CS 211 - Spring 2008

- very quick overview of Java basics
- actually use inheritance and interfaces
- intro to threads
- GUIs
- recursion/induction, efficiency, sorting
- data structures (lists, queues, stacks, trees, etc)
- graph algorithms
- applications
- LOTS of programming !

Books etc.

- at java.sun.com

/reference/api

/docs/books/tutorial

- IDE from www.eclipse.org

- The Java Language Specification (Gosling et al)

- Data Structures and Algorithm Analysis in Java (Weiss)

- Java ⟶ uses classes and objects = hyperorganised !

- A class Car is like a manufacturer who only constructs individual new cars.

- A class Bucket will only construct individual new buckets.

- Cars and buckets have natural things which belong to every car or bucket, although of course cars have different colours, etc.!

- To build a red car called ferrari, we might write

  Car ferrari = new Car(red);

  - I'm not promising that this will work!!!!

  and to build a yellow car called ccbb, we might write

  Car ccbb = new Car(yellow);

  Of course,

  Bucket rollsroyce = new Bucket(huge);

  will only give you a peculiarly named huge bucket.

- If you want to access stuff in your car, then the dot . is the "genitive case", so ferrari.colour would be red, and ccbb.colour would be yellow. This is also like a path; looking into the ferrari or the ccbb to find the individual colours.

More on this later .....

- Enough of such generalities! How do we write a simple program in Java?

- First we need to be able to get stuff in to and out from the computer!

```
System.out.println ( "Once upon a time ..." ) ;
```

looks into the System where it finds an out, and looks into System's out where it finds a method (or function or routine) which can print a String of characters onto a fresh line on the standard output screen.

```
System.out.print ( "Golly gosh" ) ;
```

does exactly the same, except the method print doesn't finish with a "new line".

- To read in a String of characters from the standard input keyboard,

```
InputStreamReader nab = new InputStreamReader(System.in);
BufferedReader grab     = new BufferedReader(nab);
```

constructs a BufferedReader called grab so that

```
grab.readLine( );
```

reads a whole line of input.

- Java is a language of "let's pretend!", so grab is a virtual keyboard which has the ability (amongst other skills) of readLine( ) - all the other stuff is there to establish a connection between "make believe" and "reality".

- We can do the same thing with files,

```
FileReader secret = new FileReader ( "spy.oops" ) ;
BufferedReader james = new BufferedReader (secret) ;
```

constructs a BufferedReader called james so that

```
james.readLine( ) ;
```

reads a whole line of input from spy.oops. As a matter of common courtesy, you should

```
secret.close( ) ;
```

close the 'file' when you've finished with it! (If you need to specify a path for your file, you can have

```
= new FileReader ( "c:/money/penny/spy.oops" ) ;
```

or whatever is appropriate for your system.)

- Similarly,

```
FileOutputStream plop = new FileOutputStream ( "meow.t" ) ;
PrintWriter scribble = new PrintWriter ( plop ) ;
```

allows

```
scribble.println( "What big teeth you have!" ) ;
```

to write to the file meow.t , which again should be closed by

```
plop.close( ) ;
```

when finished with.

- Of course, we could have done the same thing when writing to the screen,

```
PrintWriter tube = new PrintWriter ( System.out , true ) ;
tube.println ( "How time flies!" ) ;
```

Here, tube is the name of the make believe computer screen.

- Now that we can get stuff into and out of the computer, let's actually write a program ...

- import java.io.* ; *// so that i/o stuff is available*

action starts HERE *in case of silliness*

```
public class PlayTime {
    public static void main (String [ ] args) throws Exception {
        InputStreamReader ca = new InputStreamReader(System.in) ;
        BufferedReader va    = new BufferedReader(ca) ;
        PrintWriter bon      = new PrintWriter(System.out , true) ;

        int x , y = 2 ;

        bon.println( "Enter an integer." ) ;
        x = Integer.parseInt(  va.readLine( )  ) ;
        y = y * x - x / 2 ;

        bon.println( "x was " +x+ " and y is " +y ) ;
        ca.close( ) ;
    } // end of main method
} // end of class PlayTime
```

flushes the pipe

- This whole file would be called PlayTime.java and 'compiled' and run as relevant to your computer system.

Now for some routine details ...

- Primitive Types

byte	-128 <= integer <= 127	
short	-32768 <= " <= 32767	*These have some amusing consequences!*
int	-2^31 <= " <= 2^31 - 1	
long	-2^63 <= " <= 2^63 - 1	
float	+- 2^-149 < decimal < (2^24 - 1)2^104	
double	+- 2^-1074 < " < (2^53 - 1)2^971	
char	unicode \u0000 to \uffff , i.e. 0 to 65535	
boolean	false , true	

(Float and double are described in IEEE 754, cf java.sun language spec 4.2.3)

- The declaration

  int boo;

  makes boo an allowable name for an integer. The declaration and initialisation

  int boo = 13074;

  be careful that = is really assignment, not 'equals'

  makes boo an allowable name for an integer, and before it can be used, initialises its value to 13074.

