From Functions to Objects

- Functional languages (Scheme, ML)
  - ADT is a type and a collection of functions

$$\textbf{make-fish} : (\texttt{num} \rightarrow \texttt{fish})$$
$$\textbf{grow-fish} : (\texttt{fish num} \rightarrow \texttt{fish})$$
$$\textbf{fish-size} : (\texttt{fish} \rightarrow \texttt{num})$$

- Object-oriented languages (Java, C++, Smalltalk)
  - ADT is a class

$$\texttt{fish}\ \textbf{class}$$
$$\textbf{method initialize} : (\texttt{num} \rightarrow)$$
$$\textbf{method grow} : (\texttt{num} \rightarrow)$$
$$\textbf{method size} : (\rightarrow \texttt{num})$$

From Functions to Objects

We can implement objects with functions:

```
(define (mk-fish size)
  (letrec ([get-size (lambda () size)]
           [grow (lambda (s)
                   (set! size (+ s size)))]
           [eat (lambda (fish)
                  (grow ((fish 'get-size))))])
    (lambda (msg)
      (cond
       [(eq? msg 'get-size) get-size]
       [(eq? msg 'grow) grow]
       [(eq? msg 'eat) eat]))))
```

but it's not convenient!

Elements of an OO Language

- (Expressed) values = objects
- Classes
  - superclass
  - fields
  - methods
- Expression forms
  - new
  - method call
  - super call
- Program = class declarations + expression

Syntax

```
<prog>          ::=  <class-decl>* <expr>

<class-decl>    ::=  class <id> extends <id>
                       <field-decl>*
                       <method-decl>*
<field-decl>    ::=  field <id>
<method-decl>   ::=  method <id>(<id>*(,))<expr>

<expr>          ::=  new <id>(<expr>*(,))
                ::=  send <expr> <id>(<expr>*(,))
                ::=  super <id>(<expr>*(,))
                ::=  ...
```

Example

```
class fish extends object
  field size
  method initialize (s) set size = s
  method get_size() size
  method grow(food)
    set size = +(size, food)
  method eat(other_fish)
    let s = send other_fish get_size()
     in send self grow(s)

let f = new fish(10)
 in begin
     send f grow(2);
     send f get_size()
    end
```

Example

```
class fish extends object
  field size
  method initialize (s) set size = s
  method get_size() size
  method grow(food)
    set size = +(size, food)
  method eat(other_fish)
    let s = send other_fish get_size()
     in send self grow(s)

class colorfish extends fish
  field color
  method set_color(c) set color = c
  method get_color() color
...
```

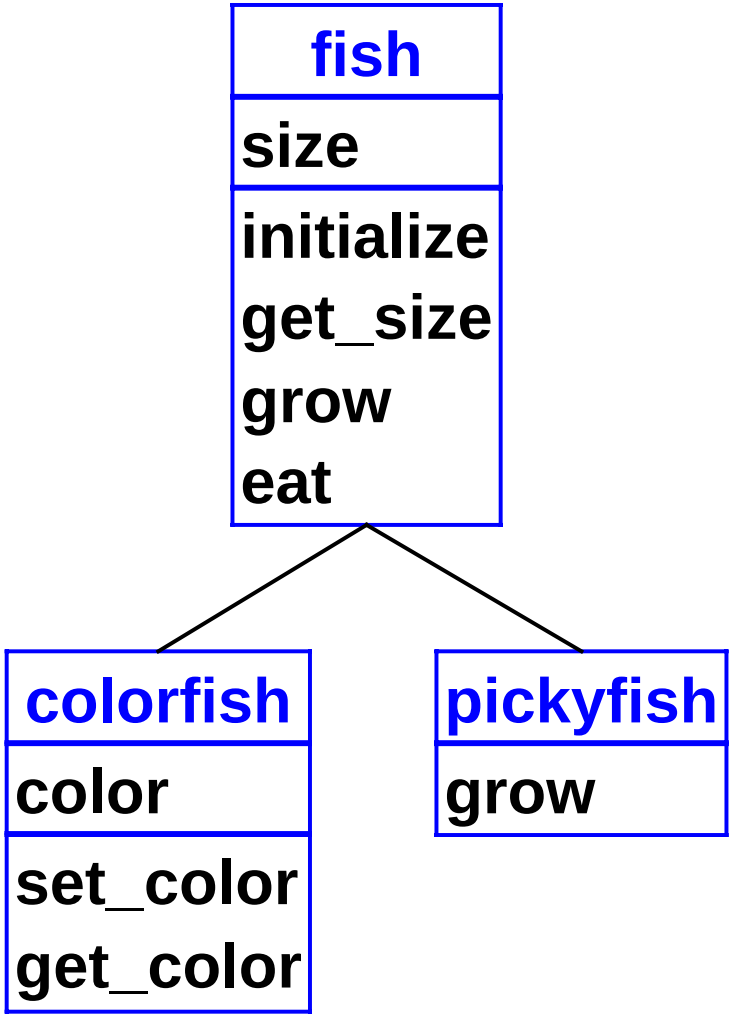
Example

```
class fish extends object
  field size
  method initialize (s) set size = s
  method get_size() size
  method grow(food)
    set size = +(size, food)
  method eat(other_fish)
    let s = send other_fish get_size()
     in send self grow(s)

...
class pickyfish extends fish
  method grow(food)
    super grow(-(food, 1))
...
```

