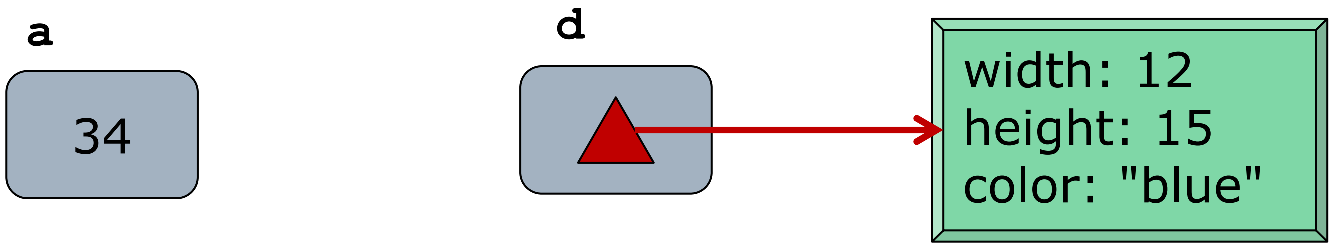
Ruby: Objects and Dynamic Types

Lecture 6

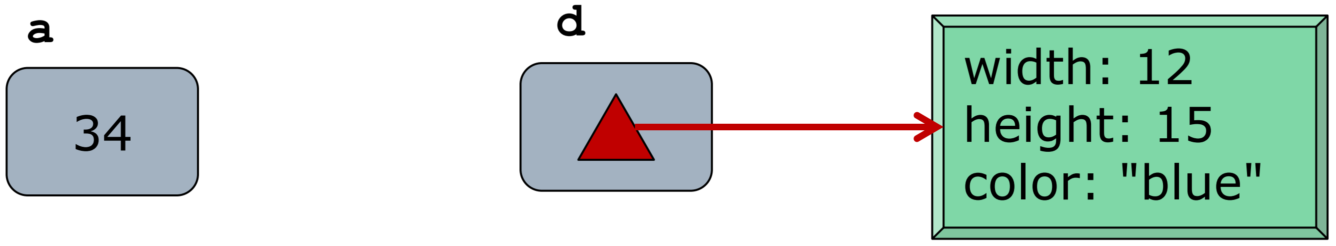
Primitive vs Reference Types

- Recall Java type dichotomy:
  - Primitive: int, float, double, boolean,…
  - Reference: String, Set, NaturalNumber,…
- A variable is a "slot" in memory
  - Primitive: the slot holds the *value* itself
  - Reference: the slot holds a *pointer* to the value (an object)



Object Value vs Reference Value

- Variable of reference type has *both*:
  - Reference value: value of the slot itself
  - Object value: value of object it points to (corresponding to its mathematical value)
- Variable of primitive type has *just one*
  - Value of the slot itself, corresponding to its mathematical value



Two Kinds of Equality

- Question: “Is x equal to y?”
  - A question about the *mathematical* value of the variables x and y
- In Java, depending on the type of x and y we either need to:
  - Compare the values of the *slots*

```
x == y // for primitive types
```

  - Compare the values of the *objects*

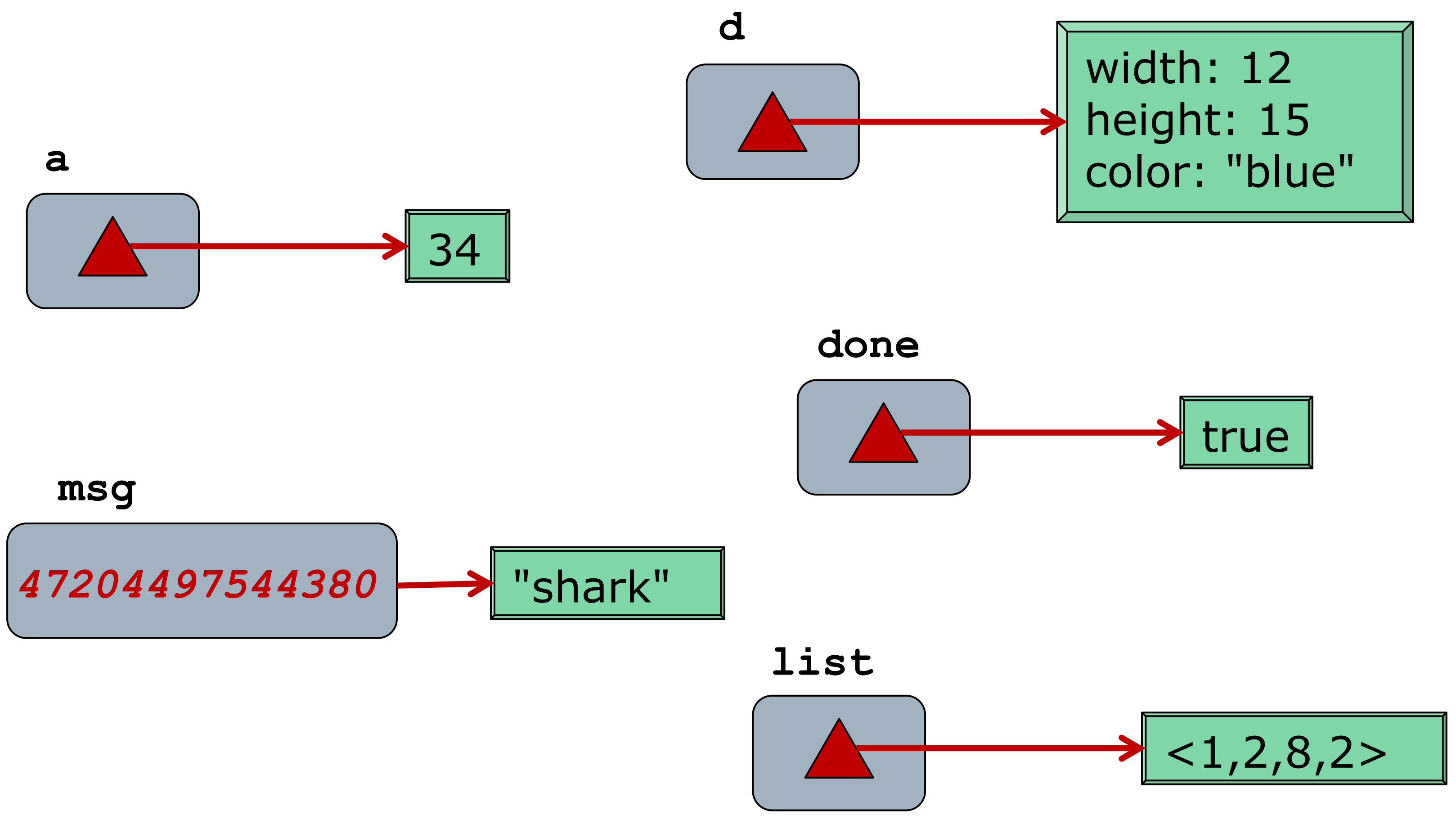
```
x.equals(y) // for non-primitive types
```