- Similarly we can have

  double whoosh = 9.874;
  char cuckoo = 'A';
  boolean ouch = false;

Awkward characters like ? or ' can be assigned using \ as in

cuckoo = '\?' ;
cuckoo = '\'' ;

- Arithmetic

+	plus	3 + 4 ;	→ 7
-	minus	3 - 4 ;	→ -1
*	times	3 * 4 ;	→ 12
/	divide	3 / 4 ;	→ 0
%	remainder	3 % 4 ;	→ 3

What do you think (-3) % 4 ; evaluates to?

As an aside, it's worth noting that there is a non-primitive type String which carries a string of characters, and

```
String tut = "Methought I was," ;
String um = " there is no man ..." ;
tut = tut + um ;
```

gives tut the updated value of

Methought I was, there is no man ...

So for strings, + appends the second string to the end of the first string.

- Also, for those who like calculating ...

```
Math.sin(1.78) ;
Math.atan(72.4) ;    etc.
```

all do the obvious. Math is a repository of lots of useful stuff!

- Now for an example ...

- import java.io.* ;

```
public class Multiplier {
    public static void main ( String [ ] args ) throws Exception {
        InputStreamReader isr = new InputStreamReader ( System.in ) ;
        BufferedReader comingIn = new BufferedReader ( isr ) ;
        PrintWriter goingOut = new PrintWriter ( System.out , true ) ;

        int x , y ; // space to store input
        long z = 0 ; // bigger space for answer!
        String ask = "Please enter an integer." ; // may as well be polite!

        goingOut.println ( ask ) ;
        x = Integer.parseInt ( comingIn.readLine( ) ) ;
        goingOut.println ( ask ) ;
        y = Integer.parseInt ( comingIn.readLine( ) ) ;

        z = x * y ;

        goingOut.print ( "The value of " +x+ " times " +y ) ;
        goingOut.println ( " is " +z ) ;
        goingOut.println ( "Thanks for using \"Multiplier\".  Do come again!" ) ;
        comingIn.close( ) ;
    } // end of main method
} // end of class Multiplier
```

setting up the i/o

getting the first number

getting the next number

actually PERFORM the multiplication!!!

giving out the answer

unremitting courtesy!

- There are also various 'shorthands' ...

```
                        int a , b ;
                        a = 17 ;
a = a + 12 ;            a += 12 ;     ⟶   a ↔ 29
a = a - 4 ;             a -= 4 ;      ⟶   a ↔ 25
a = a * 3 ;             a *= 3 ;      ⟶   a ↔ 75
a = a / 5 ;             a /= 5 ;      ⟶   a ↔ 15
a++ .... a = a + 1      b = 2 * ( a++ ) ;  ⟶  a ↔ 16   and  b ↔ 30
a-- ... a = a - 1       a = 4 * ( ++b ) ;  ⟶  a ↔ 124  and  b ↔ 31
                        a-- ;         ⟶   a ↔ 123
                        --b ;         ⟶   b ↔ 30
```

- Type conversion is also very handy ...

```
int a = 73 , b = 10 ;
double c ;
c = a / b ;  ⟶   c ↔ 7
c = ( double ) a / b ;  ⟶  c ↔ 7.3
```

precedence ... anon double variable

- Comparisons

a == b	a < b	a > b
a != b	a <= b	a >= b

These have the obvious meaning for the primitive types.

- Logic

A && B	AND	A & B
A || B	OR	A | B
! A	NOT	

So for example, A != B and !(A == B) are equivalent. The difference between & and && (similarly for | and ||) relies on "short-circuiting".

(3 == 7) && (2 == 3/0)

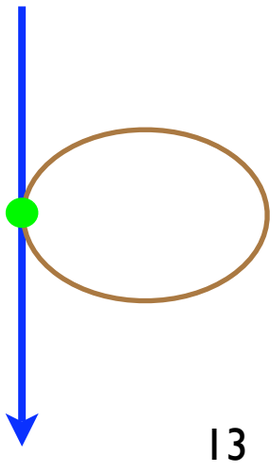
evaluates comfortably to false, since failure occurred in the first term there was no need to go further, but

(3 == 7) & (2 == 3/0)

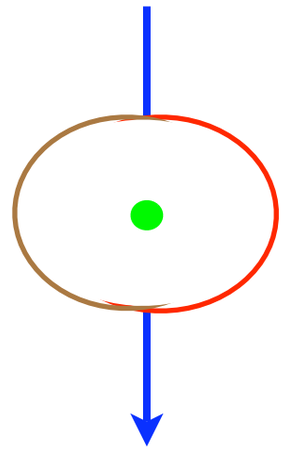
is a disaster, since the single ampersand has no short-circuit provision. Typically we use the 'single' flavour when we need to ensure that each term of the expression is evaluated, such as when incrementing variables.