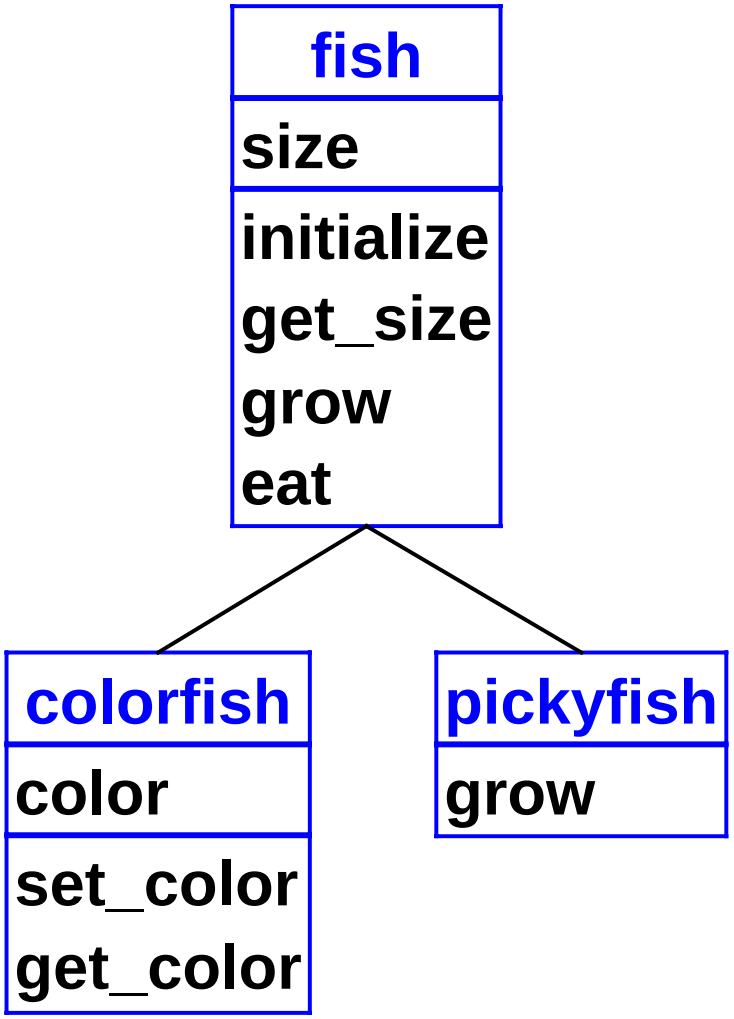
Class Tree

```
class fish ...

class colorfish
  extends fish
 ...

class pickyfish
  extends fish
 ...
```

⇒

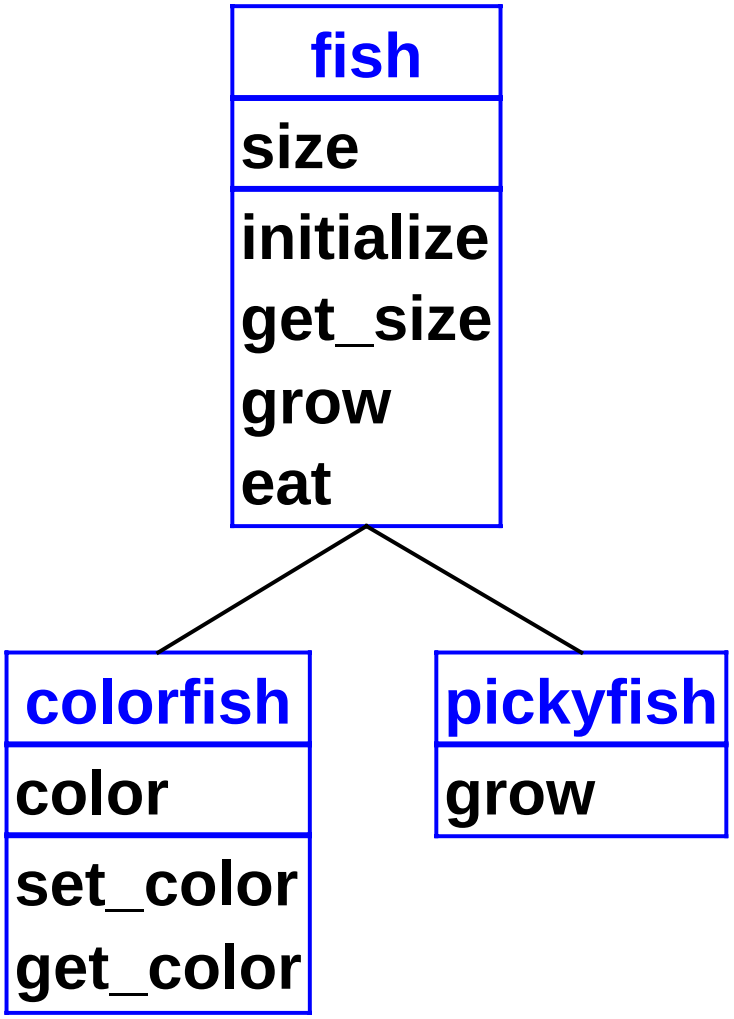


Evaluation Sketch



new colorfish(1)