Ruby: "Everything is an Object"

- In Ruby, *every* variable maps to an object
  - Integers, floats, strings, sets, arrays, …
- Benefit: A more consistent mental model
  - References are *everywhere*
  - Every variable has *both* a reference value and an object value
  - Comparison of mathematical values is *always* comparison of object value
- Ruby terminology: Reference value is called the *object id*
  - The 4- or 8-byte number stored in the slot
  - Unique identifier for corresponding object

```
msg = "shark"
msg.object_id #=> 47204497544380
```

Everything is an Object



Operational Detail: Immediates

- For small integers, the mathematical value is *encoded in the reference value!*
  - LSB of reference value is 1
  - Remaining bits encode value, 2's complement

```
x = 0
x.object_id  #=> 1 (0b00000001)
y = 6
y.object_id  #=> 13 (0b00001101)
```

- Benefit: Performance
  - No change to model (everything is an object)
- Known as an “immediate” value
  - Other immediates: true, false, nil, symbols

Objects Have Methods

- Familiar "." operator to invoke (instance) methods

```
list = [6, 15, 3, -2]
list.size #=> 4
```

- Since numbers are objects, they have methods too!

```
3.to_s   #=> "3"
3.odd?   #=> true
3.lcm 5  #=> 15
3.+ 5 #=> 8
3.class  #=> Integer
3.methods #=> [:to_s, :inspect, :+, …]
```

Pitfall: Equality Operator

- Reference value is still useful sometimes
  - "Do these variables refer to the same object?"
- So we still need 2 methods:

```
x == y
x.equal? y
```

- Ruby semantics are the *opposite* of Java!
  - == is *object value* equality
  - .equal? is *reference value* equality
- Example

```
s1, s2 = "hi", "hi"
s1 == s2 #=> true (obj values equal)
s1.equal? s2 #=> false (ref vals differ)
```

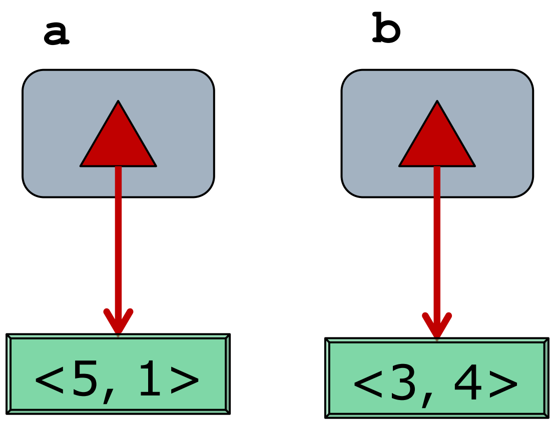
To Ponder

Evaluate (each is true or false):

```
3 == 3

3.equal? 3

"hello" == "hello"

"hello".equal? "hello"
```