- Control
  - if (.....)
    { ---------- }

Branching processes

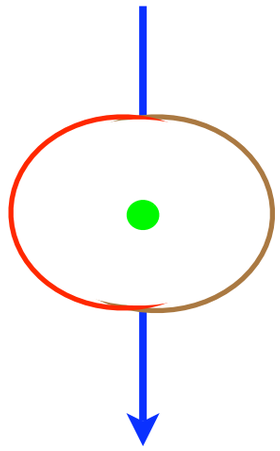


  - if (.....)
    { ---------- }
    else
    { ---------- }

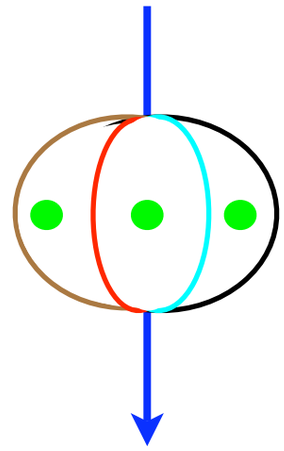


- ----- ? ----- : ----- ;

More branching processes

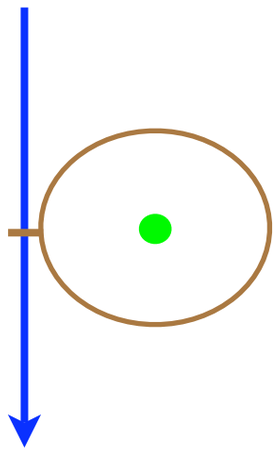


- switch (name) {
  case value : ----- break ;
  case value : ----- break ;
  case value : ----- break ;
  default : -----
  }

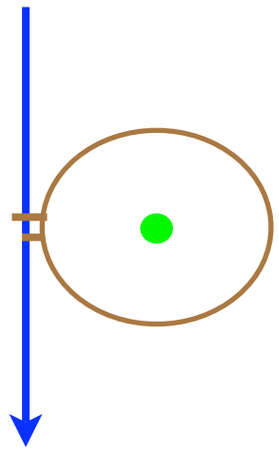


- while (.....)
  { ---------- }

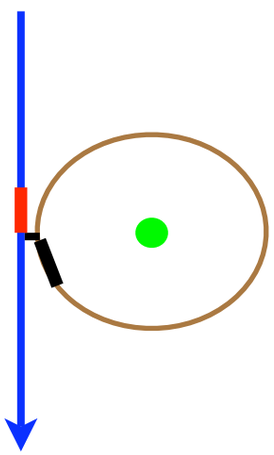
Looping processes



- do
  { ---------- }
  while (.....) ;



- for (----- ; ..... ; -----)
  { ---------- }



We can now broaden our previous example ...

-
```
import java.io.* ;

public class Arithmetic {
    public static void main ( String [ ] args ) throws Exception {
        InputStreamReader isr = new InputStreamReader ( System.in ) ;
        BufferedReader comingIn = new BufferedReader ( isr ) ;
        PrintWriter goingOut = new PrintWriter ( System.out , true ) ;

        char op ; // space to hold a character representing some arithmetic operator
        int x , y ; // space to store input
        double answer = 0 ; // space for answer, possibly decimal because of division!
        String ask = "Please enter an " ; // more generic this time -- notice the space for legibility

        goingOut.println ( ask + "integer." ) ;
        x = Integer.parseInt ( comingIn.readLine( ) ) ;
        goingOut.println ( ask + "operator.") ;
        op = ( comingIn.readLine( ) ).charAt(0) ;
        goingOut.println ( ask + "integer.") ;
        y = Integer.parseInt ( comingIn.readLine( ) ) ;

        switch ( op ) {
            case '+' : answer = x + y ; break ;
            case '-' : answer = x - y  ; break ;
            case '*' : answer = x * y  ; break ;
            case '/' : answer = y != 0   ?   x / y   :   Double.NaN ;      break ;
            default : goingOut.println( "Sorry, I didn't understand what you meant ... bye-bye!" ) ; answer = Double.NaN ;
        } // end switch statement interpreting the arithmetic operation to be performed

        goingOut.println ("The value of " +x+ " " +op+ " " +y+ " is " +answer) ;
        goingOut.println ("Thanks for using \"Multiplier\".  Do come again!" ) ;
        comingIn.close( ) ;
    } // end of main method
} // end of class Arithmetic
```

