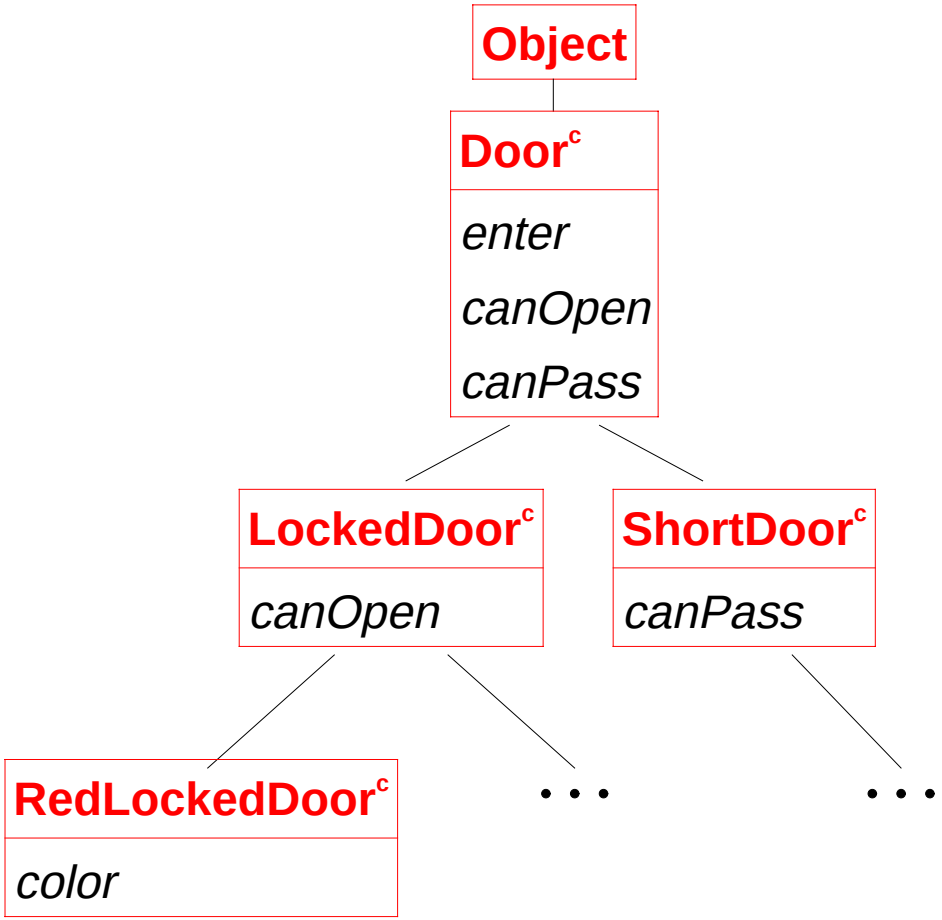
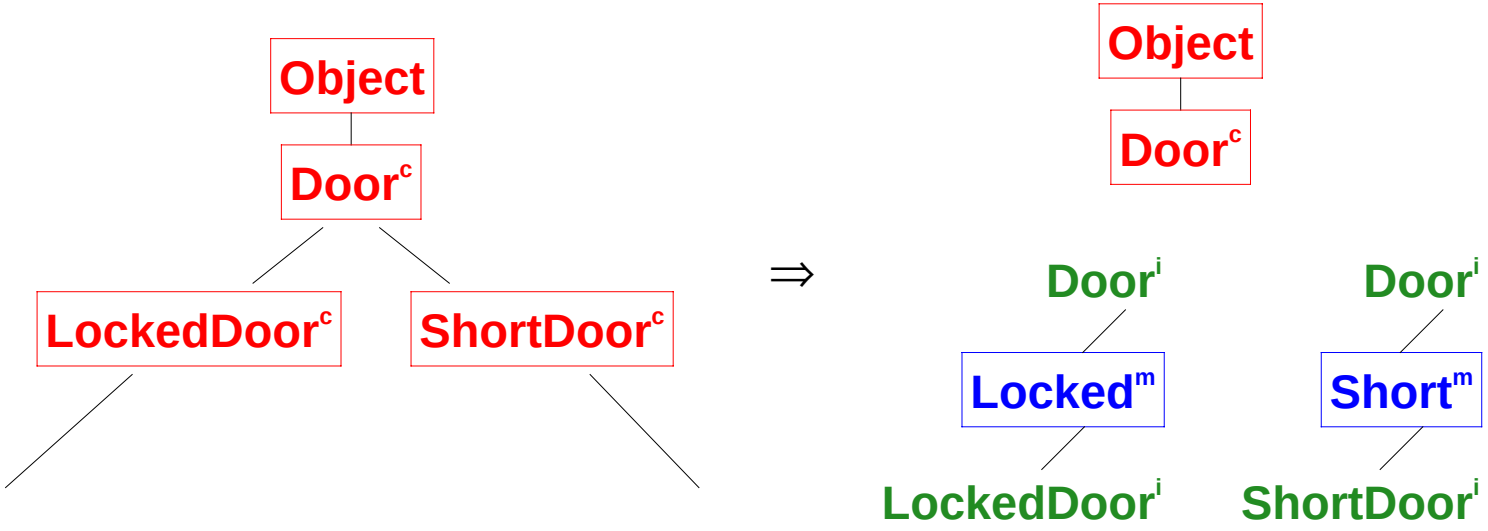
Classes



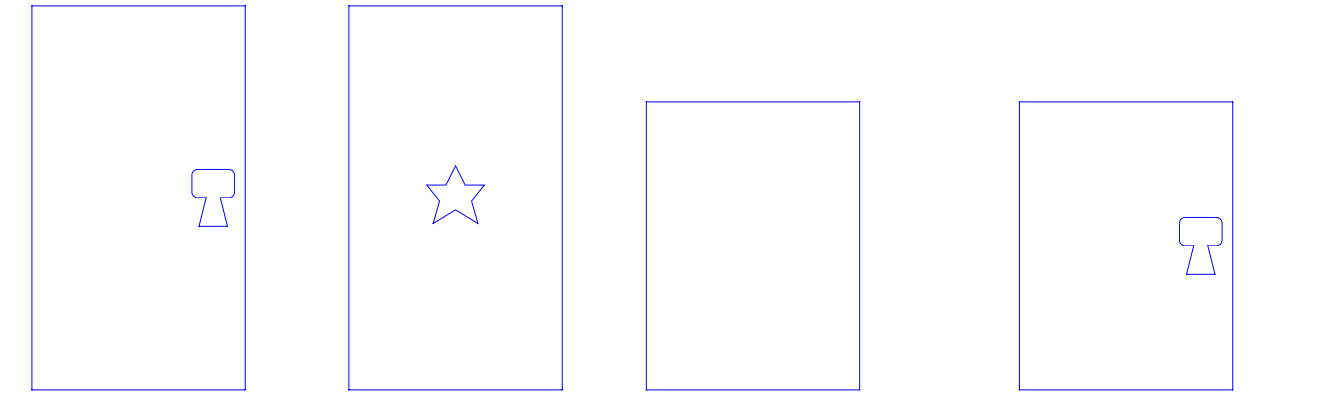
- Each node is a ***class extension***
- Each chain of nodes to the root is a ***class***