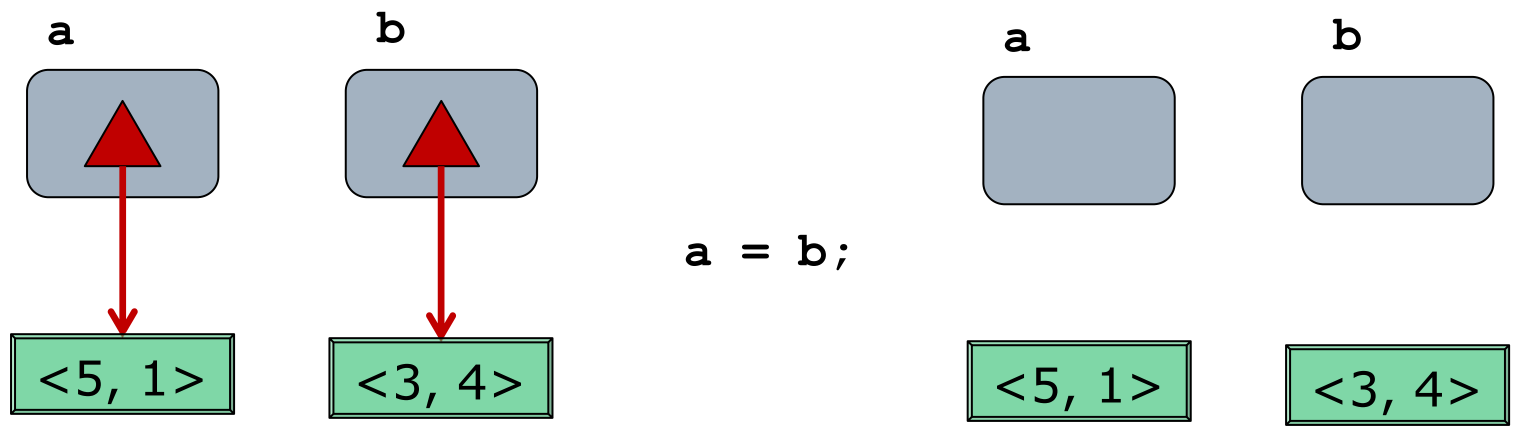
Assignment (Just Like Java)

- Assignment copies the *reference value*
- Result: Both variables point to the *same* object (ie an "alias")
- Parameter passing works this way too



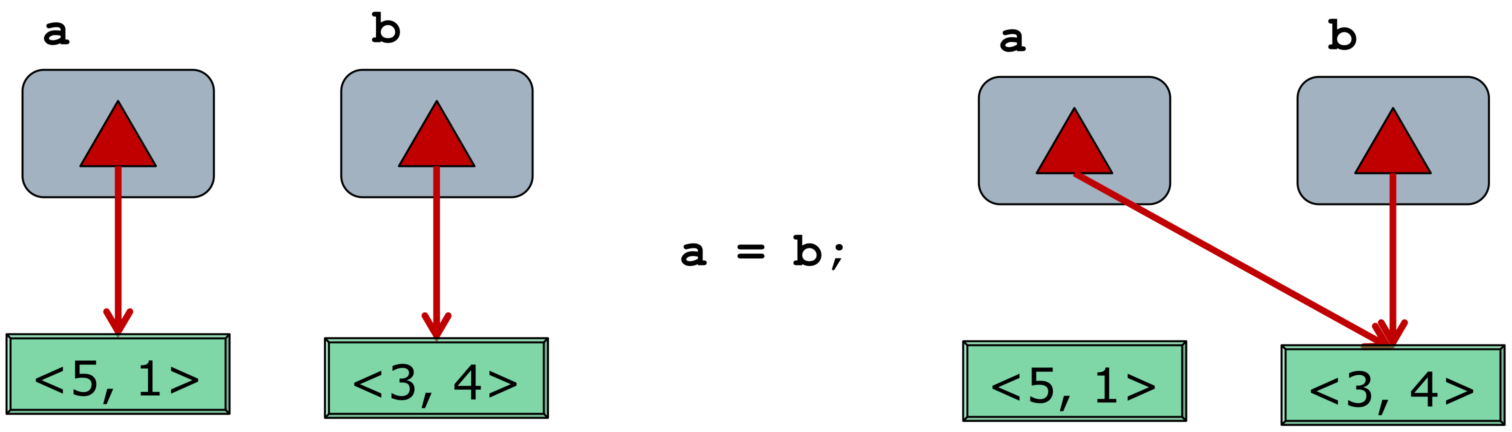
Assignment (Just Like Java)

- Assignment copies the *reference value*
- Result: Both variables point to the *same* object (ie an “alias”)
- Parameter passing works this way too



Assignment (Just Like Java)

- Assignment copies the *reference value*
- Result: Both variables point to the *same* object (ie an "alias")
- Parameter passing works this way too



Aliasing Mutable Objects

- When aliases exist, a statement can change a variable's object value without mentioning that variable

```
x = [3, 4]
y = x       # x and y are aliases
y[0] = 13 # changes x as well!
```

- Question: What about numbers?

```
i = 34
j = i       # i and j are aliases
j = j + 1 # does this increment i too?
```

Immutability

- Recall in Java strings are *immutable*
  - No method changes the value of a string
  - A method like concat returns a new instance
- Benefit: Aliasing immutable objects is safe
- Immutability is used in Ruby too
  - Numbers, true, false, nil, symbols

```
list = [3, 4]
list[0] = 13 # changes list's object value
             # list points to same object
n = 34
n = n + 1    # changes n's reference value
             # n points to different object
```

  - Pitfall: Unlike Java, strings in Ruby are *mutable*
  - But objects (including strings) can be "frozen"