- Delegation - There are times when it's sensible to delegate certain tasks within a program. Javaspeak for this is methods (alias functions or subroutines). For example ...

```
public class Stats {
    public static void main ( String [ ] args ) {
        int a = 7 , b = 12 , c = 24 ;
        double d ;

        d = avg ( a , b ) ;
        System.out.println ( "The average of " +a+ " and " +b+ " is " +d+ "." ) ;
        System.out.println ( "Including" +c+ " changes this to" + avg( a , b , c ) + "." ) ;
    } // end of main method

    public static double avg ( int x , int y ) {
        return ( x + y ) / 2.0 ;
    } // end of two-variable avg method

    public static double avg ( int x , int y , int z ) {
        return ( x + y + z ) / 3.0 ;
    } // end of three-variable avg method

} // end of class Stats
```

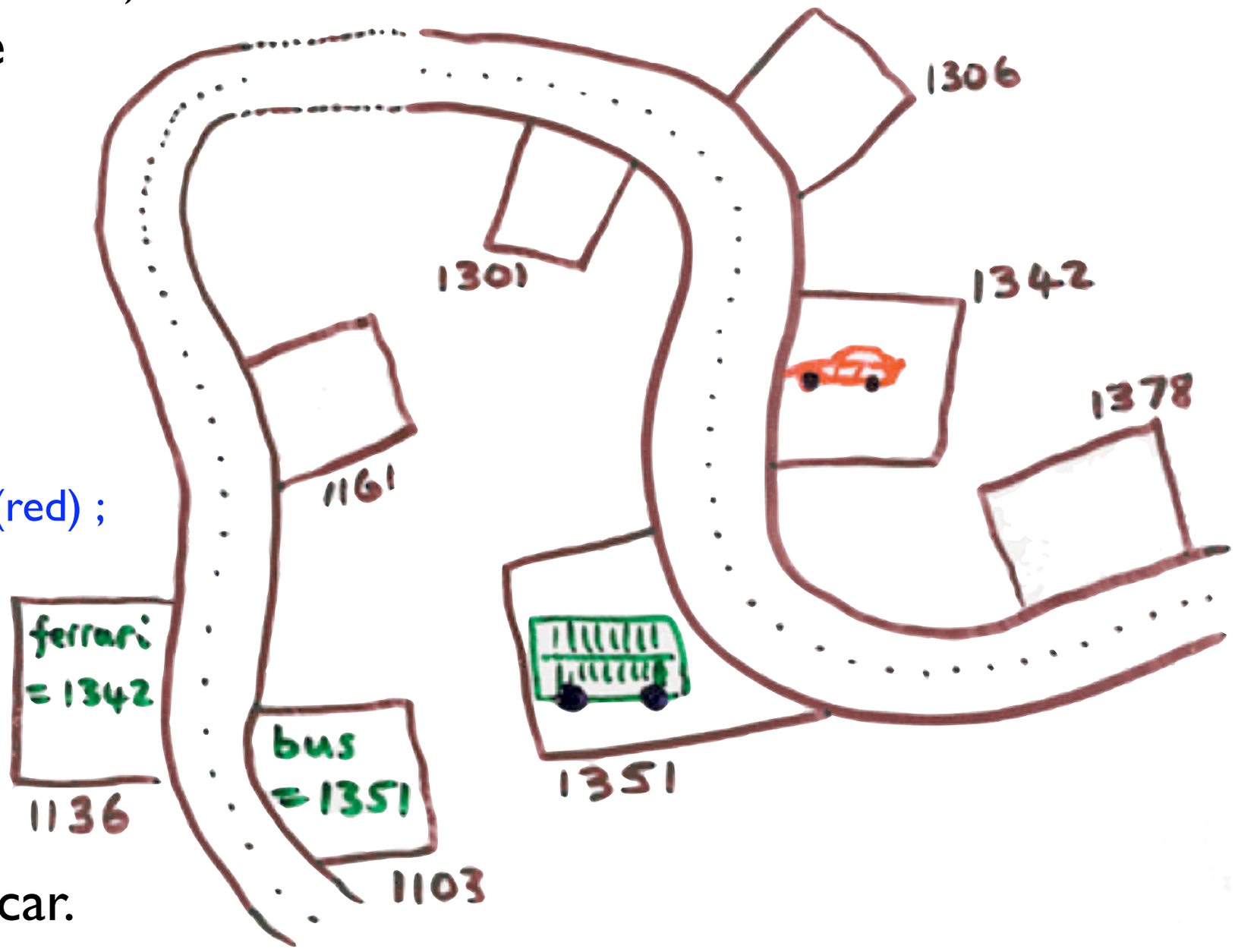
values copied

unambiguous

'overloading'

This is all playing with the thread of control, rather like passing the baton back and forth in a relay race.

- Types of types - For the primitive types, actual values are copied and passed. For any other 'types', since Java doesn't really know how big they might be, instead of copying/passing whatever constitutes value, Java copies/passes the address/reference to the object, leaving the object wherever it happens to sit in memory. Indeed ...



