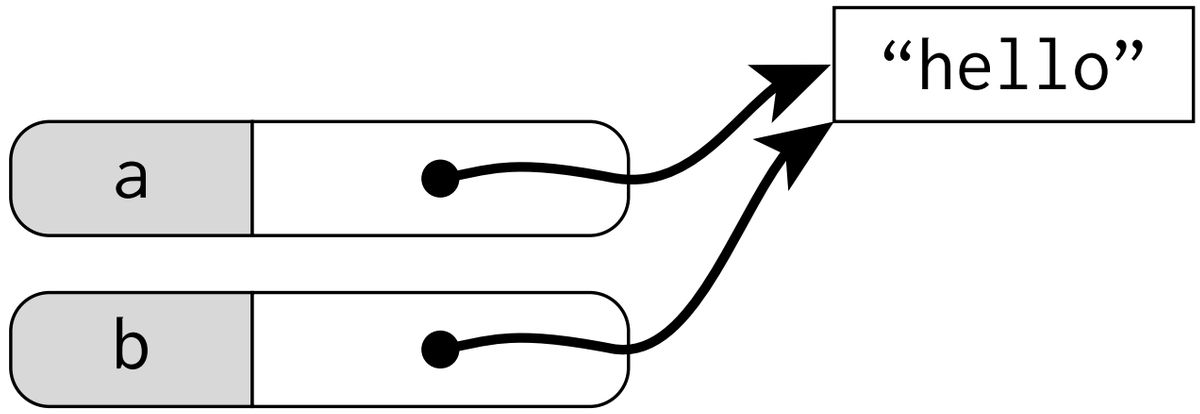
```
String s = "He";
println( "Hello" );
println( s + "llo" );
println( "Hello" == (s+"llo") );
```

```
String a = "Hello";
String b = a;
```



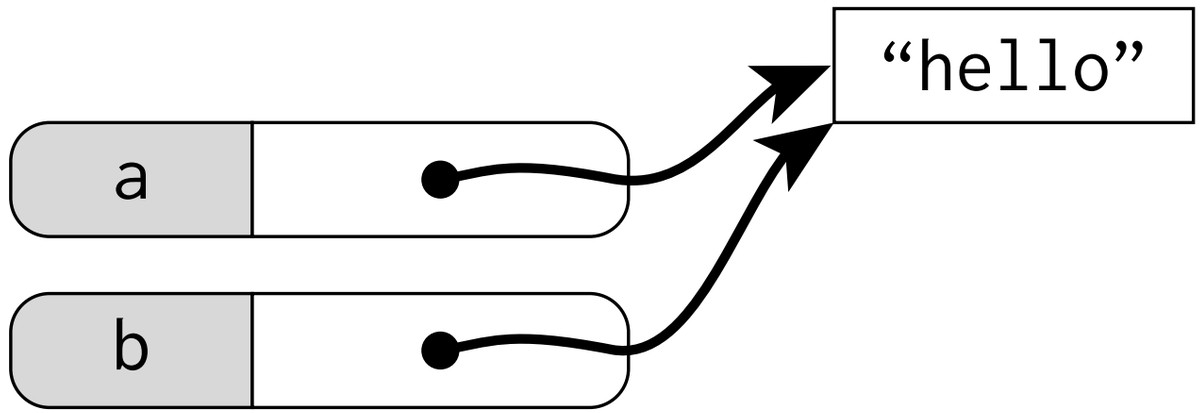

```
String a = "Hello";
String b = "Hello";
```

```
String a = "Hello";
String b = a;
```




```
String a = "Hello";
String b = "Hello";
```