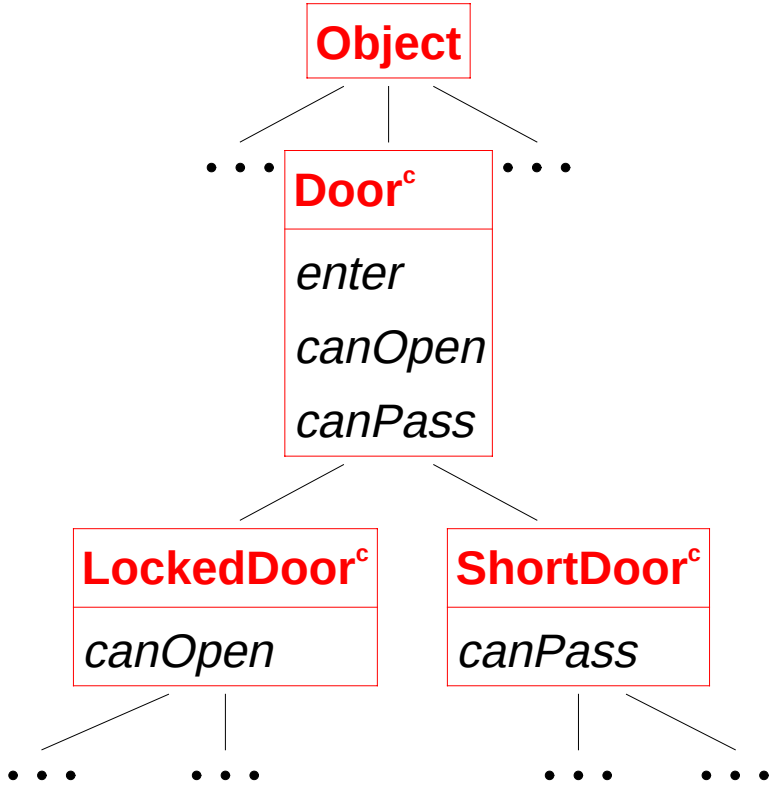
Mixins



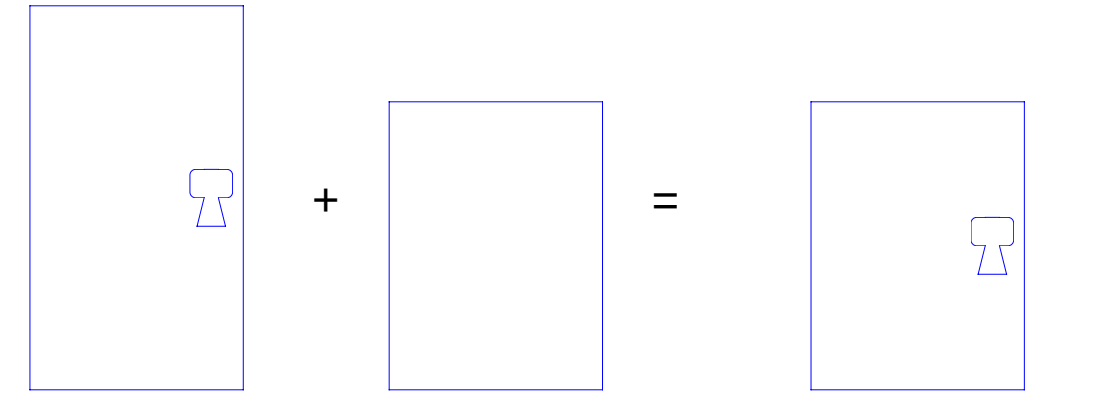
- A ***mixin*** is a class extension without a superclass
- Mixins are more reuseable than class extensions
- Mixins preserve the single-inheritance programming model

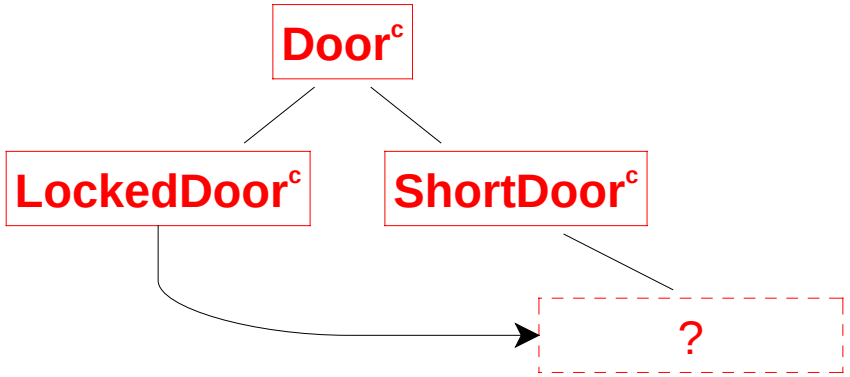
Motivating Example: Door Classes in a Maze Adventure Game