Car ferrari = new Car(red) ;

does not make ferrari the actual car; it makes instead ferrari the address of the actual car.

Car bus = new Car(green) ;

- This leads to various consequences ...

```
Hat cheap = new Hat (white) ;
Hat riding = new Hat (black) ;
```

Then

```
Hat tasteless = new Hat (white) ;
```

gives us two white hats, but

```
cheap != tasteless
```

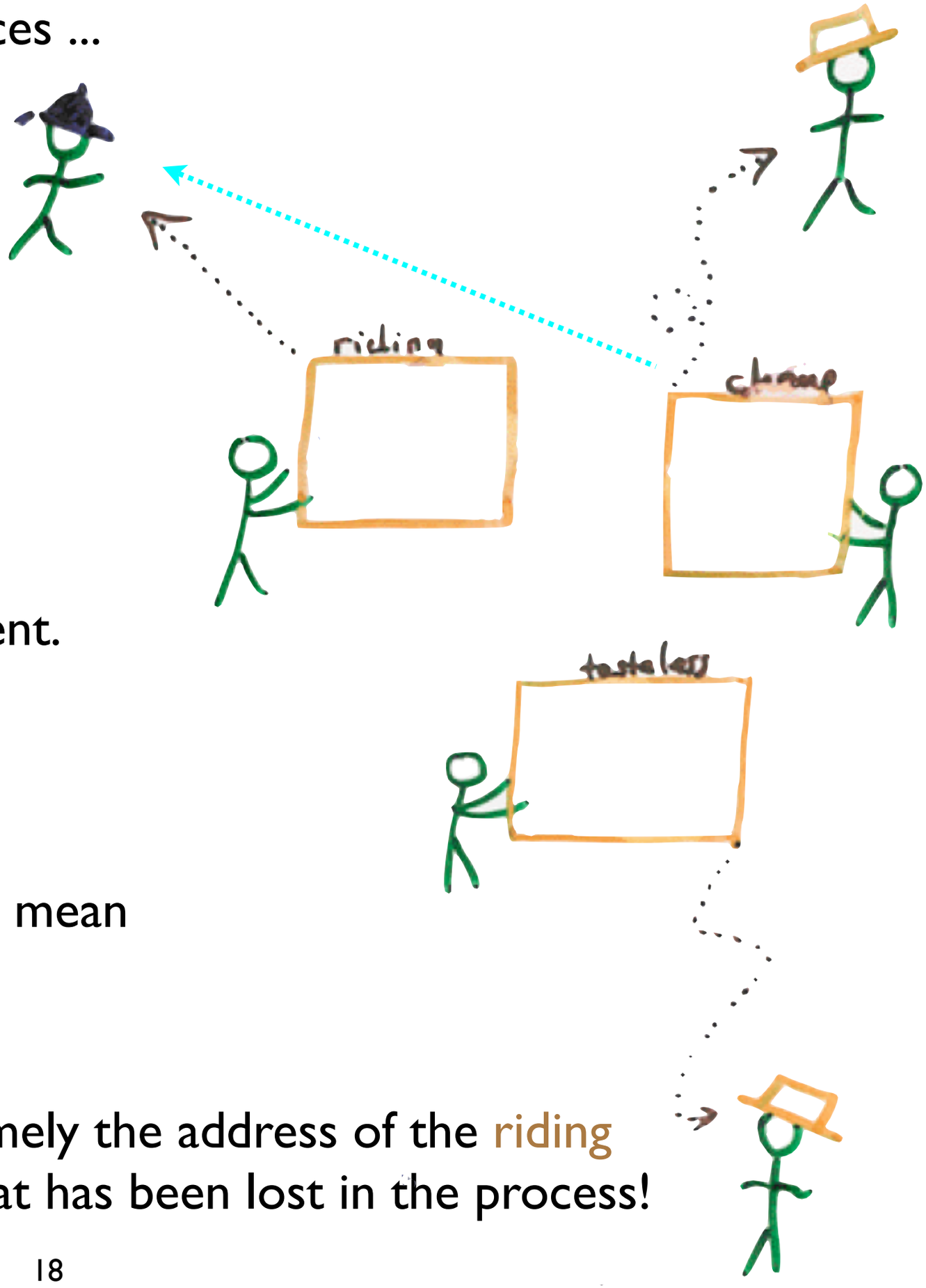
because the addresses are different.
However,

```
cheap = riding ;
```

makes the changes in cyan which mean

```
cheap == riding
```

both being the same address, namely the address of the riding hat ... the address of the cheap hat has been lost in the process!



- This raises the obvious question of what address a reference holds if it's not currently referencing any particular object. The answer is

  null

  If this situation is not picked up by the compiler, but only noticed at run-time, then we can easily get the common error message

  NullPointerException

  if we attempt to access that object's properties, i.e., a reference had been declared but not assigned the address of an actual existent object.