Evaluation Sketch

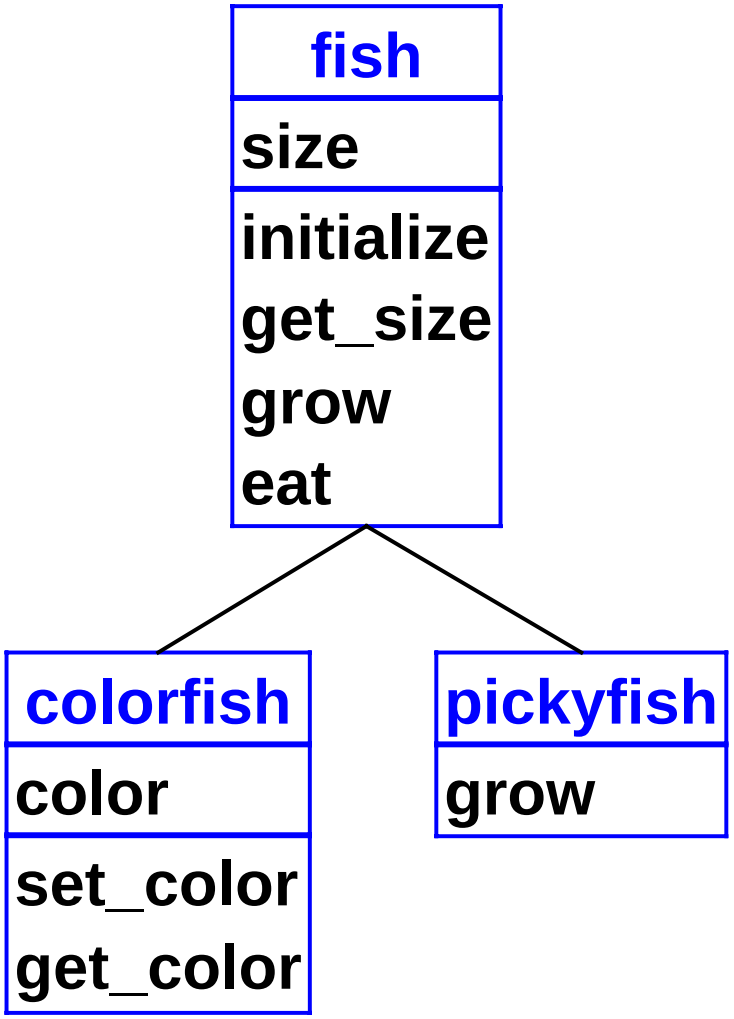


new colorfish(1)

obj =

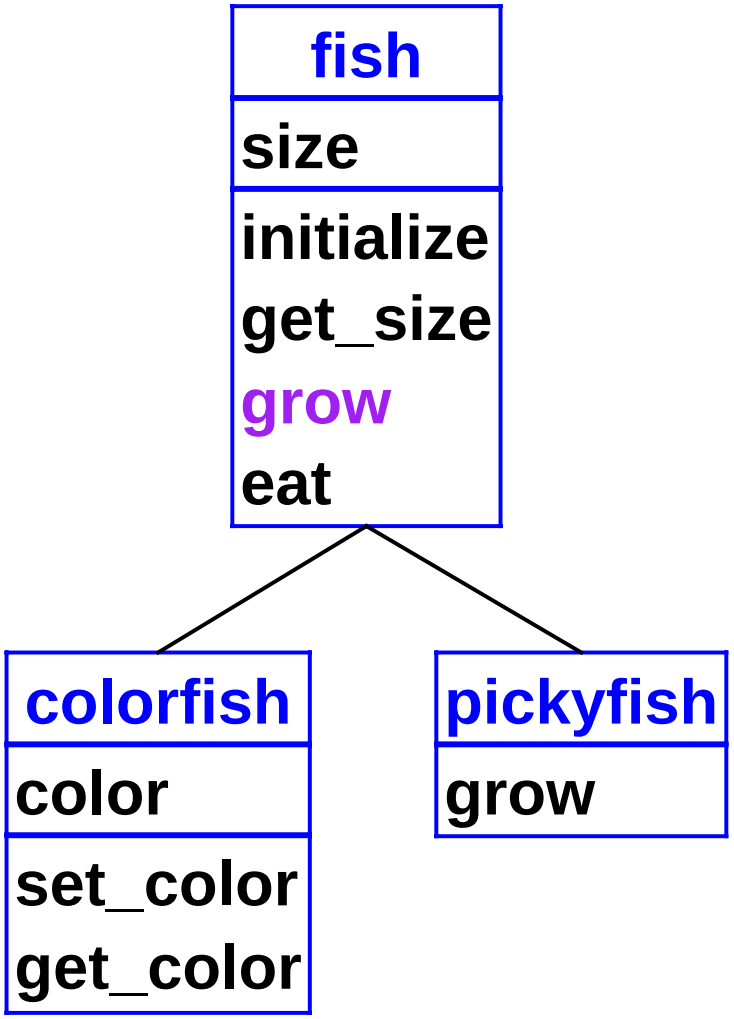
colorfish		
size	**=**	1
color	**=**	0

Evaluation Sketch




```
let
o1 = new colorfish(3)
in begin
send o1 grow(4);
send o1 get_size()
end
```

