Designing Types

From first day of class!

- **Type**: set of values and the operations on them
  - int: (**set**: integers; **ops**: +, –, *, /, …)
  - Time (**set**: times of day; **ops**: time span, before/after, …)
  - Worker (**set**: all possible workers; **ops**: hire,pay,promote,…)
  - Rectangle (**set**: all axis-aligned rectangles in 2D; **ops**: contains, intersect, …)
- To define a class, think of a *real type* you want to make
  - Python gives you the tools, but does not do it for you
  - Physically, any object can take on any value
  - Discipline is required to get what you want

Making a Class into a Type

1. Think about what values you want in the set
   - What are the attributes? What values can they have?
2. Think about what operations you want
   - This often influences the previous question

- To make (1) precise: write a *class invariant*
  - Statement we promise to keep true **after every method call**
- To make (2) precise: write *method specifications*
  - Statement of what method does/what it expects (preconditions)
- Write your code to make these statements true!

Planning out a Class

```
class  Time(object):
    """Instances  represent   times  of  day.
    Instance Attributes:
        hour: hour of day [int in 0..23]
        min:   minute of hour [int in 0..59]"""

    def  __init__(self,   hour,  min):
        """The time hour:min.
        Pre: hour in 0..23; min  in 0..59"""

    def  increment(self,    hours,  mins):
        """Move this time <hours>  hours
        and <mins> minutes  into  the future.
        Pre: hours is int >= 0; mins   in 0..59"""

    def  isPM(self):
        """Returns: this  time  is  noon or later."""
```

Class Invariant

States what attributes are present and what values they can have.

A statement that will always be true of any Time instance.

Method Specification

States what the method does.

Gives preconditions stating what is assumed true of the arguments.

Planning out a Class

```
class  Rectangle(object):
    """Instances  represent   rectangular
    regions of the plane.
    Instance Attributes:
        t: y coordinate of top edge [float]
        l: x coordinate of left edge [float]
        b: y coordinate of bottom edge [float]
        r: x coordinate of right edge [float]
    For all Rectangles,  l <= r and b <= t."""

    def  __init__(self,  t, l, b, r):
        """The rectangle [l, r] x [t, b]
        Pre: args are floats; l <= r; b <= t"""

    def  area(self):
        """Return: area of the rectangle."""

    def  intersection(self,    other):
        """Return: new Rectangle  describing
          intersection  of  self  with other."""
```

Class Invariant

States what attributes are present and what values they can have.

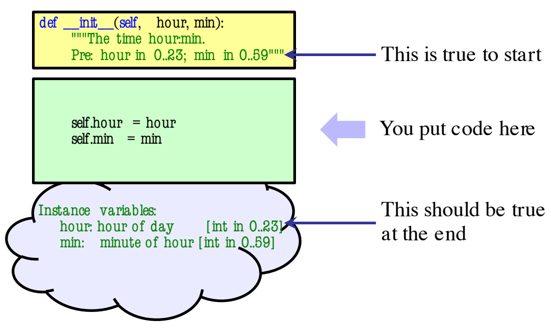
A statement that will always be true of any Rectangle instance.

Method Specification

States what the method does.

Gives preconditions stating what is assumed true of the arguments.

Implementing an Initializer



```
def  __init__(self,   hour, min):
    """The  time  hour:min.
    Pre:  hour in  0..23;  min  in  0..59"""
```

This is true to start

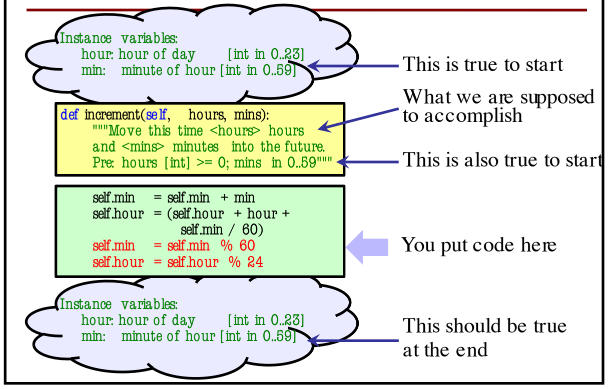
```
    self.hour   = hour
    self.min    = min
```

You put code here

```
Instance  variables:
    hour: hour of day         [int in 0..23]
    min:   minute of hour [int in 0..59]
```

This should be true at the end

Implementing a Method



```
Instance  variables:
    hour: hour of day         [int in 0..23]
    min:   minute of hour [int in 0..59]
```

This is true to start

```
def  increment(self,    hours,  mins):
    """Move  this  time  <hours>  hours
    and  <mins>  minutes   into the future.
    Pre:  hours  [int] >= 0; mins   in 0..59"""
```