Assignment Operators

- Parallel assignment
  ```
  x, y, z = y, 10, radius
  ```
- Arithmetic contraction
  - `+= -= *= /= %= **=`
  - Pitfall: no `++` or `--` operators (use `+= 1`)
- Logical contraction
  - `||= &&=`
  - Idiom: `||=` for initializing potentially nil variables
  - Pitfall (minor):
    - `x ||= y` not quite equivalent to `x = x || y`
    - Better to think of it as `x || x = y`
    - Usually amounts to the same thing

Declared vs Dynamic Types

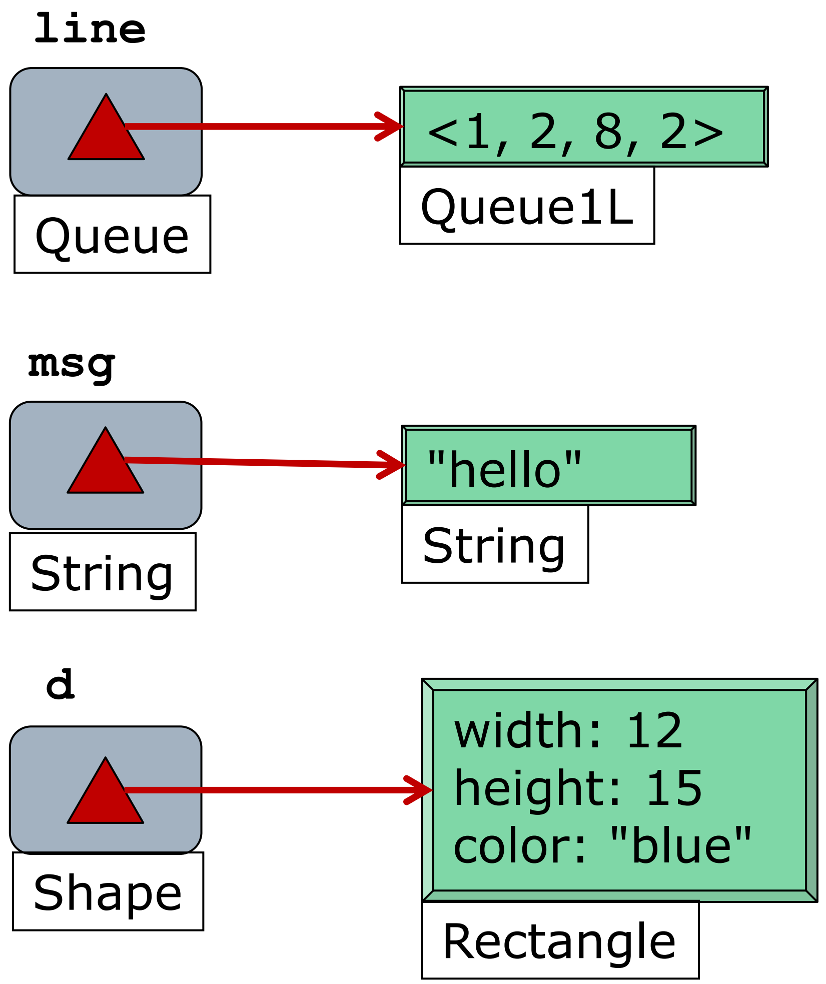
- In Java, types are associated with *both*
  - Variables (declared / static type), and
  - Objects (dynamic / run-time type)

```
Queue line = new Queue1L();
```

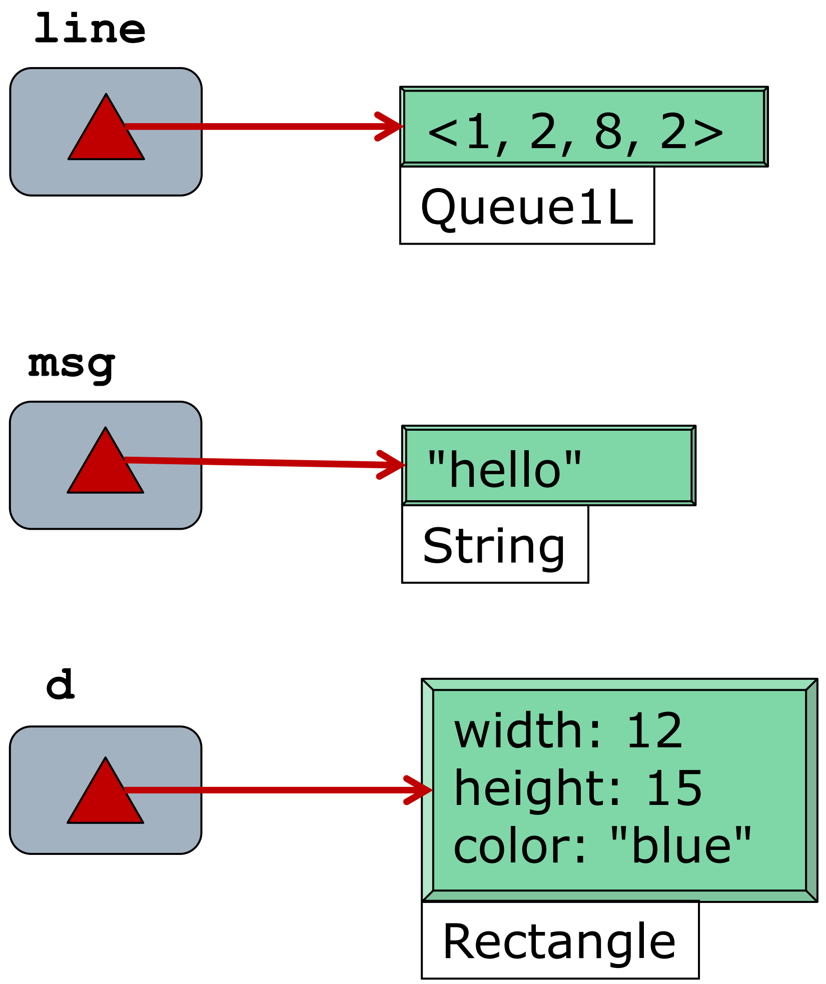
- Recall: Programming to the interface
- Compiler uses *declared* type for checks

```
line.inc(); // error no such method
line = new Set1L(); // err. wrong type

boolean isEmpty (Set s) {…}
if isEmpty(line) … // error arg type
```