Evaluation Sketch



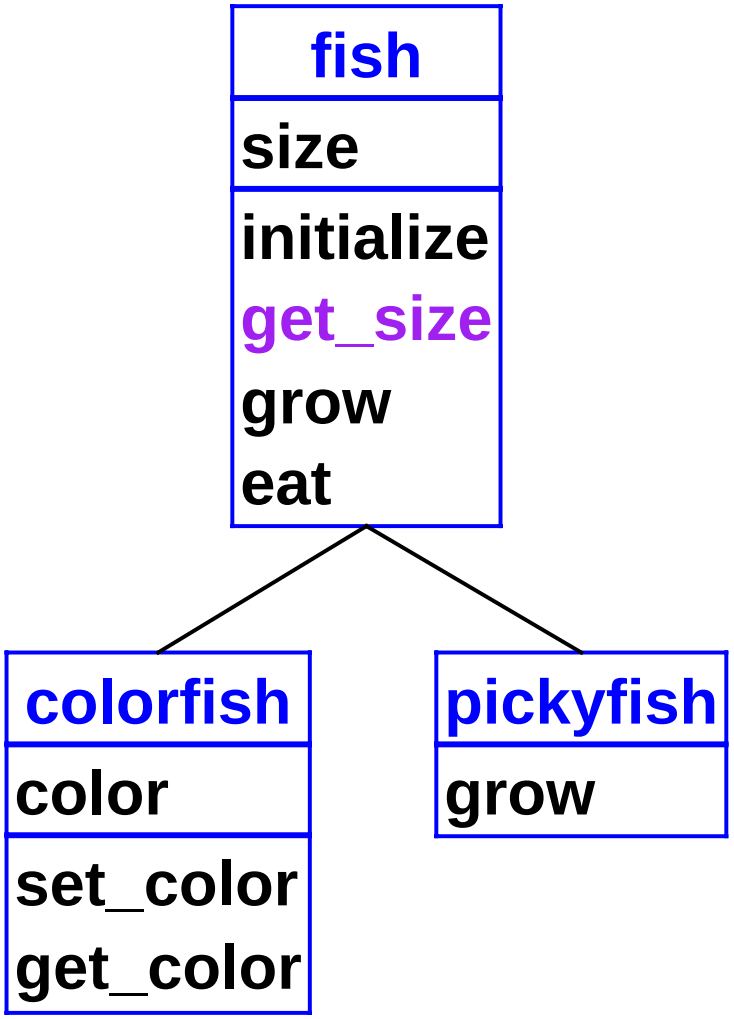
grow(f)
set size=+(size,f)

```
let
o1 = new colorfish(3)
in begin
send o1 grow(4);
send o1 get_size()
end
```

o1 =

colorfish		
size	=	3
color	=	0

Evaluation Sketch



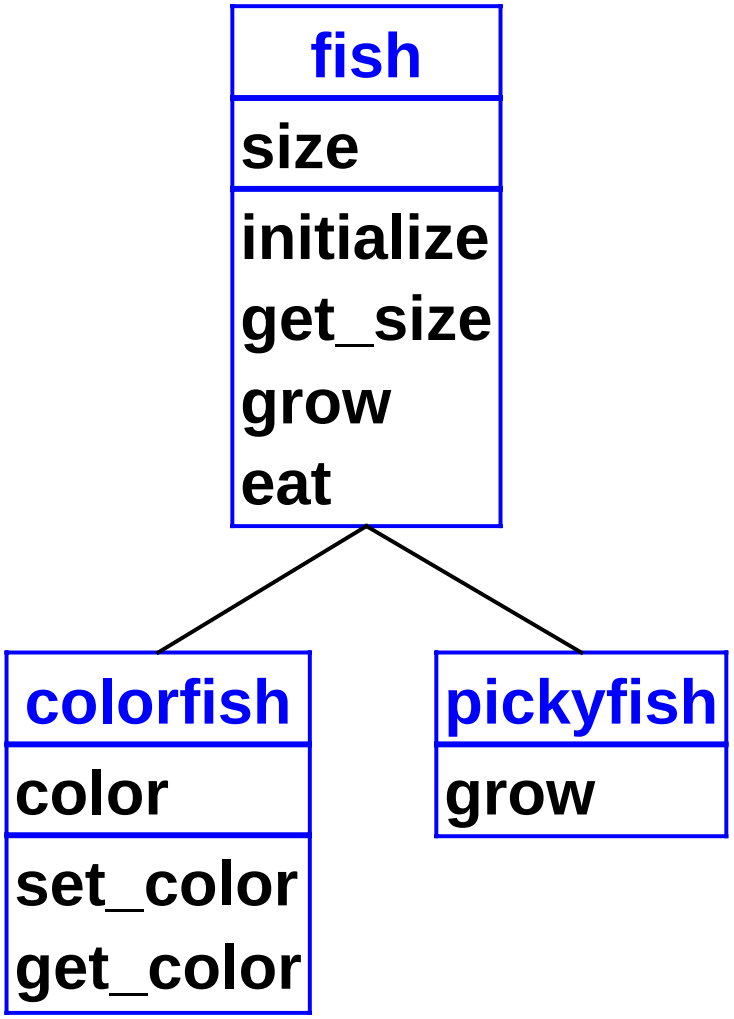
get_size() size

```
let
o1 = new colorfish(3)
in begin
send o1 grow(4);
send o1 get_size()
end
```