What we are supposed to accomplish

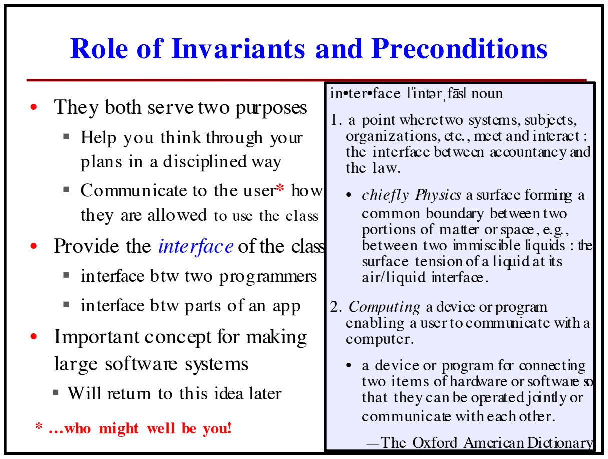
This is also true to start

```
    self.min     = self.min   + min
    self.hour   = (self.hour   + hour +
                          self.min  /  60)
    self.min     = self.min   %  60
    self.hour   = self.hour   %  24
```

You put code here

```
Instance  variables:
    hour: hour of day         [int in 0..23]
    min:   minute of hour [int in 0..59]
```

This should be true at the end



Role of Invariants and Preconditions

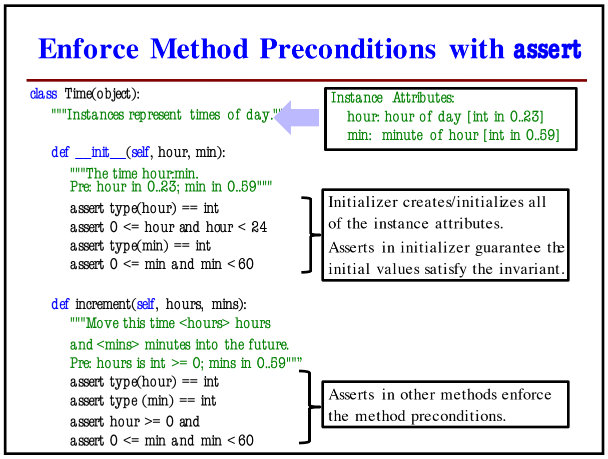
- They both serve two purposes
  - Help you think through your plans in a disciplined way
  - Communicate to the user* how they are allowed to use the class
- Provide the *interface* of the class
  - interface btw two programmers
  - interface btw parts of an app
- Important concept for making large software systems
  - Will return to this idea later

*** …who might well be you!**

in•ter•face |ˈintərˌfās| noun

1. a point where two systems, subjects, organizations, etc., meet and interact : the interface between accountancy and the law.
   - *chiefly Physics* a surface forming a common boundary between two portions of matter or space, e.g., between two immiscible liquids : the surface tension of a liquid at its air/liquid interface.
2. *Computing* a device or program enabling a user to communicate with a computer.
   - a device or program for connecting two items of hardware or software so that they can be operated jointly or communicate with each other.

—The Oxford American Dictionary



Enforce Method Preconditions with assert

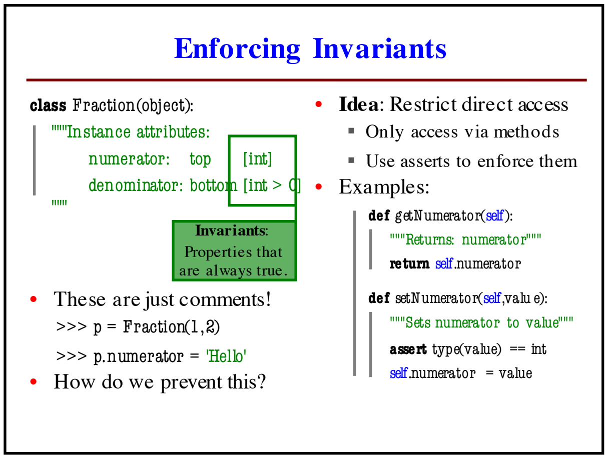
```
class Time(object):
    """Instances represent times of day."""

    def __init__(self, hour, min):
        """The time hour:min.
        Pre: hour in 0..23; min in 0..59"""
        assert type(hour) == int
        assert 0 <= hour and hour < 24
        assert type(min) == int
        assert 0 <= min and min < 60

    def increment(self, hours, mins):
        """Move this time <hours> hours
        and <mins> minutes into the future.
        Pre: hours is int >= 0; mins in 0..59"""
        assert type(hour) == int
        assert type (min) == int
        assert hour >= 0 and
        assert 0 <= min and min < 60
```

Instance Attributes:
  hour: hour of day [int in 0..23]
  min: minute of hour [int in 0..59]

Initializer creates/initializes all of the instance attributes.

Asserts in initializer guarantee the initial values satisfy the invariant.

Asserts in other methods enforce the method preconditions.



