Agenda

- Class exploring
  - Class object, default / common behaviors

- Objects equality
  - Object
  - Collections

- Copying
  - Shallow copy
  - Deep copy

- Squeak object model

- The new method
Object class

- Single root to inheritance hierarchy.
- Most classes inherit (directly or indirectly) from `Object`.
- Inherits from `ProtoObject`
  - What is the super class of `ProtoObject`?
- `Object` instances have:
  - no state (no instance variables)
  - approximately 400 methods.
Methods in *Object* may:

- Define common behavior
  - Not meant to be overridden in derived classes
  - Same functionality for all derived classes.

- Define default behavior
  - Meant to be overridden by derived classes
Default and Common behavior

- **printString** method defines common behavior:
  ```plaintext
  printString
  ^self printStringLimitedTo: 50000
  ```

- **printStringLimitedTo**: calls **printOn**: method.

- **printOn**: method defines default behavior:
  ```plaintext
  printOn: aStream
  | title |
  title := self class name.
  aStream
  nextPutAll: (title first isVowel ifTrue: ['an ']
  ifFalse: ['a ']);
  nextPutAll: title
  ```
Example – Fraction class

- Class Browser:
  (method code)

```
printOn: aStream
  aStream nextPut: $(.
  numerator printOn: aStream.
  aStream nextPut: $/.
  denominator printOn: aStream.
  aStream nextPut: $).
```

- Workspace:

```
Transcript show: 2/5 printString
```

- Transcript:

```
(2/5)
```
The method == is implemented in ProtoObject, by the usage of <primitive> direction.

- It compares objects by reference.
- Supplies common behavior

~~ is based on == (also common behavior):

```ruby
~~ anObject
  anObject == self
  IfTrue:[^ false]
  IfFalse:[^ true]
```

= is first defined in class Object

- Supplies default behavior

```ruby
= anObject
  ^self == anObject
```
Collections Equality

- **SequenceableCollection** overrides `=' behavior, more suitable for its class.

  ```
  = t1
  self == t1 ifTrue: [^ true].
  self species == t1 species ifFalse: [^ false].
  ^ self hasEqualElements: t1
  ```

- Thus supplying a common behavior to all derived classes.
  - Depends on `hasEqualElements`, which uses the method `at:`, which defines default behavior.
The method **shallowCopy** returns a copy of the receiver.

- shallow copy shares references with original object.
- **shallowCopy** provides common behavior, based on **basicSize** and **basicAt**.
  - Why must these two methods be primitive?
- **copyTwoLevel** makes a shallow copy for each member.
- **deepCopy** copies members recursively (is termination guaranteed?).
Method **copy** can either be a shallow copy or a deep one:

```smalltalk
^ self shallowCopy postCopy
```

By overriding **postCopy** one can make copies of members that must not be shared.

```smalltalk
postCopy
| aLink | super postCopy.
firstLink isNil ifFalse: [ 
aLink := firstLink := firstLink copy.
[aLink nextLink isNil] whileFalse:
[ aLink nextLink: (aLink := aLink nextLink copy)].
lastLink := aLink].
```

**LinkedList postCopy**
Part II – Squeak Object Model
Rule I: *Everything* is an Object

- An object consists of:
  - **Identity** (usually the address)
  - **State** (i.e., the value of its members)
    - Fields access modifier is *protected*
  - **Behavior** (Method implementation)
    - Methods are public (can only be private by convention).
- Everything is done by passing messages to objects
- Variables are dynamically typed
Objects in Squeak (cont.)

- All objects (except `SmallInteger`, `ByteSymbol`) have reference semantics.

- Squeak has single inheritance.
Rule II: every object is an instance of one class

- A class specifies the structure and behavior of its instances.
  - All instances of a class have the same behavior.
  - Instances of the same class may vary in state.
- Classes are also objects...
- Obtaining the class of an object:

  1 class → SmallInteger
  20 factorial class → LargePositiveInteger
  '236703' class → String
  (1-> 'Parker') class → Association
  {1. 1. 3} class → Array
Rule III – Every class has a single superclass

- Each class inherits its structure and behavior from another class.

```
0 class superclass → SmallInteger
Integer superclass → Number
Number superclass → Magnitude
Magnitude superclass → Object
Object superclass → ProtoObject
ProtoObject superclass → nil
```

- Rule IV – Everything happens by sending messages to objects.
Rule V - Method lookup follows the inheritance chain.

- The method to be invoked is searched for in the class of the message receiver.
- If the method is not found, the method search continues in the superclass.
- In case a method to handle a message could not be found, the receiver sends:

```reason
self doesNotUnderstand: <message name>
```
Calling $aB\ foo$:

c := self class.

1. Look up the method in the method dictionary of c.

2. If not found \textbf{then}
   
c := c superclass.