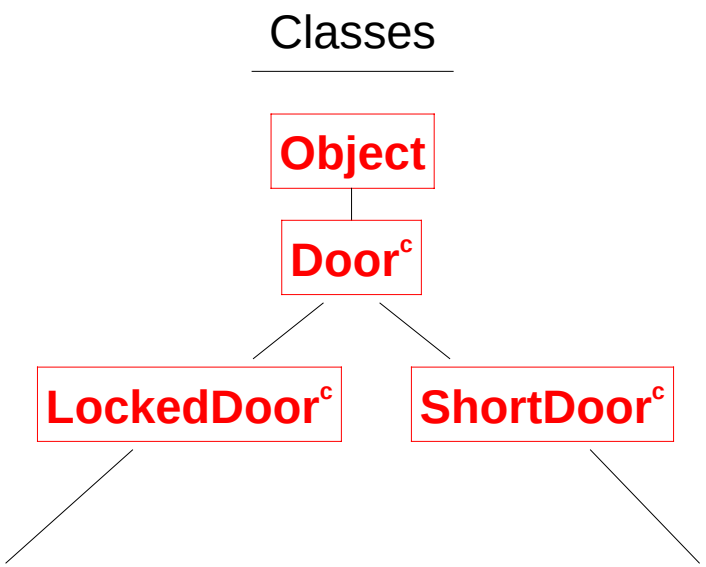


Combining Locked and Short Doors

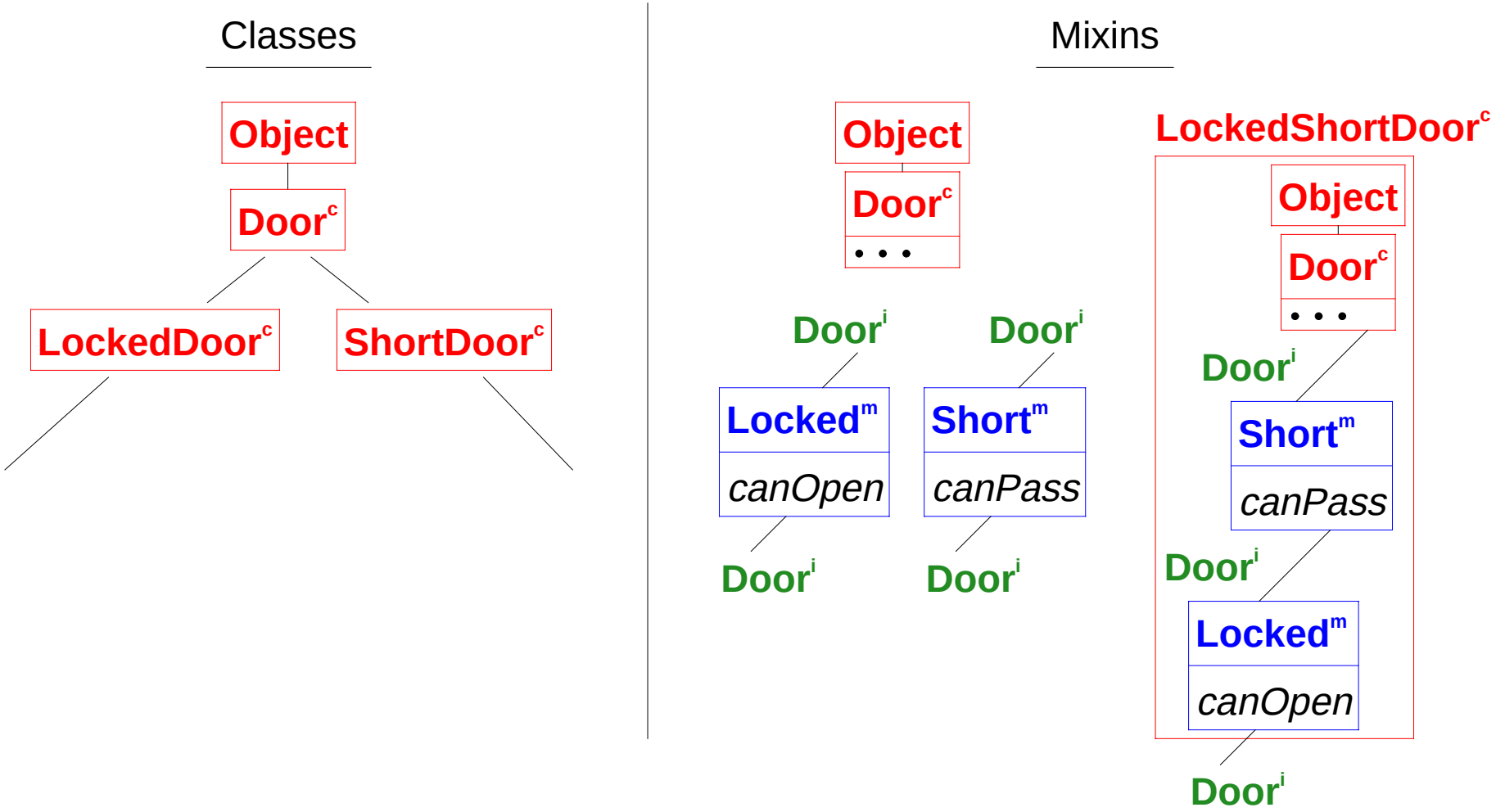




Mixins Allow Combinations



Mixins Allow Combinations



Mixins Allow Combinations

Classes

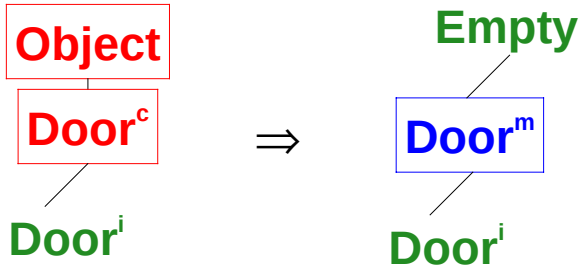
```
class LockedDoor^c extends Door^c {
  boolean canOpen(Person^c p) {
    ....
  }
}

class ShortDoor^c extends Door^c {
  boolean canPass(Person^c p) {
    ....
  }
}

/* LockedShortDoor^c? */
```

Mixins

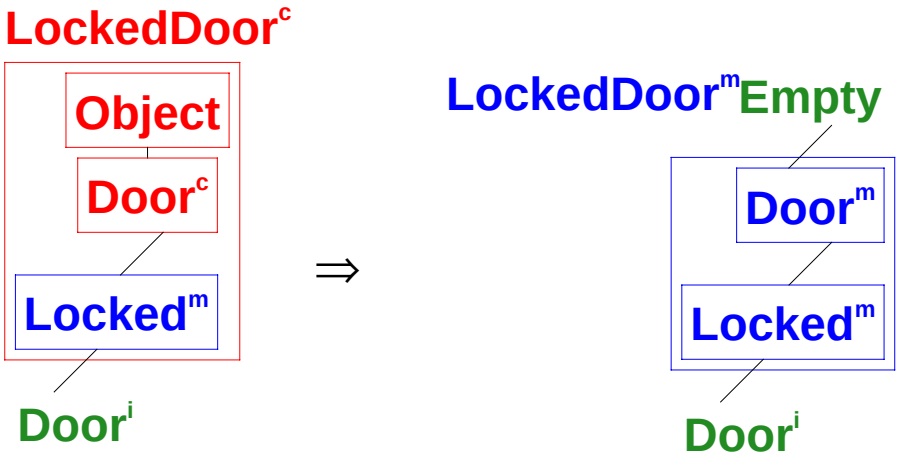
```
mixin Locked^m extends Door^i {
  boolean canOpen(Person^c p) {
    ....
  }
}

mixin Short^m extends Door^i {
  boolean canPass(Person^c p) {
    ....
  }
}

class LockedDoor^c = Locked^m(Door^c);
class ShortDoor^c = Short^m(Door^c);
class LockedShortDoor^c
    = Locked^m(Short^m(Door^c));
```