Statically Typed Language



Dynamically Typed Language



Dynamically Typed Language

- Equivalent definitions:
  - No static types
  - Dynamic types only
  - Variables do not have type, objects do

Function Signatures

- Statically typed

```
String parse(char[] s, int i) {… return e;}
out = parse(t, x);
```

  - Declare parameter and return types
    - See s, i, and parse
  - The *compiler* checks conformance of
    - (Declared) types of arguments (t, x)
    - (Declared) type of return expression (e)
    - (Declared) type of expression *using* parse (out)
- Dynamically typed

```
def parse(s, i) … e end
out = parse t, x
```

  - You are on your own!

Type Can Change at Run-time

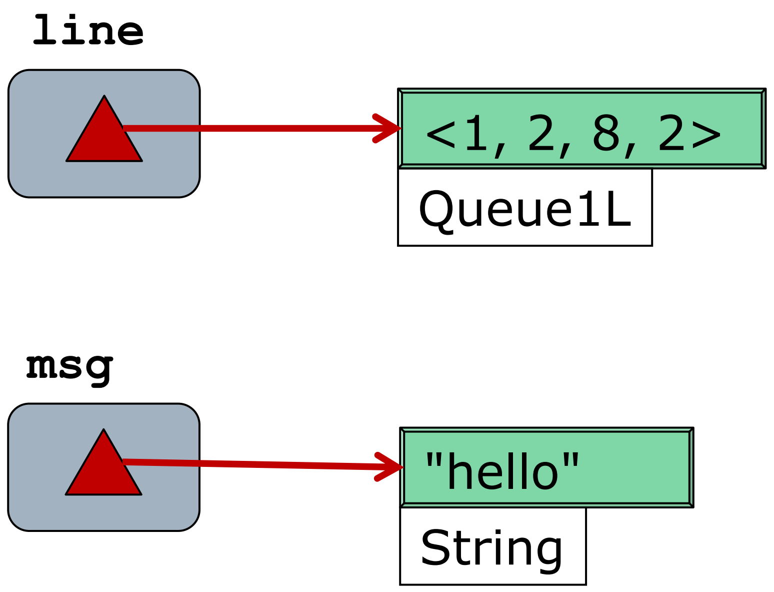
Statically Typed

```
  //a is undeclared
String a;
  //a is null string
a = "hi;
  //compile-time err
a = "hi";
a = 3;
  //compile-time err
a.push();
  //compile-time err
```

Dynamically Typed

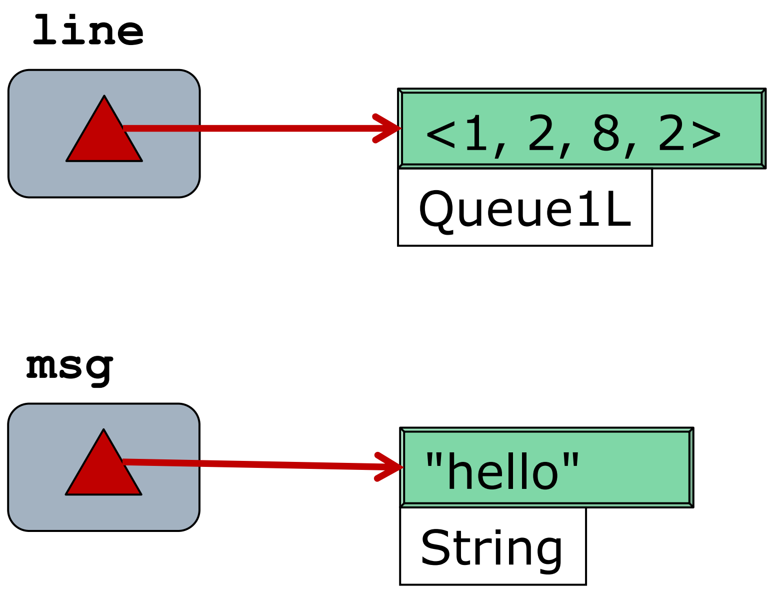
```
  # a is undefined
a = a
  # a is nil
a = "hi
  # load-time error
a = "hi"
a = 3
  # a is now a number
a.push
  # run-time error
```