3. If c is \texttt{nil} \textbf{then} error...
   else goto 1.
Reflection

- **respondsTo**: in class **Object**:

  ```smalltalk
  respondsTo: aSymbol
  ^ self class canUnderstand: aSymbol
  ```

- **canUnderstand**: defined in **Behavior**:

  ```smalltalk
  canUnderstand: t1
  (self includesSelector: t1) ifTrue: [^ true].
  superclass ifNil: [^ false].
  ^ superclass canUnderstand: t1
  ```

  **includeSelector**: defined in **Behavior**:

  ```smalltalk
  includesSelector: aSymbol
  "Answer whether the message whose selector is the argument
  is in the method dictionary of the receiver's class."
  ^ self methodDict includesKey: aSymbol
  ```
Since Smalltalk is *dynamically typed* it is useful to ask about the identity of the objects.

The methods `isMemberOf:` and `isKindOf:` defined in `Object` may be used for type checking:

```smalltalk
isMemberOf: t1
  ^self class == t1
```

```smalltalk
isKindOf: t1
  self isMemberOf: t1
  ifTrue: [^ true].
  ^ self class inheritsFrom: t1
```
• Reminder:
  • Everything is an object
  • Every object is an instance of a class
• Thus, logically:
  • Every class is an object
  • Every class object is an instance of a class.
• What is this “class of a class?”
  • meta-class
**Meta-classes and Metaclass**

- **Class**: (Examples: `Integer`, `Number`, `Array`)
  - Every object is an instance of a class
  - All classes eventually inherit from `ProtoObject`
  - A class is an instance of its corresponding meta-class.

- **Meta-class**: (Examples: `Integer class`, `Array class`):
  - Inheritance hierarchy is parallel to class hierarchy.
  - All meta-classes eventually inherit from class `Class`.
    - Which eventually inherits from `ProtoObject`.
  - All meta-classes are instances of `MetaClass`.

- **MetaClass**:
  - Sort of a meta-meta-class
Every class is an object too!

Meta-classes have only one instance – the class object (classes are singletons).
Metaclasses (cont.)

- Metaclasses are implicit.
  - Created implicitly when classes are created.
  - Each class has a unique metaclass.

- Metaclasses are anonymous (cannot be directly referred from code).

<table>
<thead>
<tr>
<th>Integer class → Integer class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object class → Object class</td>
</tr>
</tbody>
</table>

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Meta class inheritance hierarchy

- **Object class**
- **ProtoObject class**
  - **Class**
    - **ClassDescription**
      - **Behavior**
        - **Super class**
        - **Method dictionary**
        - **Code compilation**
        - **new**
  
- **Object**
  - **Instance variables**
  - **Method categories**
  - **Change set and logging**

- **Class name**
- **The set of subclasses**
- **Class categories**
- **fileOut**
- **etc.**
Metaclasses and classes

- A bit lighter than Class
- `new` creates a singleton class

All meta-classes are singleton classes, but Metaclass isn’t!
What we’ve learned so far:

• Every class object is an instance of a class (a meta-class)
• Every meta-class is an object.
• Every meta-class object is an instance of a class (Metaclass)

So, according to the rules:

• Metaclass is an object
• Metaclass is an instance of a class
  • By squeak naming conventions Metaclass class
  • Which is a meta-class... (class of a class)
  • So it’s also an instance of Metaclass....
• **Metaclass** is an instance of **Metaclass class**

• **Metaclass class** is an instance of **Metaclass**
A class has the following attributes:

- Name
- Set of methods
- Set of instance variables
- Instance size

A class has a behavior, defined by the methods in its class (meta-class).

Factory method (new) – creates new instances.

Looked up in the *meta-class* inheritance hierarchy.
Types of Variables

Defined in the class:
• Instance Variables

Defined in the meta-class:
• Class Variables
  – Like static variables in C++/Java
• Class-Instance Variables
  – Instance variables for the class object.
The method `new`

- First defined in class `Behavior`.
- May be overridden in derived meta-classes.
  - `new` always returns an instance of `self` (self is a class, can be instantiated)
- New first creates a new instance, and then sends an `initialize` message to it.

```
new
^ self basicNew initialize
```

- `basicNew` allocates memory using `<primitive>`.
  - When overriding `new`, make sure `basicNew` is called at some point.
new Method (cont.)

- **new** is redefined in **Metaclass**:
  - Meaning the behaviors of its instances change: the meta-classes.

```
new
"The receiver can only have one instance. Create it or complain that one already exists."

thisClass class ~~ self
  ifTrue: [^
    thisClass := self basicNew].
  self error: 'A Metaclass should only have one instance!'
```

- So every **instance** of **Metaclass** is in fact a singleton class.
Summary questions

• Why is there a meta-class for every class, but only one `MetaClass`?

• When looking up a method, `methodDict` should be searched. But fields are protected, so a method should be used. That method should be defined in the meta-class, so another lookup is required. How is an infinite recursion avoided as the lookup deepens?