o1 =

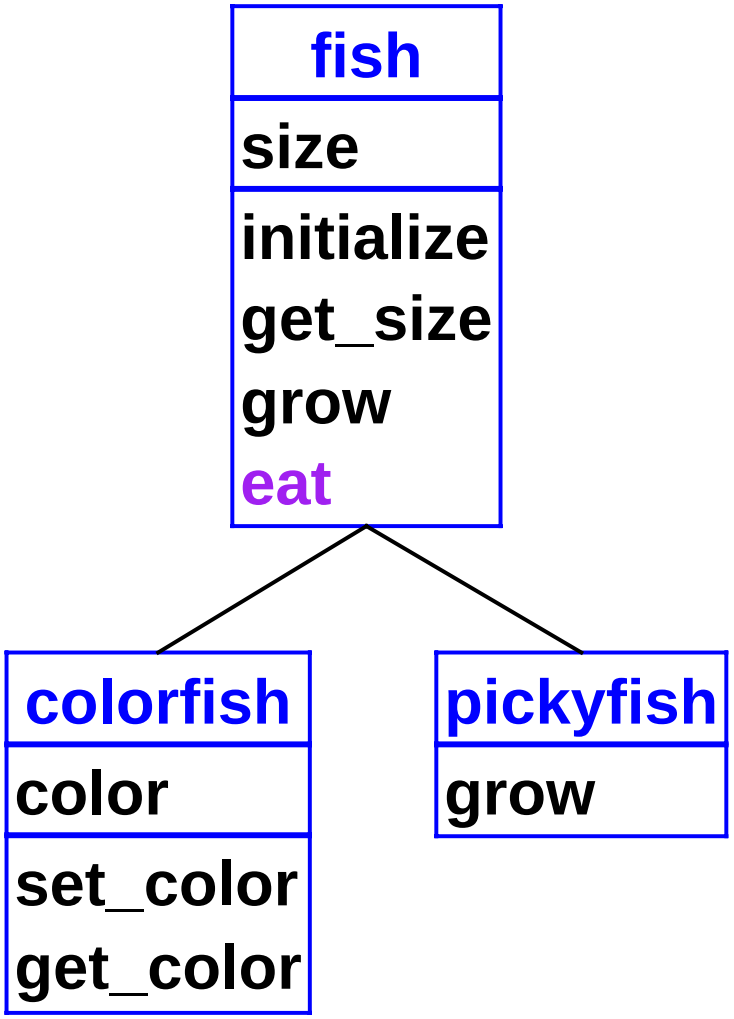
colorfish		
size	=	7
color	=	0

Evaluation Sketch




```
let
o1 = new colorfish(3)
o2 = new pickyfish(6)
in begin
send o2 eat(o1);
send o2 get_size()
end
```

Evaluation Sketch



eat(o) let s = send o get_size()
in send self grow(s)

```
let
o1 = new colorfish(3)
o2 = new pickyfish(6)
in begin
send o2 eat(o1);
send o2 get_size()
end
```