Changing Dynamic Type



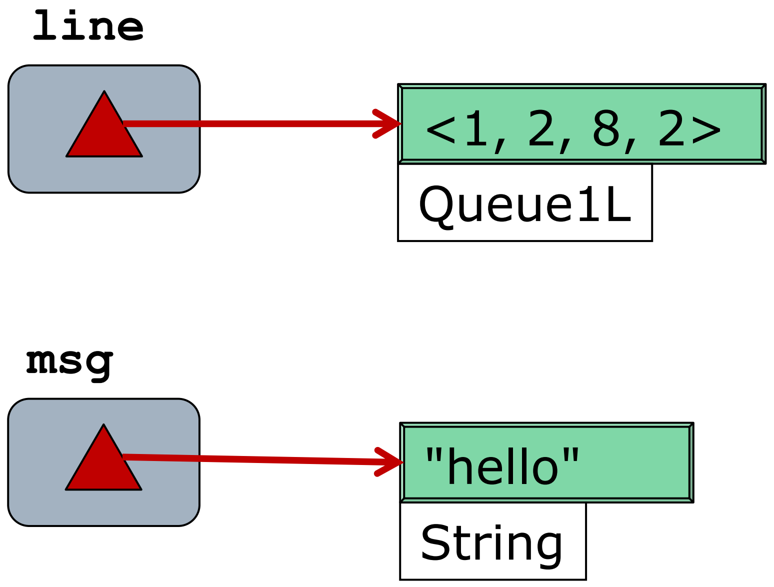
Changing Dynamic Type

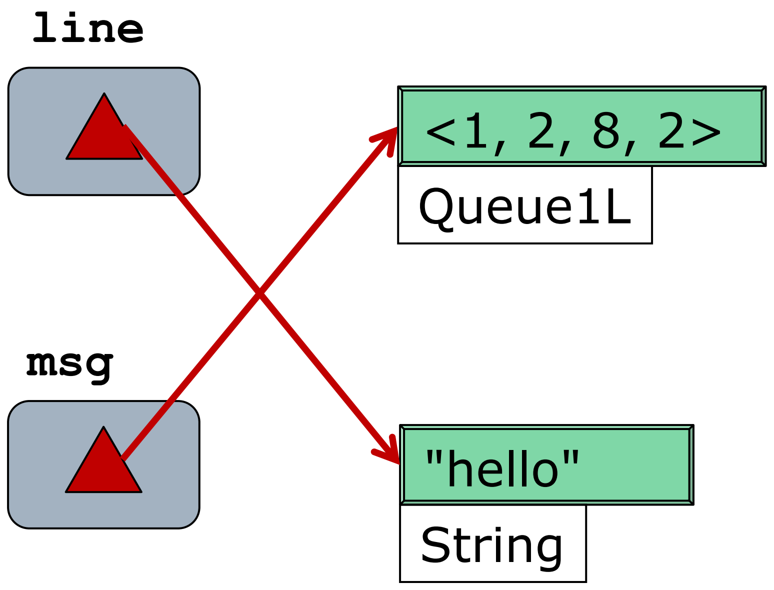
```
msg, line = line, msg
```



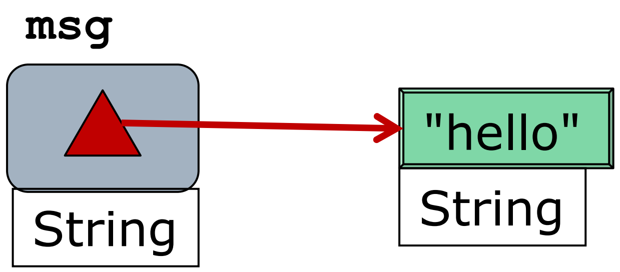
Changing Dynamic Type

```
msg, line = line, msg
```