- It's also worth noting that once an object is no longer being referenced, as in cheap after the assignment cheap = riding ; Java allows the memory allocated to the object cheap to be written over (whenever that may happen) ... this is called automatic garbage collection.

- A reference cannot reference a primitive variable (hence the existence of wrapper classes like Integer, Double, Character, Boolean, etc.).

- As a final comment in this vein, suppose

```
yummy ( rhubarb ) ;
```

is a call to a method yummy with declaration

```
public int yummy ( ------ custard ) { ..... }
```

then if ------ is a primitive type the variable custard copies the value of rhubarb, but if ------ is a reference type then custard points to the same object that rhubarb does.

- We should observe that in

```
Car ferrari  =  new Car (red) ;
```

the word new creates an anonymous object according to the manufacturer class Car which has been told explicitly to make it red; the phrase Car ferrari makes ferrari an allowable reference to a Car-like object; finally the = assigns the address of the anonymous car to the name ferrari !!!

- Strings - We've seen already that there is a non-primitive class String for which the operator + is defined by 'concatentation'. Some other things about the String class are worth listing ...

```
String vide = "" ; // no space between the pair of double quotes
```

creates vide as an empty String. Be aware that 'a' is a single character whereas "a" is a String with length one, and that char is a primitive but String is a reference type, so they cannot be the same.

Be aware also that using == and != to compare Strings will probably* fail as with other reference types ... they refer to addresses not values. To test value, use either

```
trois.equals (two)   ⟶   true , false
```

or

```
                                  trois   <      =      >   two
trois.compareTo (two)  ⟶  neg integer , 0 , pos integer
```

Formally the compareTo( ) method comes from the Comparable interface, about which we'll hear more later.

- Other String tricks are ...

```
myriad.length( ) ;
```

which if the String myriad is "Did I blink?" returns the integer value 12, and ...

```
myriad.charAt ( 9 ) ;
```

which returns the character value 'n', since the count starts with D being in position 0 *not* 1 !! Also ...

```
myriad.substring ( 2 , 9 ) ;
```

returns the String "d I bli" , since the method counts from the first location number (included) to the last one (excluded).

Any primitive type can be converted to a String by, for example,

```
Integer.toString ( 9746 ) ;
```

which returns the String (really the reference to the String) "9746", so then if PI were to be defined in Math with the natural meaning, then

```
Double.toString ( Math.PI ) ;
```

would return the address of a horribly long String!

(It's worth looking at the API to see the various methods in the wrapper classes for the primitive types.)

- Some of the other useful String methods, assuming **s** has been initialised to be some String, include ...

s.toUpperCase( )	*returns the obvious new String*	s.toLowerCase( )	*returns the obvious new String*
s.charAt(7)	*returns the char at position 7*	s.indexOf('t')	*returns the position number of the first 't'*
s.length( )	*returns the length of s*	String.valueOf(91.6)	*returns the input as a String "91.6". Not just for numbers*
s.toCharArray( )	*returns an array of chars formed from s*	s.replace('t' , 'o')	*returns a new String by replacing all t's by o's in s*

Again, you should look up the String class in the API to see other methods and more detail.

- Finally, the following 'conversions' have equivalent effect ...

```
int n  =  Integer.parseInt ( "96" ) ;
int n  =  Integer.valueOf ( "96" ).intValue( ) ;
int n  =  new Integer ( "96" ).intValue( ) ;
```

For primitives other than byte, short, int, long , only the analogues of the last two forms work.

*(Filling in details from the * on slide 21, formally a String is an immutable object, but there are some oddities. If a String is initialised to a String literal by String wow = "gosh"; then "gosh" has a particular memory location, so String a = "gosh", b = "go"+"sh", tail = "sh"; make wow == a and wow == b both true since as String literals they will point to the same created String location. But if run-timing a String, as String c = new String("gosh"), d = "go"+tail, e = "go"+(true? "sh":"duh"); all of wow == c and wow == d and wow == e will be false, yet f = a.toString() gives a == f to be true. In all these cases the reference flavour of, for example, a.equals(d) will be true. So == can give surprising results!)*

- Arrays - arrays in Java are reference types, so

```
int [ ] boxes ;          or          int boxes [ ] ;
```

declares boxes to be the reference for an integer array which doesn't yet exist (so the value of boxes is null). To create, we of course use new ...

```
boxes  =  new int [2010] ;
```

which creates an anonymous array to hold *2010* integers pointed to by boxes (i.e., it holds the address of that array), which might be initialised by ...

```
for ( int i = 0 ; i < boxes.length ; i++ )  // so length is a property, not a method, for arrays
    boxes [ i ]  =  i * i % 12 ;  // or any other silly calculation you like!
```

Arrays of reference types are created similarly, though to avoid the dreaded NullpointerException , if our *array* were to be built by ...

```
Rhubarb [ ] holes  =  new Rhubarb [2010] ;  // an array ready to hold 2010 Rubarbs
```

then the initialisation might be ...

```
for ( int i = 0 ; i < holes.length ; i++ )  // just as with Strings, arrays start counting from 0
    holes [ i ]  =  new Rhubarb( i ) ;  // now there are some actual Rhubarbs there to access!
```

assuming that the class Rhubarb knows how to build with an integer i !

