Module 23

# Abstraction

# Case Study: Fractions

- Want to add a new ***type***
  - Values are fractions: ½, ¾
  - Operations are standard multiply, divide, etc.
  - **Example**: ½*¾ = ⅜
- Can do this with a class
  - Values are fraction objects
  - Operations are methods
- **Example**: frac1.py

```
class Fraction(object):
    """Instance is a fraction n/d"""
    # INSTANCE ATTRIBUTES:
    # _numerator:    an int
    # _denominator: an int > 0

    def __init__(self,n=0,d=1):
        """Init: makes a Fraction"""
        self._numerator = n
        self._denominator = d
```

# Case Study: Fractions

- Want to add a new ***type***
  - Values are fractions: ½, ¾
  - Opera
    multi
  - **Exan**
- Can do
  - Values are fraction objects
  - Operations are methods
- **Example**: frac1.py

**Reminder**: Hide attributes, use **getters/setters**

```
class Fraction(object):
    """Instance is a fraction n/d"""
    # INSTANCE ATTRIBUTES:
    # _numerator:   an int
    # _denominator: an int > 0

    def __init__(self,n=0,d=1):
        """Init: makes a Fraction"""
        self._numerator = n
        self._denominator = d
```

# Problem: Doing Math is Unwieldy

| What We Want | What We Get |
|---|---|
| $$\left(\frac{1}{2}+\frac{1}{3}+\frac{1}{4}\right)*\frac{5}{4}$$ | `>>> p = Fraction(1,2)`<br>`>>> q = Fraction(1,3)`<br>`>>> r = Fraction(1,4)`<br>`>>> s = Fraction(5,4)`<br>`>>> (p.add(q.add(r))).mult(s)` |

This is confusing!

# Problem: Doing Math is Unwieldy

## What We Want

$$\left(\frac{1}{2}+\frac{1}{3}+\frac{1}{4}\right)*\frac{5}{4}$$

Why not use the standard Python math operations?

## What We Get

```
>>> p = Fraction(1,2)
>>> q = Fraction(1,3)
>>> r = Fraction(1,4)
>>> s = Fraction(5,4)
>>> (p.add(q.add(r))).mult(s)
```

This is confusing!

# Abstraction

- **Goal:** Hide unimportant details from user
  - Replace unfamiliar with the familiar
  - Focus on the core functionality of the type
- Data encapsulation is one part of it
  - Hide direct access to the attributes
  - Only allow getters and setters
- But also involves **operator overloading**
  - Replace method calls with operators
  - Make class feel like a built-in type

# Operator Overloading

- Many operators in Python a special symbols
  - +, -, /, *, ** for mathematics
  - ==, !=, <, > for comparisons
- The meaning of these symbols depends on type
  - 1 + 2 vs 'Hello' + 'World'
  - 1 < 2 vs 'Hello' < 'World'
- Our new type might want to use these symbols
  - We *overload* them to support our new type

# Special Methods in Python

- Have seen three so far
  - __init__ for initializer
  - __str__ for str()
  - __repr__ for repr()
- Start/end with 2 underscores
  - This is standard in Python
  - Used in all special methods
  - Also for special attributes
- We can **overload operators**
  - Give new meaning to +, *, -

```
class Point3(object):
    """Instances are points in 3D space"""
    …

    def __init__(self,x=0,y=0,z=0):
        """Initializer: makes new Point3"""
        …

    def __str__(self,q):
        """Returns: string with contents"""
        …

    def __repr__(self,q):
        """Returns: unambiguous string"""
        …
```

# Returning to Fractions

## What We Want

$$\left(\frac{1}{2}+\frac{1}{3}+\frac{1}{4}\right)*\frac{5}{4}$$

Why not use the standard Python math operations?

## Operator Overloading

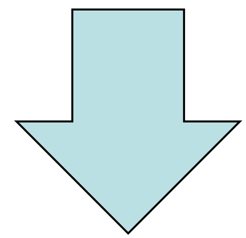
- Python has methods that correspond to built-in ops
  - `__add__` corresponds to +
  - `__mul__` corresponds to *
  - `__eq__` corresponds to ==
  - Not implemented by default
- To overload operators you implement these methods

# Operator Overloading: Multiplication

```
class Fraction(object):
    """Instance is a fraction n/d"""
    # _numerator:    an int
    # _denominator:  an int > 0

    def __mul__(self,q):
        """Returns: Product of self, q
        Makes a new Fraction; does not
        modify contents of self or q
        Precondition: q a Fraction"""
        assert type(q) == Fraction
        top= self._numerator*q._numerator
        bot= self._denominator*q._denominator
        return Fraction(top,bot)
```

```
>>> p = Fraction(1,2)
>>> q = Fraction(3,4)
>>> r = p*q
```



Python converts to

```
>>> r = p.__mul__(q)
```

Operator overloading uses method in object on left.