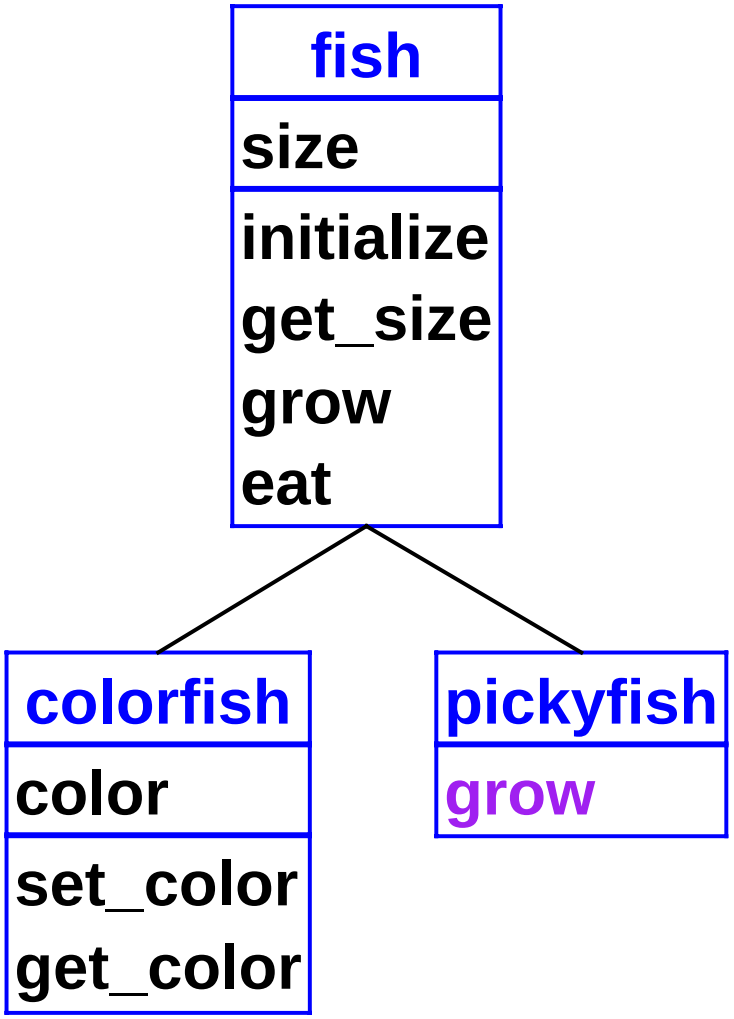
o1 =

colorfish		
size	=	3
color	=	0

o2 =

pickyfish		
size	=	6

Evaluation Sketch



grow(**f**)
super grow(-(**f**, 1))

```
let
o1 = new colorfish(3)
o2 = new pickyfish(6)
in begin
send o2 eat(o1);
send o2 get_size()
end
```

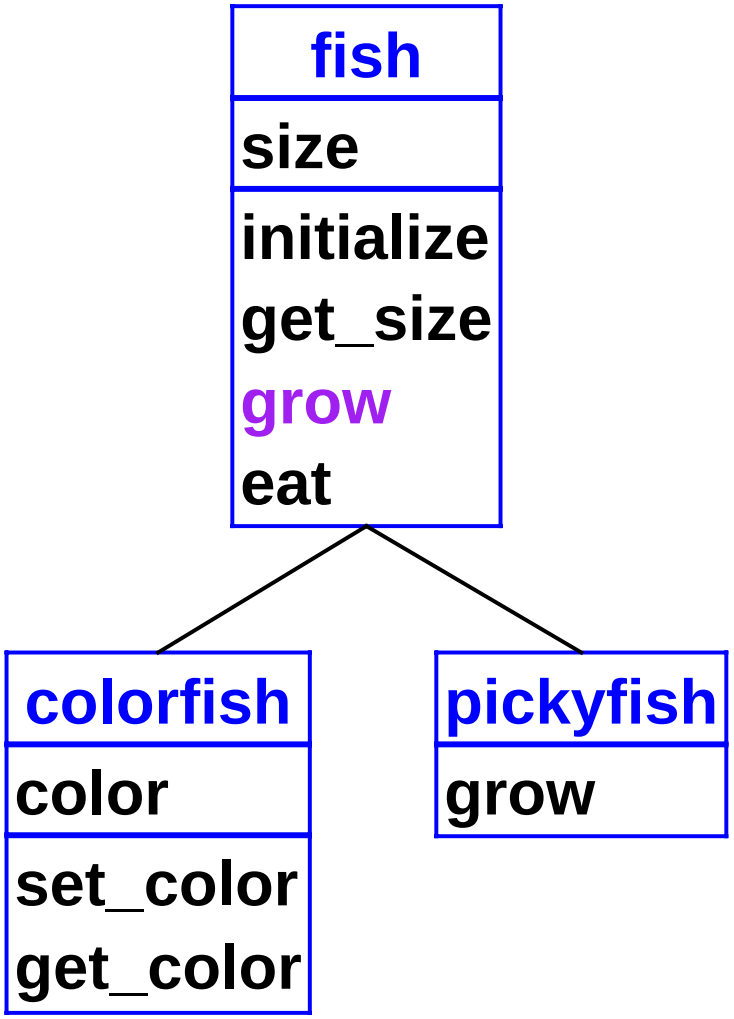
o1 =

colorfish		
size	=	3
color	=	0

o2 =

pickyfish		
size	=	6

Evaluation Sketch



grow(f)
set size=+(size,f)

```
let
o1 = new colorfish(3)
o2 = new pickyfish(6)
in begin
send o2 eat(o1);
send o2 get_size()
end
```