Mixins Replace Classes

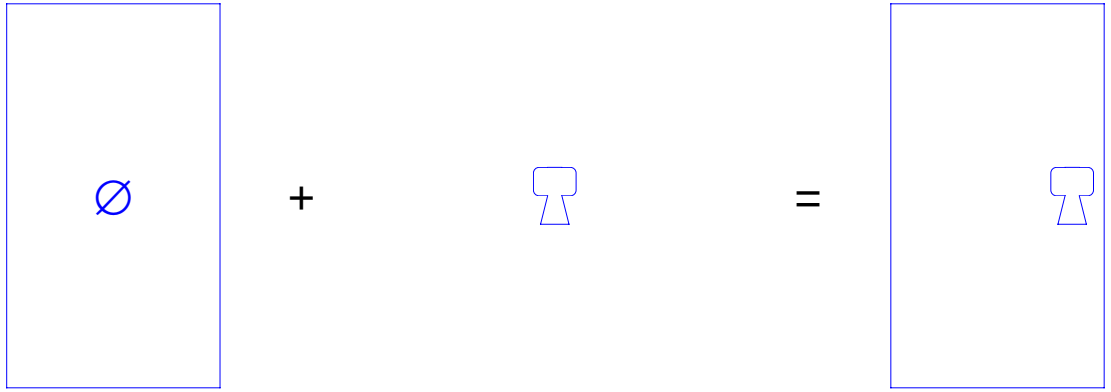
Empty is a special built-in interface



Mixin applications can be replaced with mixin compositions



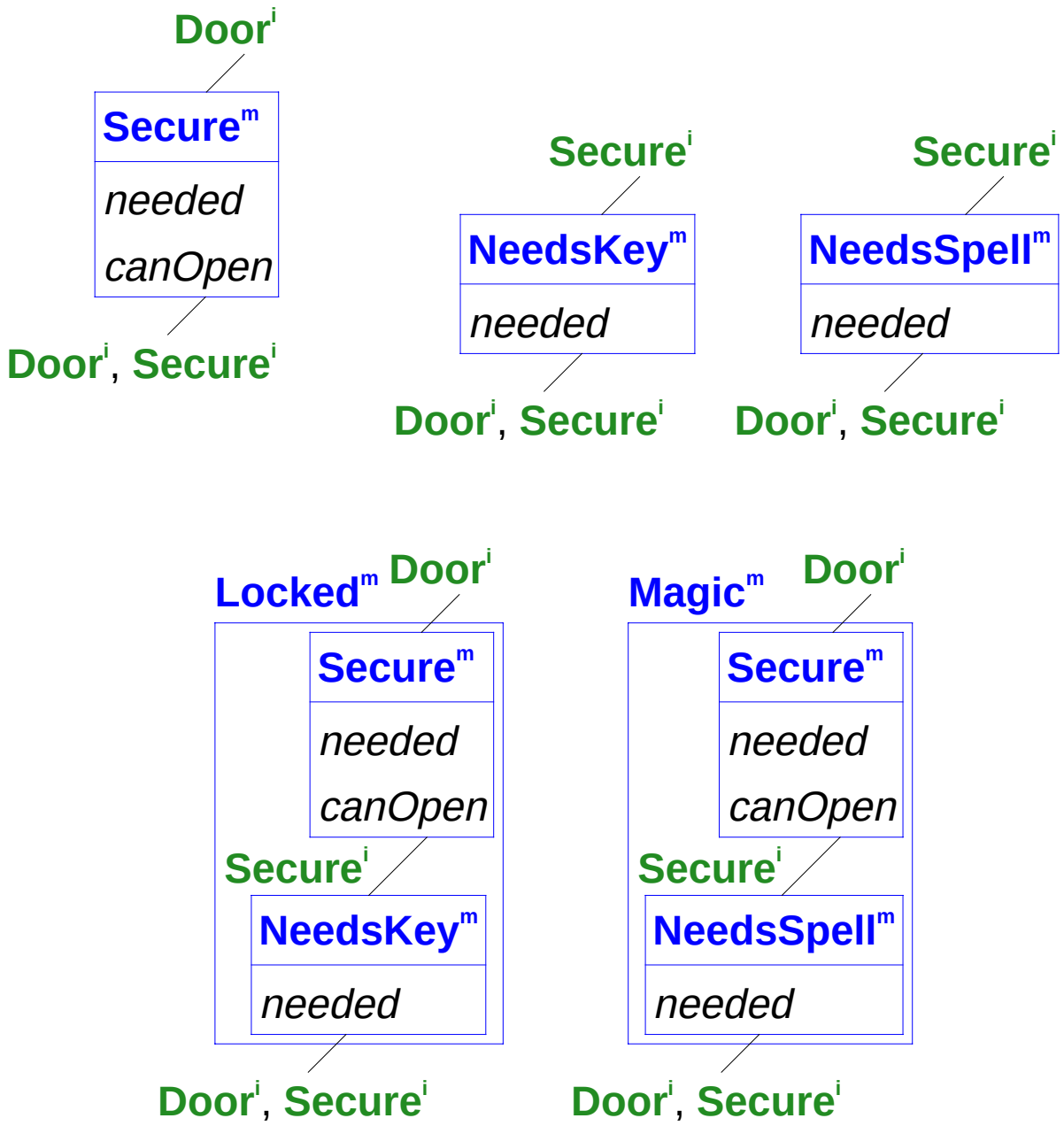
Locked and Magic Doors are Secure Doors



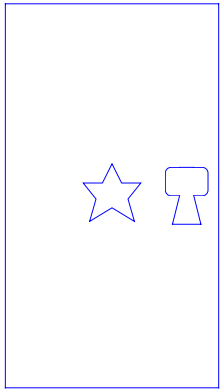
Secure Door Locked Needs Key Locked Door

