



# Functions and Data

Principles of Functional Programming

# Functions and Data

In this section, we'll learn how functions create and encapsulate data structures.

## **Example:** Rational Numbers

We want to design a package for doing rational arithmetic.

A rational number  $\frac{x}{y}$  is represented by two integers:

- ▶ its *numerator*  $x$ , and
- ▶ its *denominator*  $y$ .

## Rational Addition

Suppose we want to implement the addition of two rational numbers.

```
def addRationalNumerator(n1: Int, d1: Int, n2: Int, d2: Int): Int  
def addRationalDenominator(n1: Int, d1: Int, n2: Int, d2: Int): Int
```

but it would be difficult to manage all these numerators and denominators.

A better choice is to combine the numerator and denominator of a rational number in a data structure.

# Classes

In Scala, we do this by defining a *class*:

```
class Rational(x: Int, y: Int):  
  def numer = x  
  def denom = y
```

This definition introduces two entities:

- ▶ A new *type*, named Rational.
- ▶ A *constructor* Rational to create elements of this type.

Scala keeps the names of types and values in *different namespaces*. So there's no conflict between the two entities named Rational.

# Objects

We call the elements of a class type *objects*.

We create an object by calling the constructor of the class:

## Example

```
Rational(1, 2)
```

## Members of an Object

Objects of the class `Rational` have two *members*, `numer` and `denom`.

We select the members of an object with the infix operator `'.'`.

### Example

```
val x = Rational(1, 2) // x: Rational = Rational@2abe0e27
x.numer                // 1
x.denom                // 2
```

# Rational Arithmetic

We can now define the arithmetic functions that implement the standard rules.

$$\frac{n_1}{d_1} + \frac{n_2}{d_2} = \frac{n_1 d_2 + n_2 d_1}{d_1 d_2}$$

$$\frac{n_1}{d_1} - \frac{n_2}{d_2} = \frac{n_1 d_2 - n_2 d_1}{d_1 d_2}$$

$$\frac{n_1}{d_1} \cdot \frac{n_2}{d_2} = \frac{n_1 n_2}{d_1 d_2}$$

$$\frac{n_1}{d_1} / \frac{n_2}{d_2} = \frac{n_1 d_2}{d_1 n_2}$$

$$\frac{n_1}{d_1} = \frac{n_2}{d_2} \quad \text{iff} \quad n_1 d_2 = d_1 n_2$$

## Implementing Rational Arithmetic

```
def addRational(r: Rational, s: Rational): Rational =  
  Rational(  
    r.numer * s.denom + s.numer * r.denom,  
    r.denom * s.denom)
```

```
def makeString(r: Rational): String =  
  s"${r.numer}/${r.denom}"
```

```
makeString(addRational(Rational(1, 2), Rational(2, 3))) > 7/6
```

*Note:* `s"..."` in `makeString` is an *interpolated string*, with values `r.numer` and `r.denom` in the places enclosed by `${...}`.



# Methods

One can go further and also package functions operating on a data abstraction in the data abstraction itself.

Such functions are called *methods*.

## Example

Rational numbers now would have, in addition to the functions `numer` and `denom`, the functions `add`, `sub`, `mul`, `div`, `equal`, `toString`.

## Methods for Rationals

Here's a possible implementation:

```
class Rational(x: Int, y: Int):  
  def numer = x  
  def denom = y  
  def add(r: Rational) =  
    Rational(numer * r.denom + r.numer * denom,  
              denom * r.denom)  
  def mul(r: Rational) = ...  
  ...  
  override def toString = s"$numer/$denom"
```

*Remark:* the modifier `override` declares that `toString` redefines a method that already exists (in the class `java.lang.Object`).

## Calling Methods

Here is how one might use the new Rational abstraction:

```
val x = Rational(1, 3)
val y = Rational(5, 7)
val z = Rational(3, 2)
x.add(y).mul(z)
```

## Exercise

1. In your worksheet, add a method `neg` to class `Rational` that is used like this:

```
x.neg          // evaluates to -x
```

2. Add a method `sub` to subtract two rational numbers.
3. With the values of `x`, `y`, `z` as given in the previous slide, what is the result of

`x - y - z`

?