- Again, since arrays are references, be careful with = , == , and != . Of course, arrays are passed by reference into methods just like any other reference ... another standard source of errors.

- Two (and higher) dimensional arrays are handled similarly ...

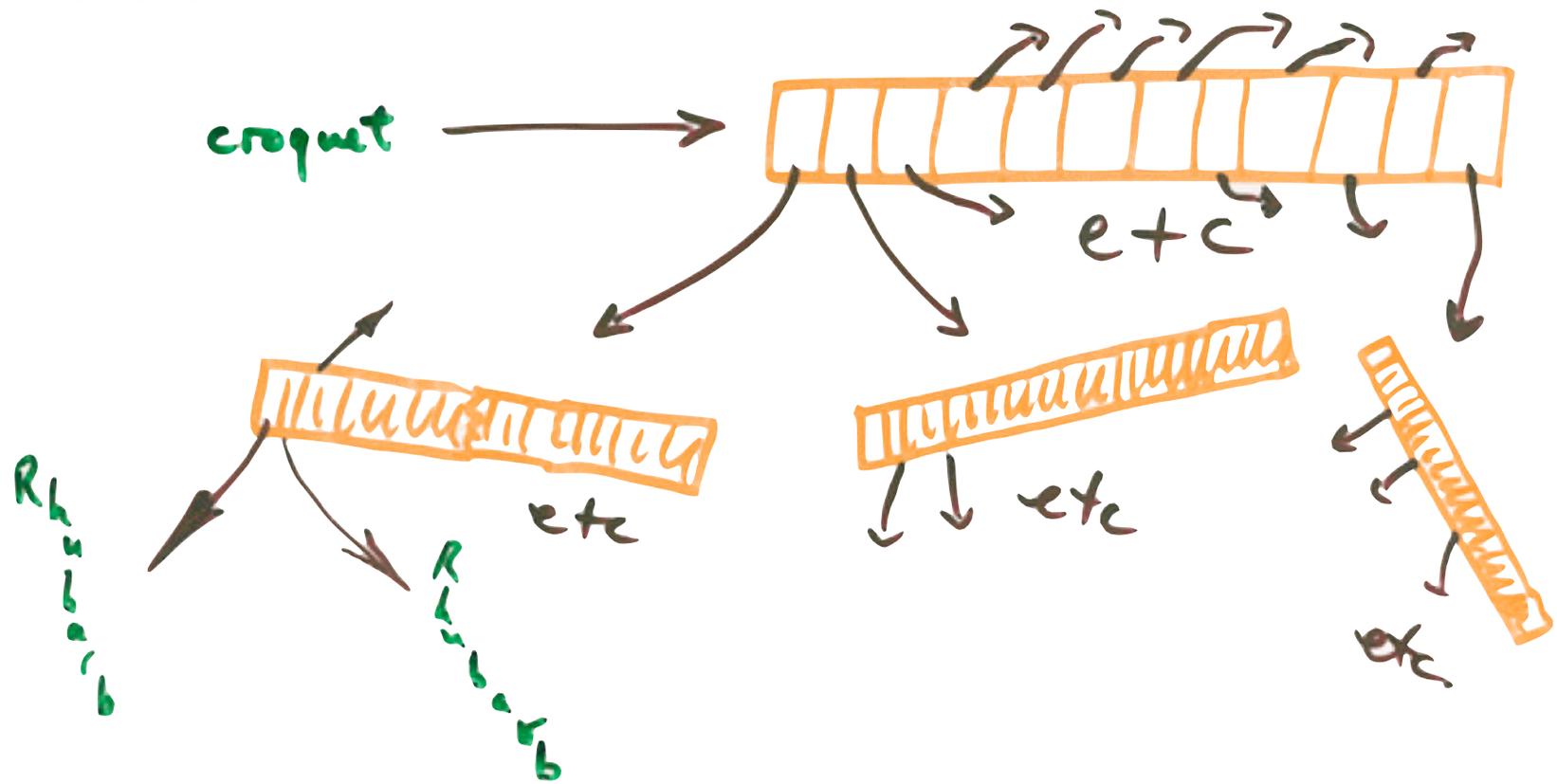
```
Rhubarb [ ] [ ] croquet ;
```

declares croquet to be the reference of a two dimensional array of Rhubarbs, and then ...

```
croquet  =  new Rhubarb [12][24] ;
```

creates an array prepared to hold two gross of Rhubarb, which then can be filled with any actually created (using new) actual Rhubarbs.