Secure Door Magic Needs Spell Magic Door

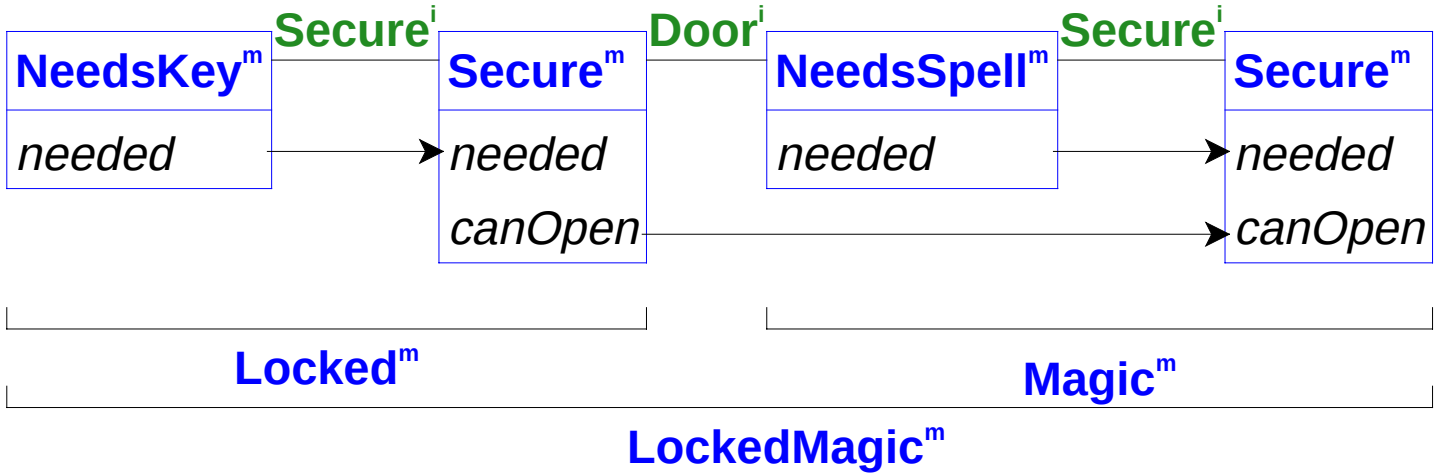
Locked and Magic Door Mixins as Compositions



Locked Magic Doors



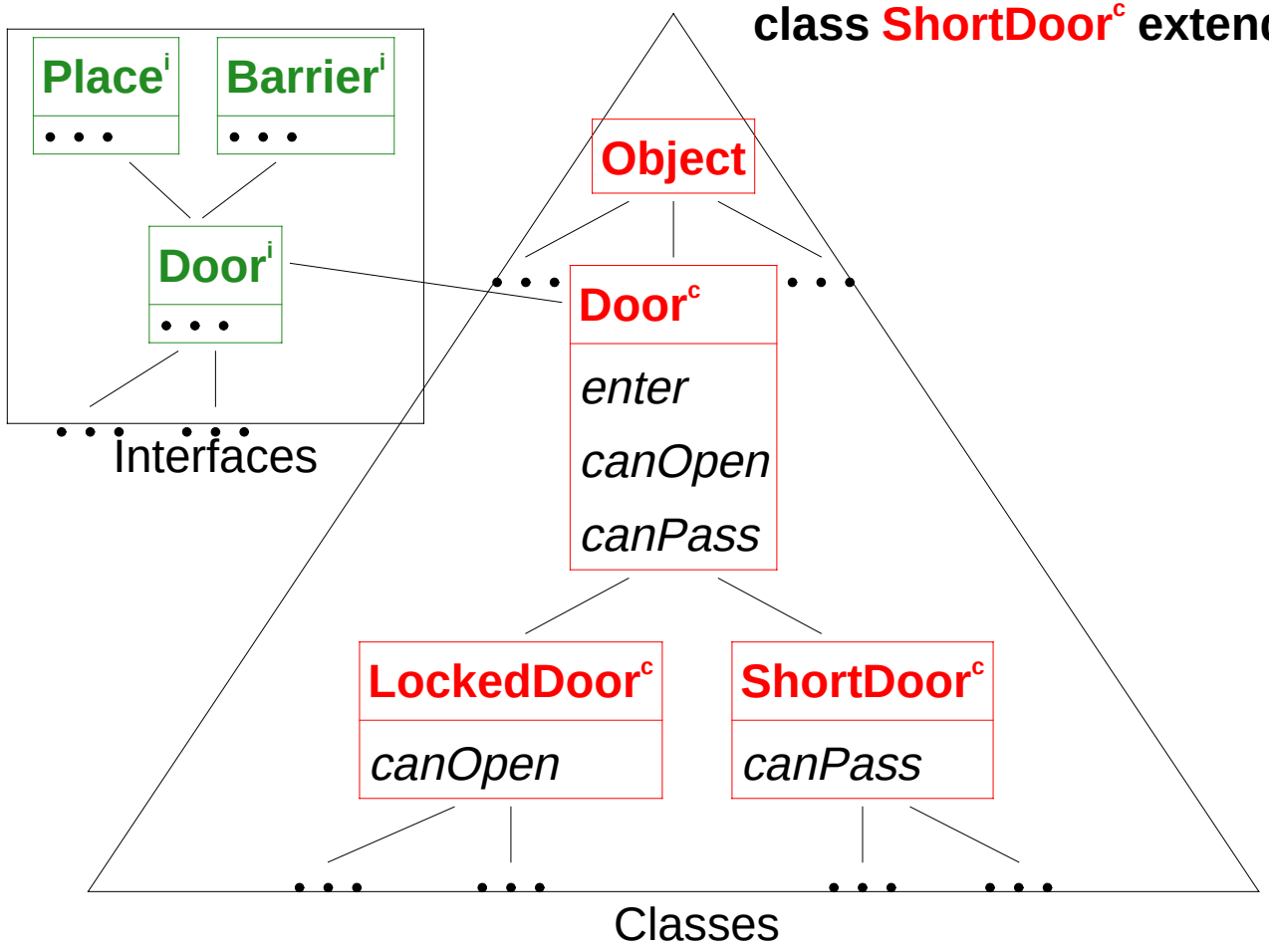
LockedMagic^{m} = **Locked^{m}** **compose** **Magic^{m}**