# Operator Overloading: Addition

```python
class Fraction(object):
    """Instance is a fraction n/d"""
    # _numerator:    an int
    # _denominator:  an int > 0

    def __add__(self,q):
        """Returns: Sum of self, q
        Makes a new Fraction
        Precondition: q a Fraction"""
        assert type(q) == Fraction
        bot= self._denominator*q._denominator
        top= (self._numerator*q._denominator+
              self._denominator*q._numerator)
        return Fraction(top,bot)
```

```
>>> p = Fraction(1,2)
>>> q = Fraction(3,4)
>>> r = p+q
```

Python converts to

```
>>> r = p.__add__(q)
```

Operator overloading uses method in object on left.

# Comparing Objects for Equality

- Earlier in course, we saw == compare object contents
  - This is not the default
  - **Default**: folder names
- Must implement `__eq__`
  - Operator overloading!
  - Not limited to simple attribute comparison
  - **Ex**: cross multiplying

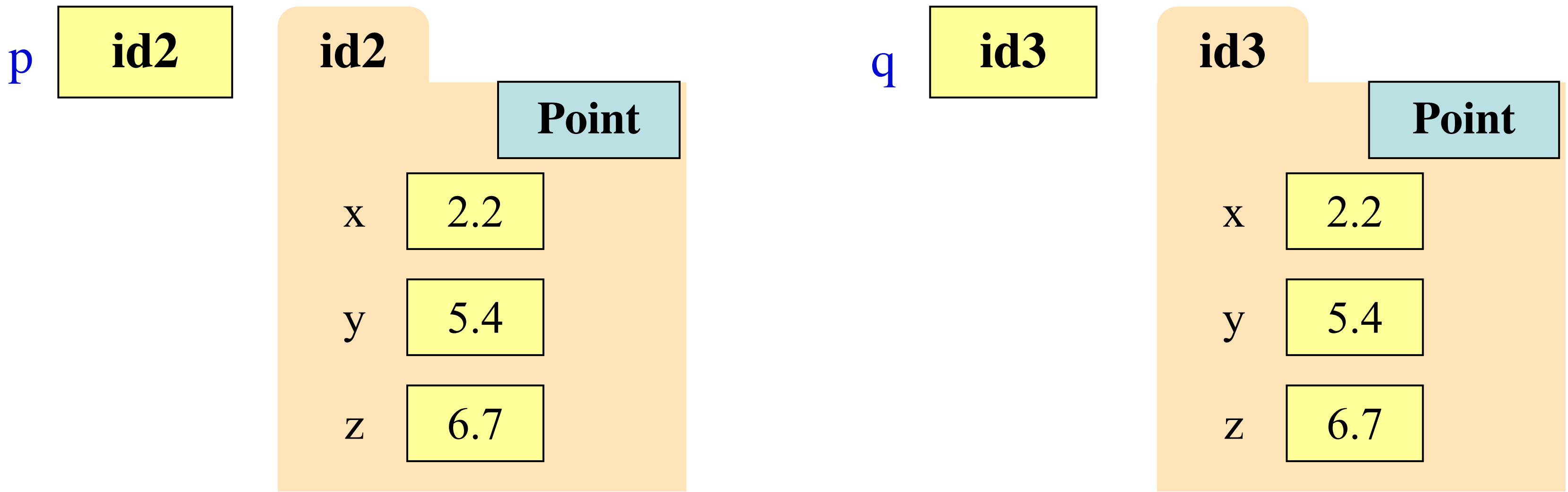
**4** $\frac{1}{2}$ $\frac{2}{4}$ **4**

```
class Fraction(object):
    """Instance is a fraction n/d"""
    # _numerator:    an int
    # _denominator:  an int > 0

    def __eq__(self,q):
        """Returns: True if self, q equal,
        False if not, or q not a Fraction"""
        if type(q) != Fraction:
            return False
        left = self._numerator*q._denominator
        rght = self._denominator*q._numerator
        return left == rght
```