- It's worth noting that the above *two dimensional* array croquet is really treated as if it were a *one dimensional* array holding *12* objects, where each of these objects is a *one dimensional* array holding *24* actual addresses of Rhubarbs. So ...



- This means we can write ...

```
croquet  =  new Rhubarb [10][  ] ;
```

which makes croquet the reference of a two dimensional array of Rhubarbs which can be thought of as having *10* rows of as yet undetermined length (note that the computer has no real sense of rows vs columns!). Of course, the length of each row will have to be fixed (using new) before the rows can be filled ...

```
for ( int i = 0 ; i < croquet.length ; i++ ) {
    croquet [ i ]  =  new Rhubarb [ i * i + 1 ] ;
        for ( int j = 0 ; j < croquet[ i ].length ; j++ )
            croquet [ i ] [ j ]  =  new Rhubarb ( i + j ) ;
} // end outer for loop on i
```

assuming this makes sense for Rhubarbs!!

thus forming a *triangular* array!

Using this and similar tricks, we can size our arrays dynamically, though always being careful to remember that we're working with references. The concrete size of the array must be fixed before it's used.

- You must have wondered what the array args is used for in ...

```
public static void main ( String [ ] args ) { ..... }
```

It's designed to allow the use of command line arguments. So ...

```
public class Average {
    public static void main ( String [ ] args ) {
        double avg  =  0.0 ;

        if ( args.length != 0 ) {  // so this array has some size!
            for ( int i = 0 ; i < args.length ; i++ )
                avg  +=  Integer.parseInt ( args [ i ] ) ;
            avg  =  avg / args.length ;
            System.out.println ( "The average of the input values is " + avg ) ;
            }  // end if args array has any length
        else
            System.out.println ( "You didn't give me any numbers!" ) ;
    }  // end main method
}  // end class Average
```

This could be invoked by running the compiled program from a command line and typing ...

- Whilst we're on the topic of arrays, there's a nice way, using the split( ) method from the String class, to deconstruct strings into potentially convenient arrays of characters, which is worth a digression ...

- Suppose we've been given the string "Once upon a time 7 168" , and would like to break it up into 'words'. We could no doubt code this using a bunch of for loops and some careful checking of spaces (try it for fun!), but alternatively ...

```
String input  =  "Once upon a time trouble 7 168" ;
String [ ] outArray  =  input.split ( " " ) ;
```

will create the following array of Strings ...

Once	upon	a	time	trouble	7	168

If we wanted instead to separate the string by the letter 'o' instead of spaces, then ...

```
outArray  =  input.split ( "o" ) ;
```

gives the array ...

Once up	n a time tr	uble 7 168

Note that it ignored the upper case 'O'. Even more adventurous is ...

```
outArray  =  input.split ( "[bcir6]" ) ;
```

which yields ...

On	e upon a t	me t	ou	ble 7 1	8

thus separating it by any of the characters within the square brackets!

- This [bcir6] is an example of a regular expression. They form a convenient collection of tricks *(often rather arcane!)* for searching for patterns amongst strings of characters. Although you can read about them easily online, we'll give a short list of some of the more useful examples ...

`[ack7]`	*any of a, c, k, or 7*	`[a-dF-H5-8]`	*any of a, b, c, d, F, G H, 5, 6, 7, 8*
`[^tvW]`	*any char other than t, v, or W*	`[a-d[m-q]]`	*any of a, b, c, d, m through q*
`[a-z&&[^b-p]]`	*any of a through z except b through p*	`[be\d\s]`	*any of b, e, any digit, any space*
`\d`	*any digit (i.e., 0,1,2,3,4,5,6,7,8,9)*	`\D`	*any non-digit*
`\s`	*any space (also tab, newline, etc.)*	`\S`	*any non-space*
`\w`	*any word char (a-z, a-Z, 0-9, and _)*	`\W`	*any non-word char*
`.`	*any character! (but not newlines)*	`gr.t`	*"gr" then any char followed by t*
`a?`	*'a' exactly once or not at all**	`ra?t`	*either "rt" or "rat"*
`ra*t`	*"rt" or "rat" or "raat" or "raaat" etc.*	`ra+t`	*"rat" or "raat" or "raaat" etc.*
`ra{3}t`	*only "raaat" ... and ra{3,5}t allows 3-5 a's*	`rat(haus)?`	*"rat" or "rathaus" ... the ( ) groups things*

So, as an example ...

```
String junk = "this is a loooongish krazy string with gaziiliions of i's in it, gosh!" ;
String test = "[io]{1,2}\\w\\s.." ;  // notice the need for \\ to ensure that the '\' is 'seen'
String [ ] stuff = junk.split(test) ;
```