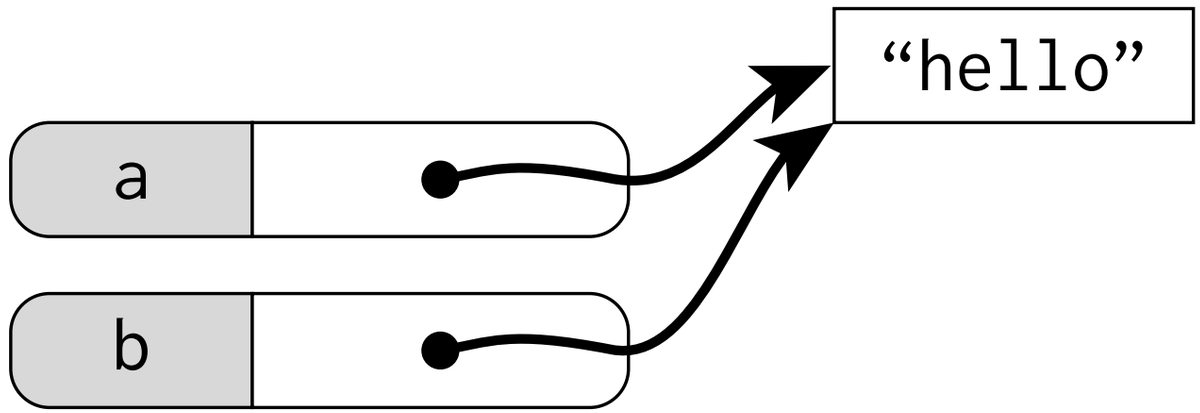
```
String a = "Hello";
String b = a;
```




```
a.equals( b ) ✓
a == b ✓
```

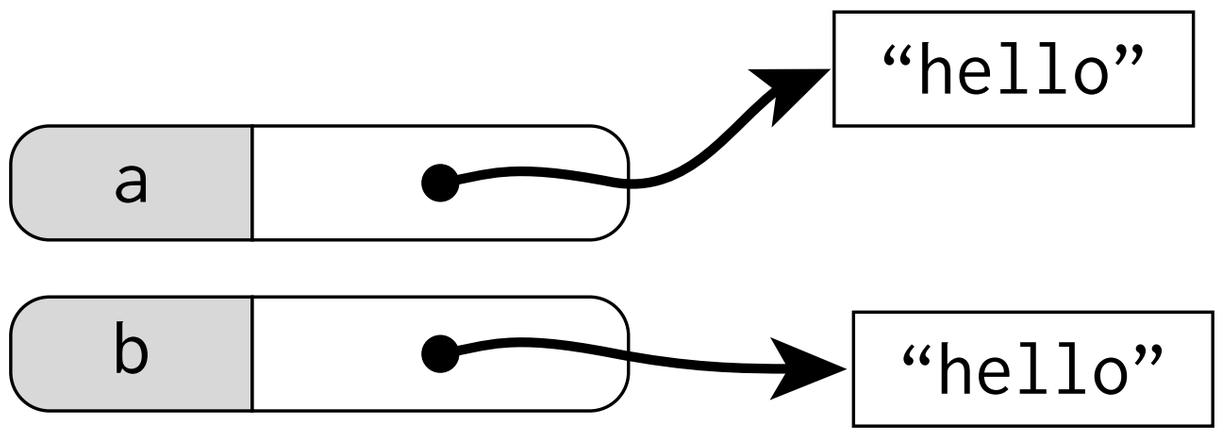
```
String a = "Hello";
String b = "Hello";
```

```
String a = "Hello";
String b = a;
```