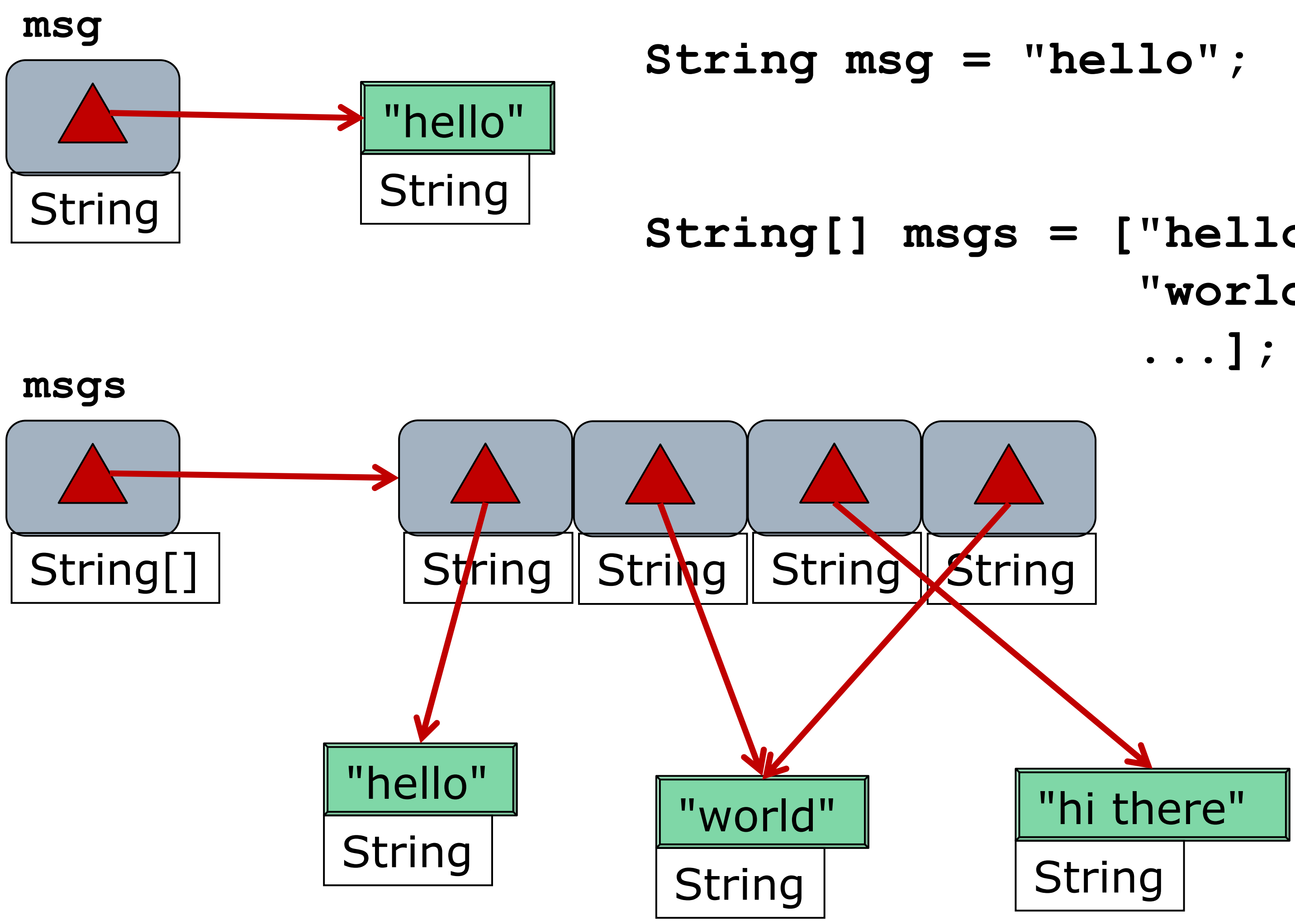
Arrays: Static Typing



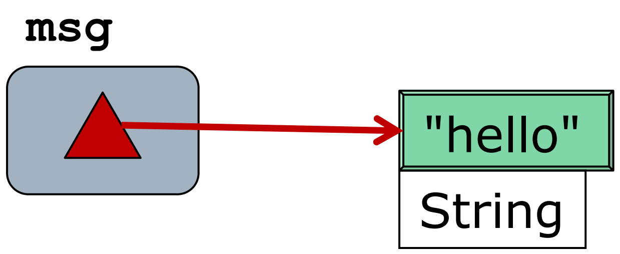
```
String msg = "hello";
```

Arrays: Static Typing

```
String msg = "hello";


String[] msgs = ["hello",
                 "world",
                 ...];
```