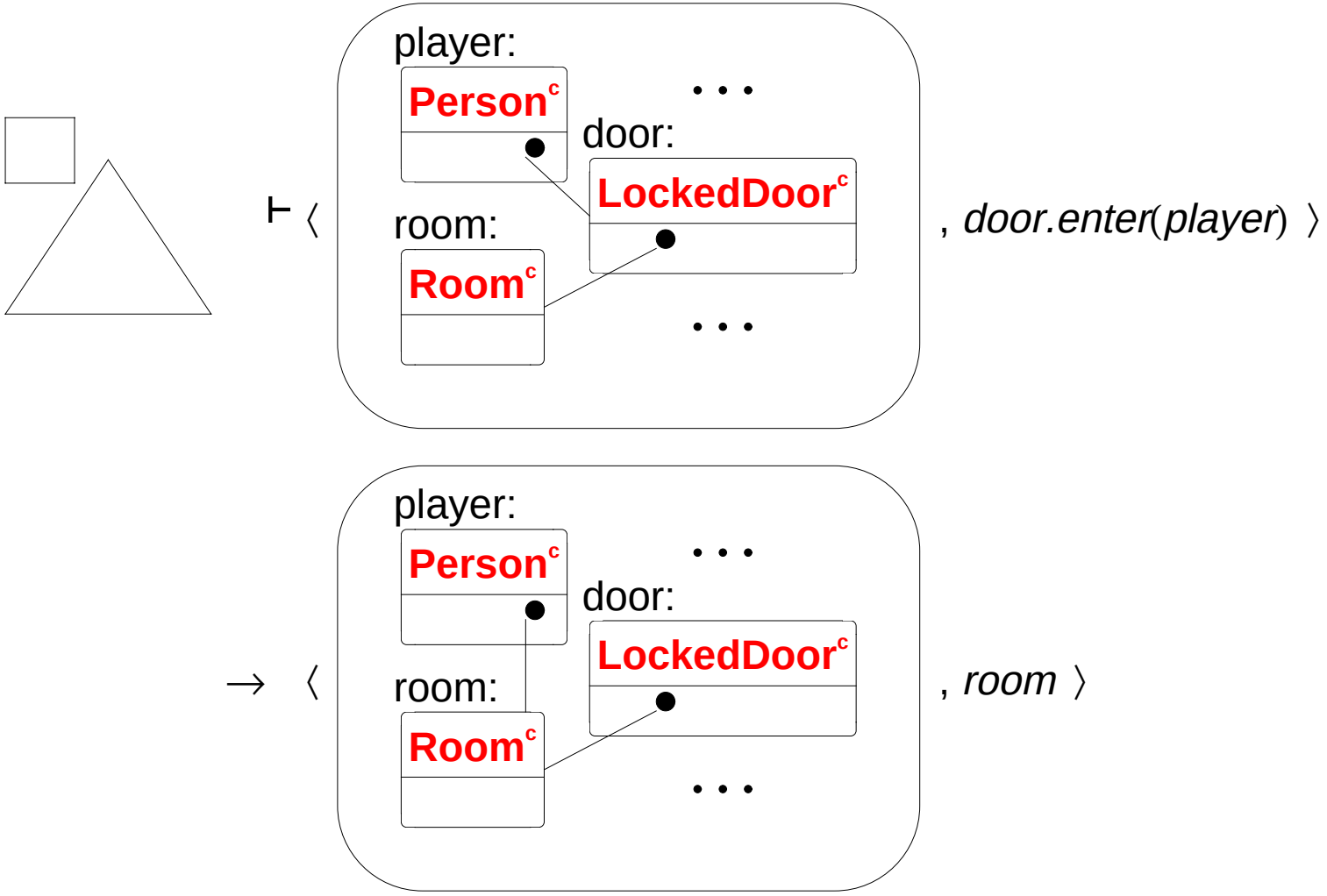
- **Door^{i}** does not contain *needed*, so there are two distinct *needed* methods in **LockedMagic^{m}**

Type Checking for Classes

```
interface Door^i extends Place^i, Barrier^i ....
class Door^c extends Object implements Door^i {
  Room^c enter(Person^c p) { .... }
  boolean canOpen(Person^c p) { .... }
  boolean canPass(Person^c p) { .... } }
class LockedDoor^c extends Door^c ....
class ShortDoor^c extends Door^c ....
```