# is Versus ==

- `p is q` evaluates to `False`
  - Compares folder names
  - Cannot change this
- `p == q` evaluates to `True`
  - But only because method `__eq__` compares contents




Always use `(x is None)` **not** `(x == None)`

# Recall: Overloading Multiplication

```python
class Fraction(object):
    """Instance is a fraction n/d"""
    # _numerator:    an int
    # _denominator:  an int > 0

    def __mul__(self,q):
        """Returns: Product of self, q
        Makes a new Fraction; does not
        modify contents of self or q
        Precondition: q a Fraction"""
        assert type(q) == Fraction
        top = self._numerator*q._numerator
        bot= self._denominator*q._denominator
        return Fraction(top,bot)
```

```python
>>> p = Fraction(1,2)
>>> q = 2 # an int
>>> r = p*q
```

Python converts to

```python
>>> r = p.__mul__(q) # ERROR
```

Can only multiply fractions.
But ints “make sense” too.

# Solution: Look at Argument Type

- Overloading use **left** type
  - p*q => p.__mul__(q)
  - Done for us automatically
  - Looks in class definition
- What about type on **right**?
  - Have to handle ourselves
- Can implement with ifs
  - Write helper for each type
  - Check type in method
  - Send to appropriate helper

```
class Fraction(object):
    …
    def __mul__(self,q):
        """Returns: Product of self, q
        Precondition: q a Fraction or int"""
        if type(q) == Fraction:
            return self._mulFrac(q)
        elif type(q) == int:
            return self._mulInt(q)
    …
    def _mulInt(self,q): # Hidden method
        return Fraction(self._numerator*q,
                        self._denominator)
```

# A Better Multiplication

```
class Fraction(object):
    ...
    def __mul__(self,q):
        """Returns: Product of self, q
        Precondition: q a Fraction or int"""
        if type(q) == Fraction:
            return self._mulFrac(q)
        elif type(q) == int:
            return self._mulInt(q)
    ...
    def _mulInt(self,q): # Hidden method
        return Fraction(self._numerator*q,
                        self._denominator)
```

```
>>> p = Fraction(1,2)
>>> q = 2 # an int
>>> r = p*q
```

Python converts to

```
>>> r = p.__mul__(q) # OK!
```

See frac3.py for a full example of this method

# What Do We Get This Time?

```
class Fraction(object):
    ...
    def __mul__(self,q):
        """Returns: Product of self, q
        Precondition: q a Fraction or int"""
        if type(q) == Fraction:
            return self._mulFrac(q)
        elif type(q) == int:
            return self._mulInt(q)
    ...
    def _mulInt(self,q): # Hidden method
        return Fraction(self._numerator*q,
                        self._denominator)
```

```
>>> p = Fraction(1,2)
>>> q = 2 # an int
>>> r = q*p
```

A: Fraction(2,2)
B: Fraction(1,1)
C: Fraction(2,4)
D: Error
E: I don't know

# What Do We Get This Time?

```
class Fraction(object):
    ...
    def __mul__(self,q):
        """Returns: Product of self, q
        Precondition: q a Fraction or int"""
        if type(q) == Fraction:
            return self._mulFrac(q)
        elif type(q) == int:
            return self._mulInt(q)
    ...
    def _mulInt(self,q): # Hidden method
        return Fraction(self._numerator*q,
                        self._denominator)
```

```
>>> p = Fraction(1,2)
>>> q = 2 # an int
>>> r = q*p
```

Meaning determined by left.
Variable q stores an **int**.

B: Fraction(1,1)
C: Fraction(2,4)
D: Error **CORRECT**
E: I don’t know

# The Python Data Model

**Note:** Slicing is done exclusively with the following three methods. A call like

```
a[1:2] = b
```

is translated to

http://docs.python.org/3/reference/datamodel.html

```
a[slice(1, 2, None)] = b
```

and so forth. Missing slice items are always filled in with `None`.

`object.__getitem__`(*self, key*)

Called to implement evaluation of `self[key]`. For sequence types, the accepted keys should be integers and slice objects. Note that the special interpretation of negative indexes (if the class wishes to emulate a sequence type) is up to the `__getitem__()` method. If *key* is of an inappropriate type, `TypeError` may be raised; if of a value outside the set of indexes for the sequence (after any special interpretation of negative values), `IndexError` should be raised. For mapping types, if *key* is missing (not in the container), `KeyError` should be raised.

> **Note:** `for` loops expect that an `IndexError` will be raised for illegal indexes to allow proper detection of the end of the sequence.