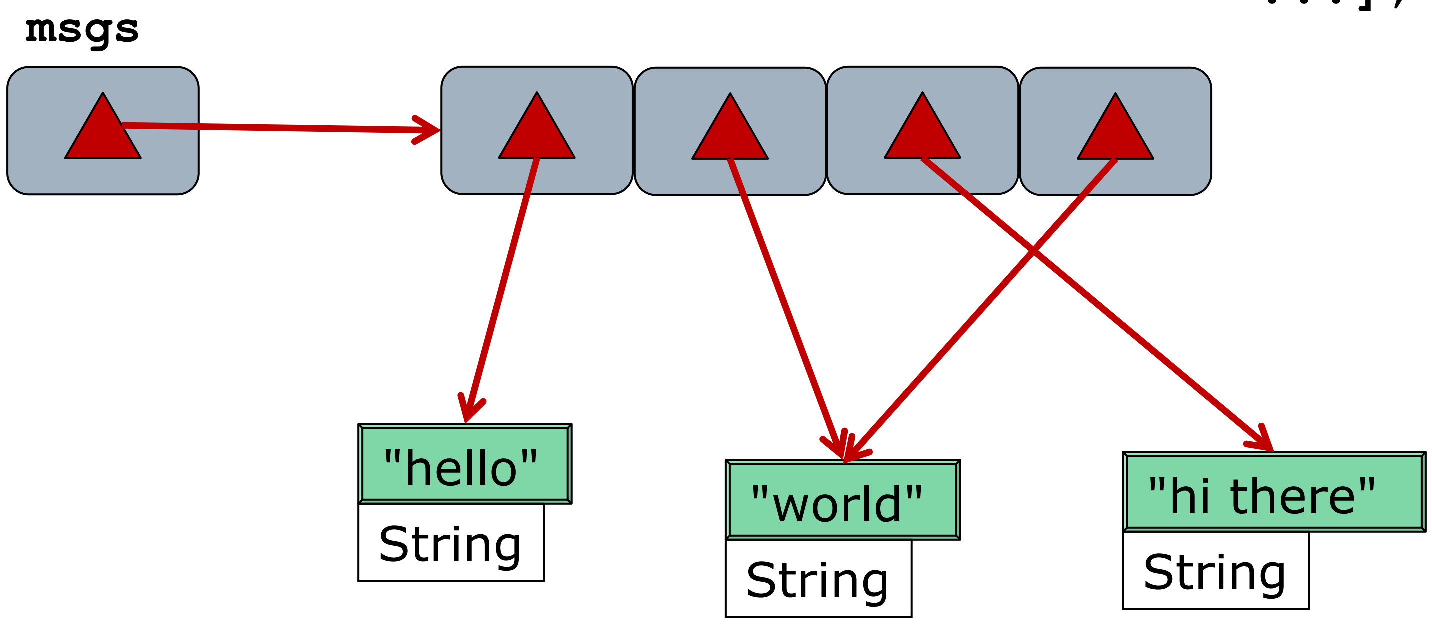


Arrays: Dynamic Typing



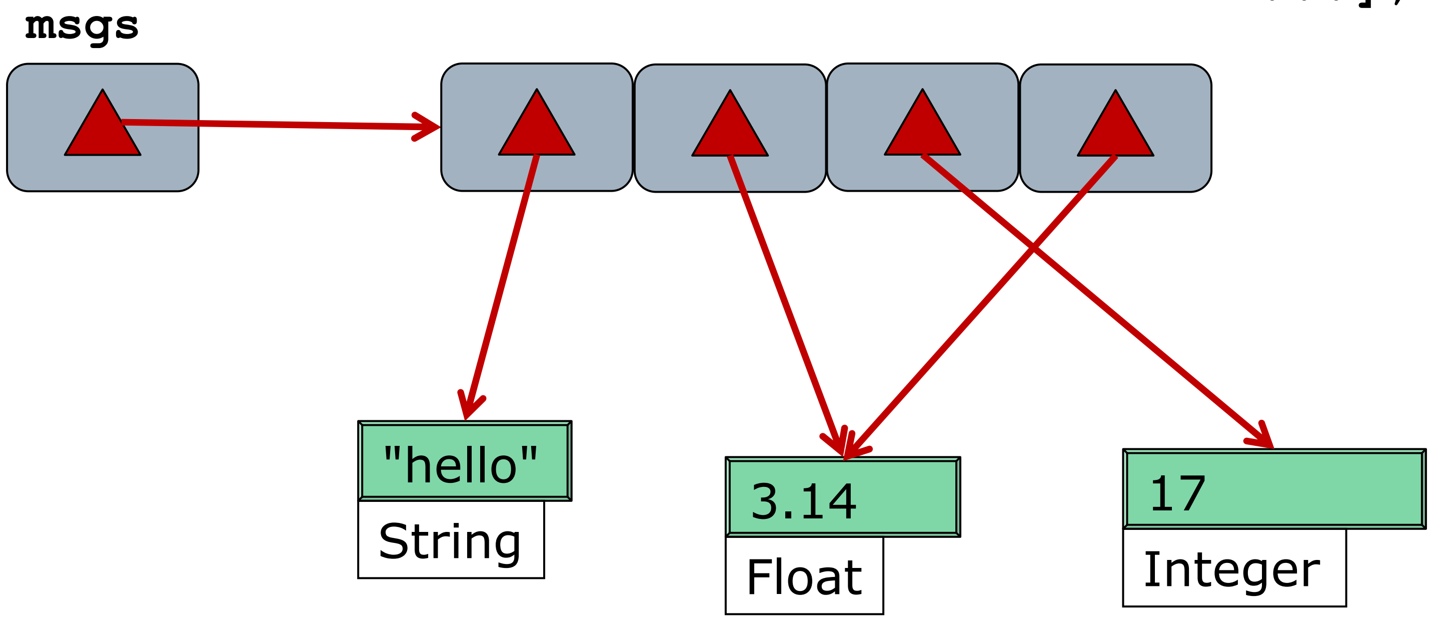
```
msg = "hello";
```

```
msgs = ["hello",
        "world",
        ...];
```



Consequence: Heterogeneity

```
msgs = ["hello",
        3.14,
        ...];
```



Tradeoffs

Statically Typed

- Earlier error detection
- Clearer APIs
- More compiler optimizations
- Richer IDE support

Dynamically Typed

- Less code to write
- Less code to change
- Quicker prototyping
- No casting needed

Strongly Typed

- Just because variables don’t have types, doesn’t mean you can do anything you want

```
>> "hi".upcase
=> "HI"
>> "hi".odd?
NoMethodError: undefined method `odd?'
for String
>> puts "The value of x is " + x
TypeError: can't convert Integer to
String
```

Summary

- Object-oriented
  - References are everywhere
  - Assignment copies reference value (alias)
  - Primitives (immediates) are objects too
  - == vs .equal? are flipped
- Dynamically type
  - Objects have types, variables do not
- Strongly Typed
  - Incompatible types produce (run time) error