Evaluation for Classes

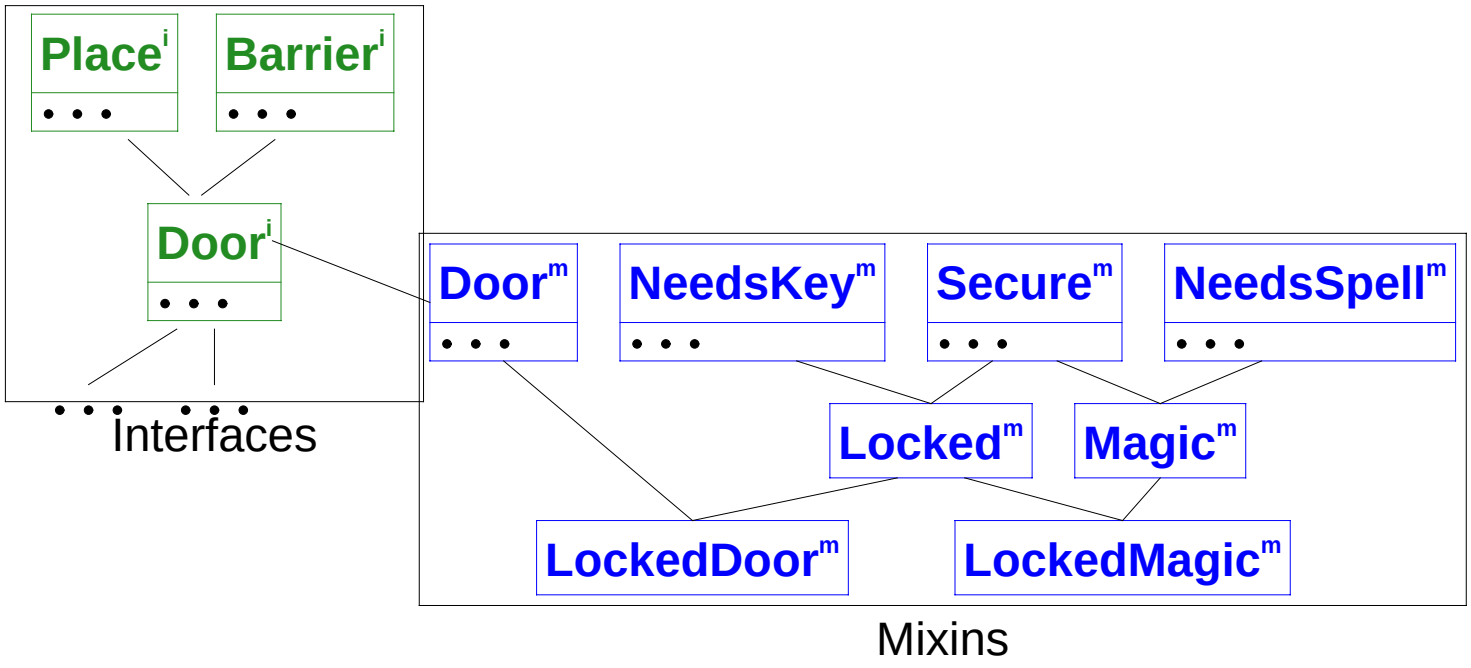


Type Checking for Mixins

Locked^m = Secure^m compose NeedsKey^m

Magic^m = Secure^m compose NeedsSpell^m

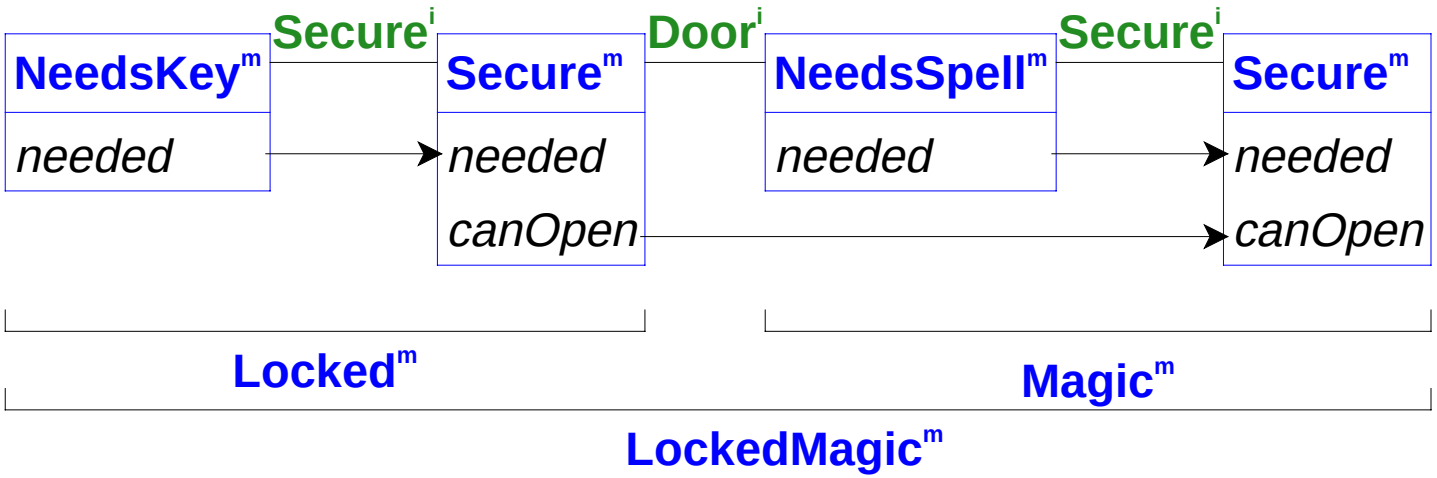
• • •



- composite mixin ⇒ linear chain of atomic mixins
- parents = supertypes, parents ≠ subsumable types

“Viewable As” Relation

X subsumes Y ⇔ X is viewable as Y



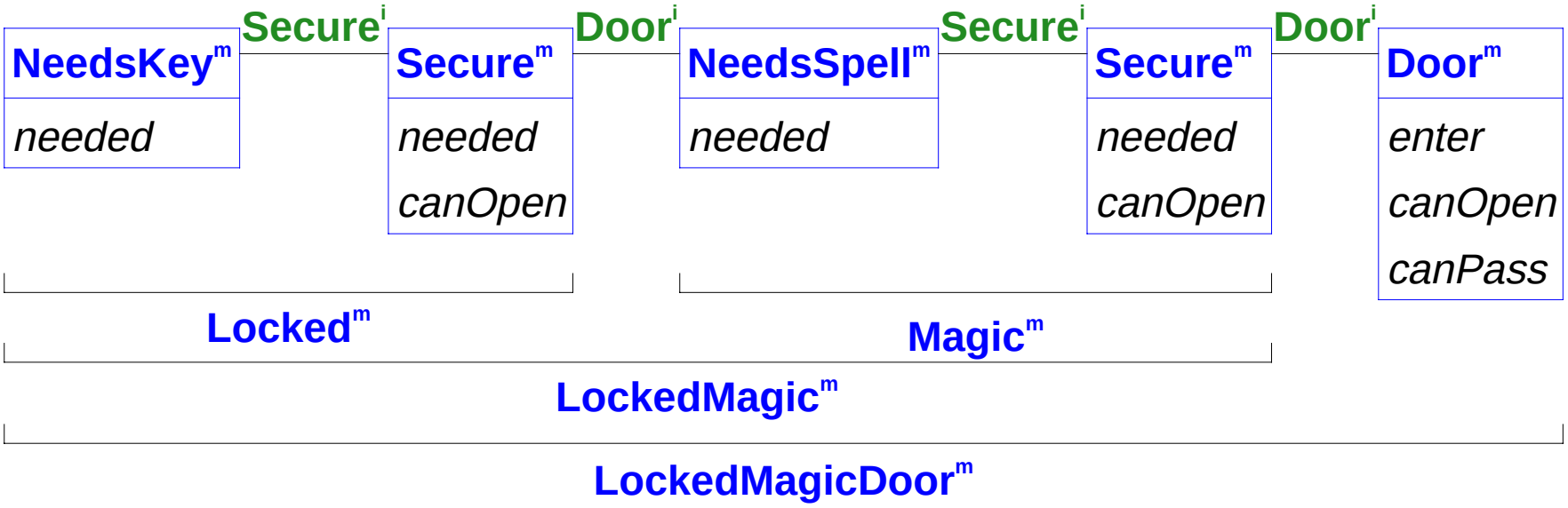
- **LockedMagic**^{m} is viewable as **Locked**^{m} and **Magic**^{m}
- **Locked**^{m} and **Magic**^{m} are viewable as **Secure**^{m}
- **LockedMagic**^{m} is *not* viewable as **Secure**^{m} because **Secure**^{m} is ambiguous in **LockedMagic**^{m}