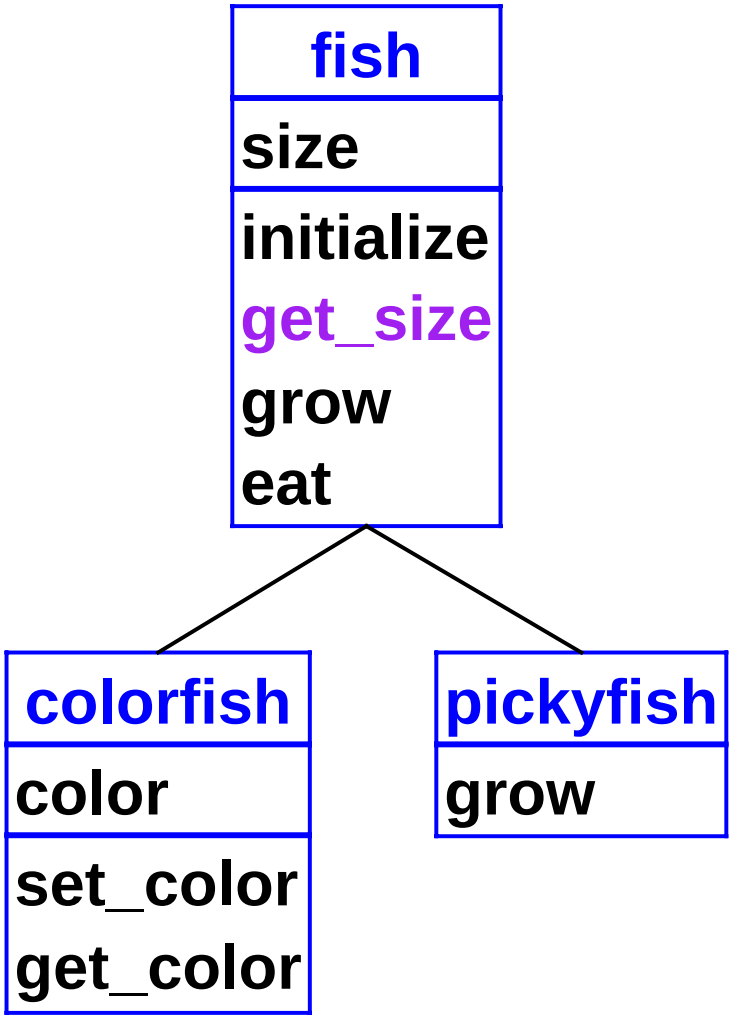
o1 =

colorfish		
size	=	3
color	=	0

o2 =

pickyfish		
size	=	6

Evaluation Sketch



get_size() size

```
let
o1 = new colorfish(3)
o2 = new pickyfish(6)
in begin
send o2 eat(o1);
send o2 get_size()
end
```

o1 =

colorfish		
size	=	3
color	=	0

o2 =

pickyfish		
size	=	8

Interpreter

- First, build class tree

```
(define eval-program
  (lambda (pgm)
    (cases program pgm
      (a-program (c-decls exp)
        (elaborate-class-decls! c-decls)
        (eval-expression exp (init-env))))))
```

```
elaborate-class-decls! : lstof-cls-decl ->
```

Interpreter

- Expression form: object creation

```
(new-object-exp (class-name rands)
  (let ((args (eval-rands rands env))
        (obj (new-object class-name)))
    (find-method-and-apply
      'initialize class-name obj args)
    obj))
```

```
elaborate-class-decls! : lstof-cls-decl ->
new-object : sym -> object
find-method-and-apply : sym sym object
                        lstof-expval -> expval
```

Interpreter

- Expression form: method call

```
(method-app-exp (obj-exp method-name rands)
  (let ((args (eval-rands rands env))
        (obj (eval-expression obj-exp env)))
    (find-method-and-apply
      method-name (object->class-name obj)
      obj args)))
```

```
elaborate-class-decls! : lstof-cls-decl ->
new-object : sym -> object
find-method-and-apply : sym sym object
                        lstof-expval -> expval
```

Interpreter

- Expression form: super call

```
(super-call-exp (method-name rands)
  (let ((args (eval-rands rands env))
        (obj (apply-env env 'self)))
    (find-method-and-apply
      method-name (apply-env env '%super)
      obj args)))
```

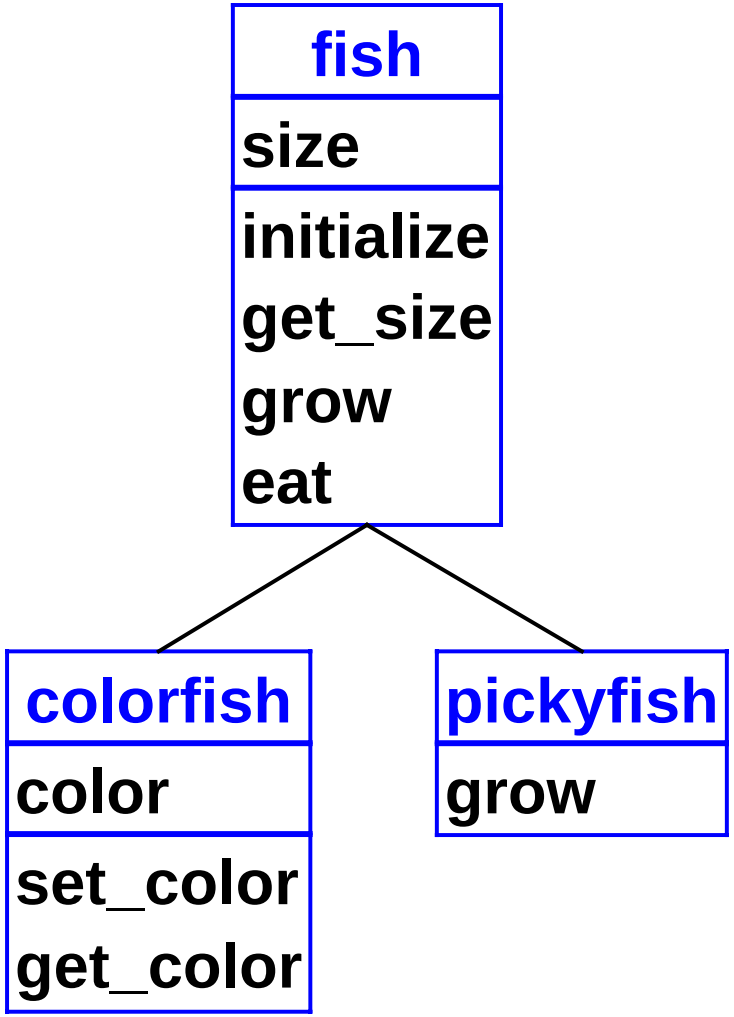
```
elaborate-class-decls! : lstof-cls-decl ->
new-object : sym -> object
find-method-and-apply : sym sym object
                        lstof-expval -> expval
```