`object.__missing__`(*self, key*)

Called by `dict.__getitem__()` to implement `self[key]` for dict subclasses when key is not in the dictionary.

`object.__setitem__`(*self, key, value*)

Called to implement assignment to `self[key]`. Same note as for `__getitem__()`. This should only be implemented for mappings if the objects support changes to the values for keys, or if new keys can be added, or for sequences if elements can be replaced. The same exceptions should be raised for improper *key* values as for the `__getitem__()` method.

`object.__delitem__`(*self, key*)

Called to implement deletion of `self[key]`. Same note as for `__getitem__()`. This should only be implemented for mappings if the objects support removal of keys, or for sequences if elements can be removed from the sequence. The same exceptions should be raised for improper *key* values as for the `__getitem__()` method.

# We Have Come Full Circle

- On the first day, saw that a **type** is both
  - a set of *values*, and
  - the *operations* on them
- In Python, **all values are objects**
  - Everything has a folder in the heap
  - Just ignore it for immutable, basic types
- In Python, **all operations are methods**
  - Each operator has a double-underscore helper
  - Looks at type of object on left to process

# Structure of a Proper Python Class

```
class Fraction(object):
    """Instance is a fraction n/d"""
    # _numerator:    an int
    # _denominator:  an int > 0

    def getNumerator(self):
        """Returns: Numerator of Fraction"""
    ...
    def __init__(self,n=0,d=1):
        """Initializer: makes a Fraction"""
     ...
    def __add__(self,q):
        """Returns: Sum of self, q"""
    ...
    def normalize(self):
        """Puts Fraction in reduced form"""
    ...
```

Docstring describing class
Attributes are all **hidden**

Getters and Setters.

Initializer for the class.
Defaults for parameters.

Python operator overloading

Normal method definitions

# Class Methods

## Normal Method

**Definition:**

```
def add(self,other):
    """Return sum of self, other"""
    …
```

**Call:**

other

```
>>> p.add(q)
```

self

## Class Method

**Definition:**

```
@classmethod
def isname(cls,n):
    """Return True if cls named n"""
    …
```

Decorator

**Call:**

cls

n

```
>>> Point3.isname('Point3')
```

# Using Class Methods

- Primary purpose is for custom constructors
  - Want method to make a custom object
  - But do not have an object (yet) for method call
  - Call using the class in front instead of object
- Custom constructors rely on normal constructor
  - They just compute the correct attrib values
  - But call the constructor using `cls` variable
  - Using `cls`(...) as constructor makes subclass safe

# Advanced Content Warning

# Properties: Invisible Setters and Getters

```
class Fraction(object):
    """Instance is a fraction n/d"""
    # _numerator:    an int
    # _denominator:  an int > 0

    @property
    def numerator(self):
        """Numerator value of Fraction
        Invariant: must be an int"""
        return self._numerator

    @numerator.setter
    def numerator(self,value):
        assert type(value) == int
        self._numerator = value
```

```
>>> p = Fraction(1,2)
>>> x = p.numerator
```

Python converts to

```
>>> x = p.numerator()
```

```
>>> p.numerator = 2
```

Python converts to

```
>>> p.numerator(2)
```

# Properties: Invisible Setters and Getters

```
class Fraction(object):
    """Instance is a fraction n/d"""
    # _numerator:    an int
    # _denominator:  an int > 0
    @property
    def numerator(self):
        """Numerator value of Fraction
        Invariant: must be an int"""
        return self._numerator

    @numerator.setter
    def numerator(self,value):
        assert type(value) == int
        self._numerator = value
```

**Decorator** specifies that next method is **getter** for property of the same name as method

Docstring describing property

Property uses **hidden** attribute.

**Decorator** specifies that next method is the **setter** for property whose name is numerator.

# Properties: Invisible Setters and Getters

```
class Fraction(object):
    """Instance is a fraction n/d"""
    # _numerator:    an int
    # _denominator:  an int > 0
    @property
    def numerator(self):
        """Numerator value of Fraction
        Invariant: must be an int"""
        return self._numerator

    @numerator.setter
    def numerator(self,value):
        assert type(value) == int
        self._numerator = value
```

**Goal**: Data Encapsulation
Protecting your data from other, "clumsy" users.

Only the **getter** is required!

If no **setter**, then the attribute is "immutable".

Replace **Attributes** w/ **Properties**
(Users cannot tell difference)