Mixin Coercions Require Run-time Work

```
Object get(Secure^m o) {
  return o.needed();
}

LockedMagicDoor^m door = new LockedMagicDoor^m;
get(view Locked^m door); /* ==> key */
get(view Magic^m door);  /* ==> magic book */
```

- Intermediate coercions allow *door* as a **Secure**^{m}
- *o.needed*() accesses a different method each time
- Method dispatching depends on the history of run-time coercions

Coercions Recorded with Views

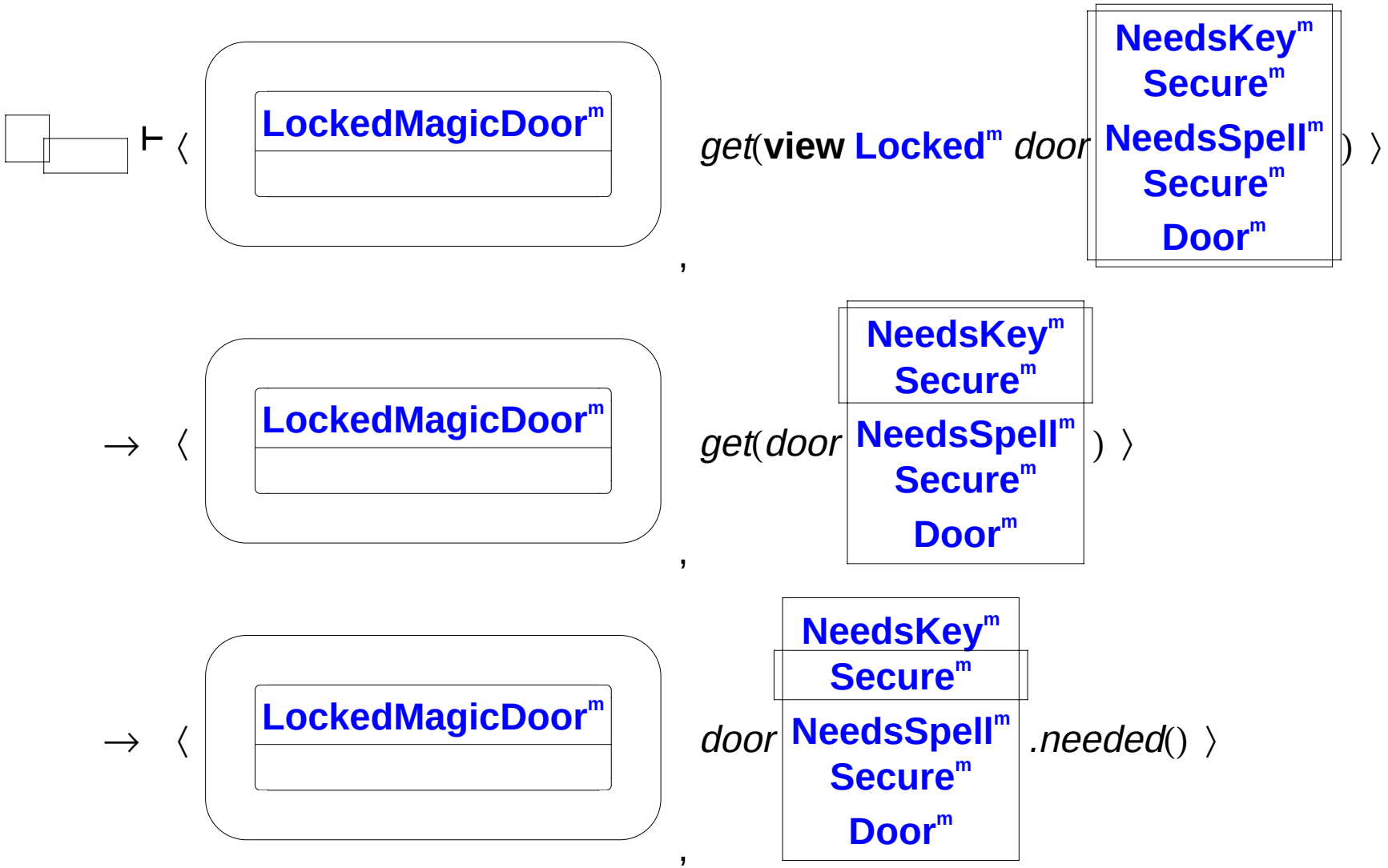


new **LockedMagicDoor**^{m} $\Rightarrow$ *door* **NeedsKey**^{m} **Secure**^{m} **NeedsSpell**^{m} **Secure**^{m} **Door**^{m}

view **Locked**^{m} *door* **NeedsKey**^{m} **Secure**^{m} **NeedsSpell**^{m} **Secure**^{m} **Door**^{m} $\Rightarrow$ *door* **NeedsKey**^{m} **Secure**^{m} **NeedsSpell**^{m} **Secure**^{m} **Door**^{m}

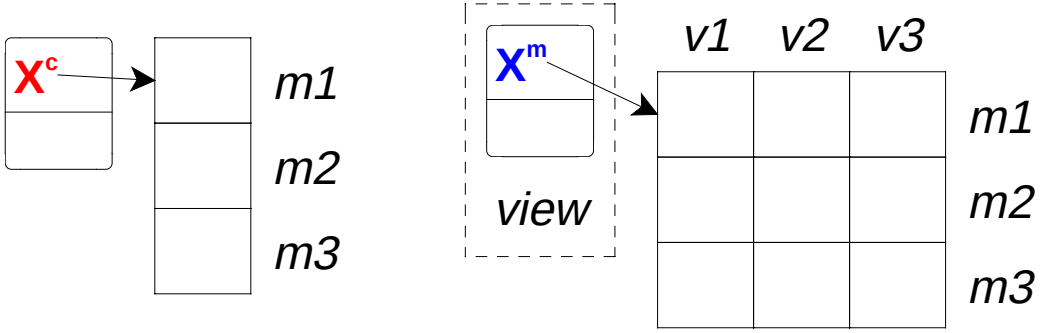
Mixin Evaluation

- Values are object-view pairs
- Coercions adjust the run-time view of an object reference



Implementing Mixins

- Every object reference is double-wide: half for object and half for view
- Method lookup requires a two-dimensional virtual table per instantiated chain



- *Cost of mixins = cost of interfaces*
- No cost to programs that do not use mixins

Mixins

- Locally, programming with mixins is the same as single-inheritance classes...
- ... but the programmer is forced to ‘‘program to an interface, not an implementation’’
- Mixin code is more reusable than class code
- Cost of mixins is reasonable (same as interfaces)