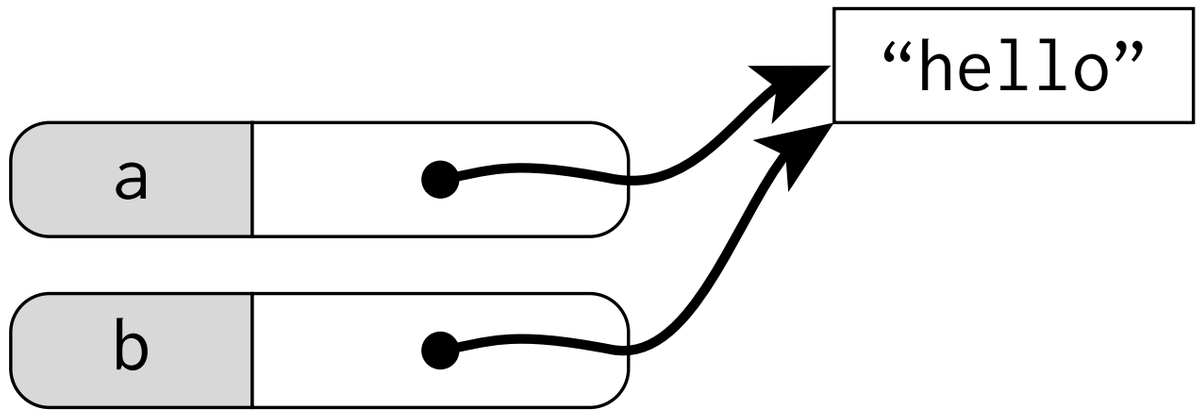



```
a.equals( b ) ✓
a == b ✓
```

```
String a = "Hello";
String b = "Hello";
```

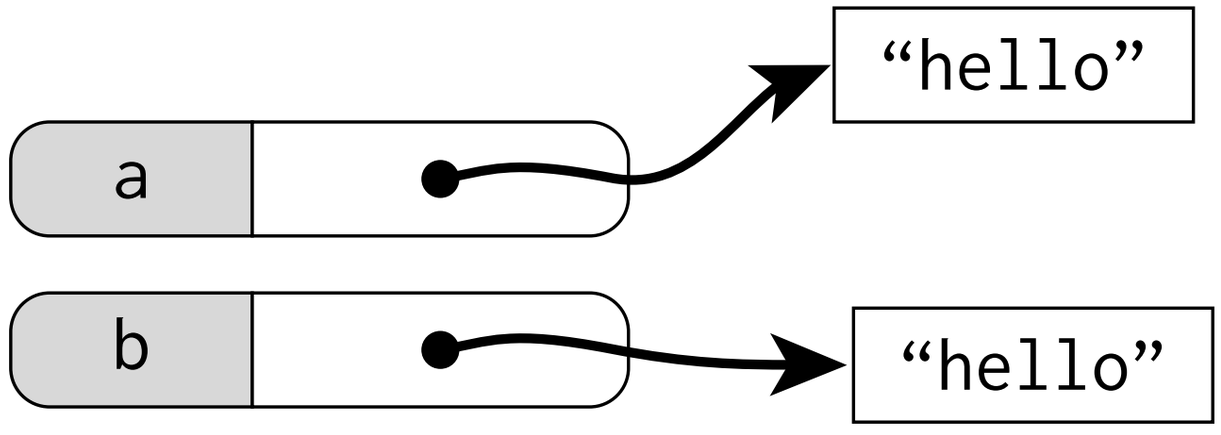


```
String a = "Hello";
String b = a;
```




```
a.equals( b )
a == b
```

```
String a = "Hello";
String b = "Hello";
```




```
a.equals( b )
a == b
```

The `.equals()` method checks if two strings have the same characters.

The == operator checks if they're the same string in the computer's memory.

(A bit like == vs. === in Javascript?)

Outputting text

The built-in `println()` function will write any text (or really, any value at all) to the console. Handy for debugging!

The built-in `text()` function will draw text at a given position in the sketch window, using the current fill colour.

See also `textSize()`, `textFont()`, `createFont()`, `textAlign()`.

```
void setup()
{
  size( 275, 400 );
  textSize( 72 );
  colorMode( HSB, 255 );
  background( 0, 0, 255 );
  for ( int y = 80; y < 380; y += 15 ) {
    fill( map( y, 80, 380, 0, 255 ),
      255, 255 );
    text( "CS 106", 10, y );
  }
}
```