Enforcing Invariants

```
class Fraction(object):
    """Instance attributes:
        numerator:   top    [int]
        denominator: bottom [int > 0]
    """
```

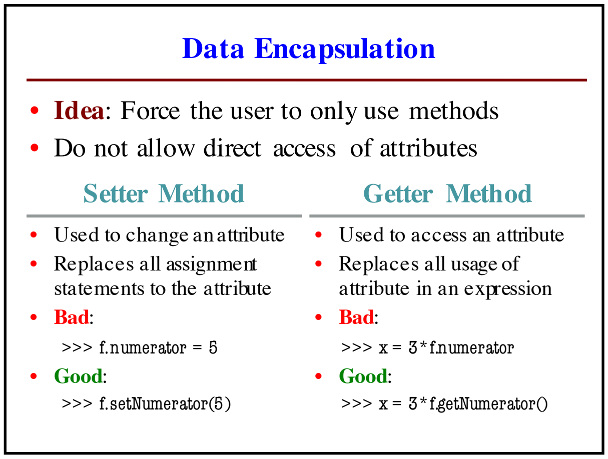
Invariants: Properties that are always true.

- These are just comments!

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

- How do we prevent this?
- **Idea**: Restrict direct access
  - Only access via methods
  - Use asserts to enforce them
- Examples:

```
def getNumerator(self):
    """Returns: numerator"""
    return self.numerator

def setNumerator(self,value):
    """Sets numerator to value"""
    assert type(value) == int
    self.numerator = value
```



Data Encapsulation

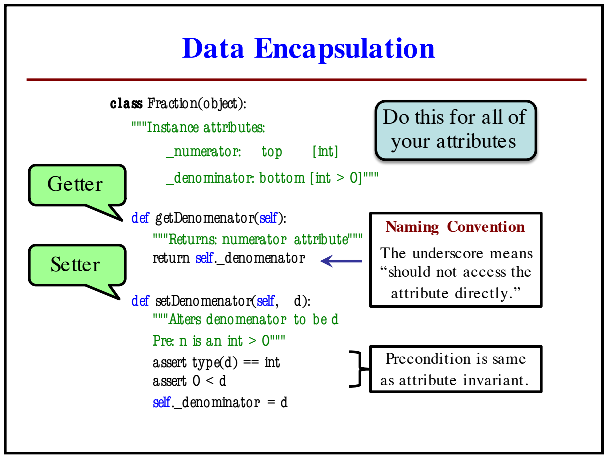
- **Idea**: Force the user to only use methods
- Do not allow direct access of attributes

Setter Method

- Used to change an attribute
- Replaces all assignment statements to the attribute
- **Bad**:
  `>>> f.numerator = 5`
- **Good**:
  `>>> f.setNumerator(5)`

Getter Method

- Used to access an attribute
- Replaces all usage of attribute in an expression
- **Bad**:
  `>>> x = 3*f.numerator`
- **Good**:
  `>>> x = 3*f.getNumerator()`



Data Encapsulation

```
class Fraction(object):
    """Instance attributes:
        _numerator:   top    [int]
        _denominator: bottom [int > 0]"""

    def getDenomenator(self):
        """Returns: numerator attribute"""
        return self._denomenator

    def setDenomenator(self,  d):
        """Alters denomenator to be d
        Pre: n is an int > 0"""
        assert type(d) == int
        assert 0 < d
        self._denominator = d
```

Do this for all of your attributes

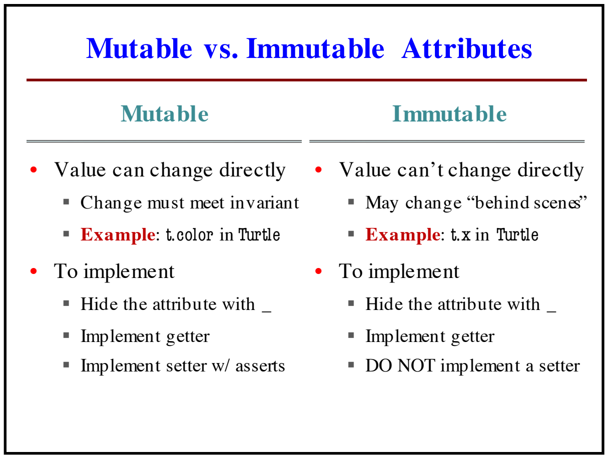
Getter

Setter

Naming Convention

The underscore means “should not access the attribute directly.”

Precondition is same as attribute invariant.



Mutable vs. Immutable Attributes

Mutable

- Value can change directly
  - Change must meet invariant
  - **Example**: t.color in Turtle
- To implement
  - Hide the attribute with _
  - Implement getter
  - Implement setter w/ asserts

Immutable

- Value can’t change directly
  - May change “behind scenes”
  - **Example**: t.x in Turtle
- To implement
  - Hide the attribute with _
  - Implement getter
  - DO NOT implement a setter