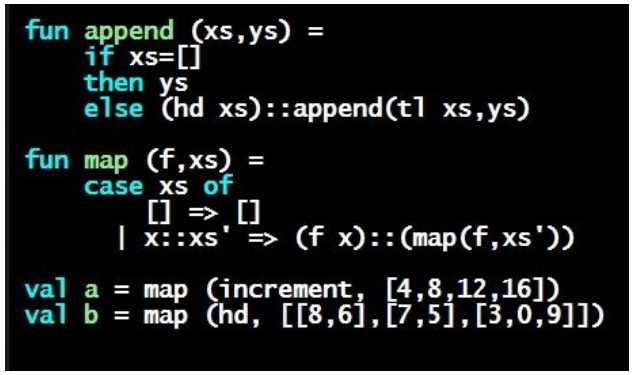

```
fun append (xs,ys) =
    if xs=[]
    then ys
    else (hd xs)::append(tl xs,ys)

fun map (f,xs) =
    case xs of
        [] => []
      | x::xs' => (f x)::(map(f,xs'))

val a = map (increment, [4,8,12,16])
val b = map (hd, [[8,6],[7,5],[3,0,9]])
```

Programming Languages

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2013

Multiple Inheritance

What next?

Have used classes for OOP's essence: inheritance, overriding, dynamic dispatch

Now, what if we want to have more than *just 1 superclass*

- *Multiple inheritance*: allow > 1 superclasses
  - Useful but has some problems (see C++)

- Ruby-style *mixins*: 1 superclass; > 1 method providers
  - Often a fine substitute for multiple inheritance and has fewer problems (see also Scala *traits*)

- Java/C#-style *interfaces*: allow > 1 types
  - Mostly irrelevant in a dynamically typed language, but fewer problems

Multiple Inheritance

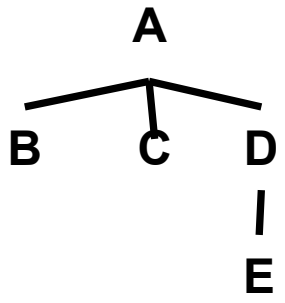
- If inheritance and overriding are so useful, why limit ourselves to one superclass?
  - Because the semantics is often awkward (this topic)
  - Because it makes static type-checking harder (not discussed)
  - Because it makes efficient implementation harder (not discussed)

- Is it useful? Sure!
  - Example: Make a **`ColorPt3D`** by inheriting from **`Pt3D`** and **`ColorPt`** (or maybe just from **`Color`**)
  - Example: Make a **`StudentAthlete`** by inheriting from **`Student`** and **`Athlete`**
  - With single inheritance, end up copying code or using non-OOP-style helper methods

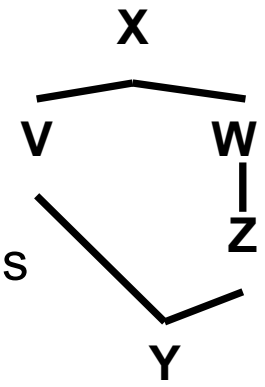
Trees, dags, and diamonds

- Note: The phrases *subclass*, *superclass* can be ambiguous
  - There are *immediate* subclasses, superclasses
  - And there are *transitive* subclasses, superclasses

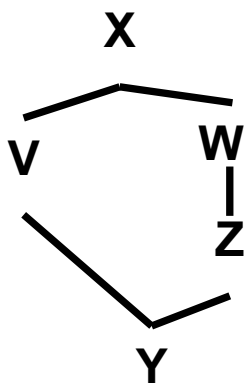
- Single inheritance: the *class hierarchy* is a tree
  - Nodes are classes
  - Parent is immediate superclass
  - Any number of children allowed



- Multiple inheritance: the class hierarchy no longer a tree
  - Cycles still disallowed (a directed-acyclic graph)
  - If multiple paths show that *X* is a (transitive) superclass of *Y*, then we have *diamonds*



What could go wrong?



- If *V* and *Z* both define a method **`m`**,
  what does *Y* inherit? What does **`super`** mean?
  - *Directed resends* useful (e.g., **`Z::super`**)

- What if *X* defines a method **`m`** that *Z* but not *V* overrides?
  - Can handle like previous case, but sometimes undesirable (e.g., **`ColorPt3D`** wants **`Pt3D`**'s overrides to "win")

- If *X* defines fields, should *Y* have one copy of them (**`f`**) or two (**`V::f`** and **`Z::f`**)?
  - Turns out each behavior can be desirable (next slides)
  - So C++ has (at least) two forms of inheritance

3DColorPoints

If Ruby had multiple inheritance, we would want `ColorPt3D` to inherit methods that share one `@x` and one `@y`

```
class Pt
  attr_accessor :x, :y
  …
end
class ColorPt < Pt
 attr_accessor :color
 …
end
class Pt3D < Pt
 attr_accessor :z
 … # override some methods
end
class ColorPt3D < Pt3D, ColorPt # not Ruby!
end
```

ArtistCowboys

This code has **`Person`** define a pocket for subclasses to use, but an **`ArtistCowboy`** wants *two* pockets, one for each **`draw`** method

```
class Person
  attr_accessor :pocket
  …
end
class Artist < Person # pocket for brush objects
 def draw # access pocket
 …
end
class Cowboy < Person # pocket for gun objects
 def draw # access pocket
 …
end
class ArtistCowboy < Artist, Cowboy # not Ruby!
end
```