Class Elaboration

- Elaboration can just keep the declarations

```
class fish ...

class colorfish
  extends fish
 ...

class pickyfish
  extends fish
 ...
```

=



Class Elaboration

```
(define the-class-env '())
(define (elaborate-class-decls! c-decls)
    (set! the-class-env c-decls)))
```

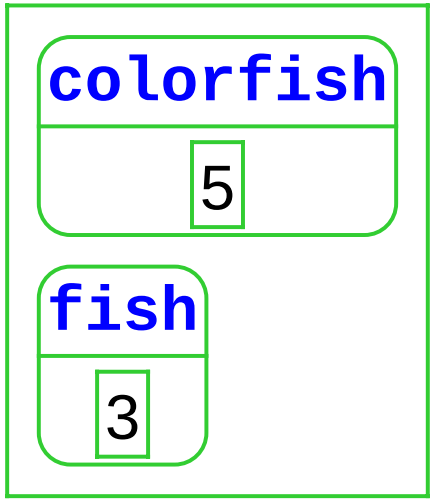
Class Elaboration

- Finding a node in the tree:

```
;; lookup-class : sym -> class-decl
(define (lookup-class name)
  (lookup name the-class-env))

;; lookup : sym lstof-cls-decl -> class-decl
(define (lookup-class-in-env name env)
  (cond
   [(null? env)
    (eopl:error 'lookup-class
                "Unknown class ~s" name)]
   [(eqv? (class-decl->class-name (car env))
          name)
    (car env)]
   [else (lookup name (cdr env))]))
```

Object Representation

- An object = a list of ***parts***
  - from instantiated class up to base class



Object Representation

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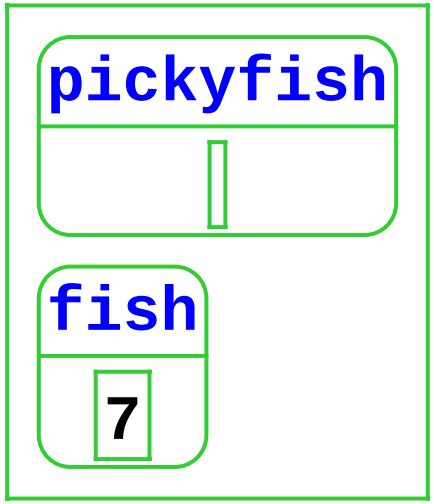
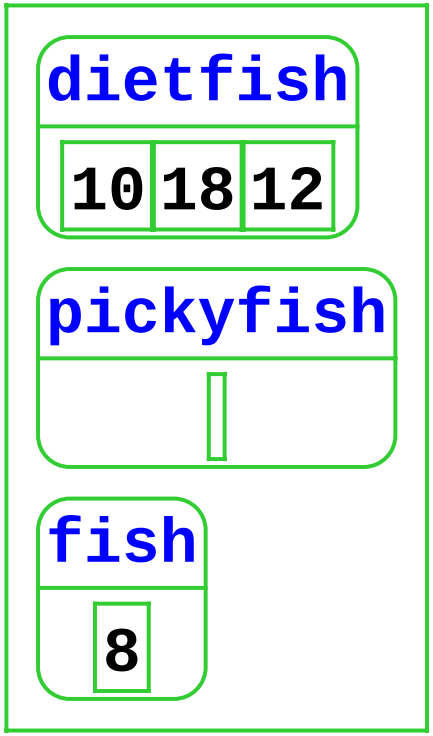


Object Representation

- An object = a list of ***parts***
  - from instantiated class up to base class

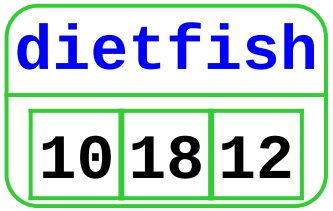
class dietfish
extends pickyfish
field carbos
field sodium
field cholesterol
...



- Use part vectors in environments

Object Representation

```
(define-datatype part part?
  (a-part
    (class-name symbol?)
    (fields vector?)))
```



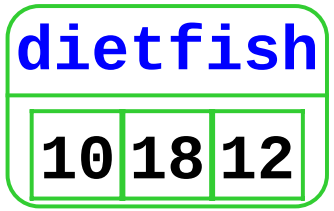

```
;; An object is a list of parts
```

Object Representation

```
;; new-object : sym -> object
(define (new-object cls-name)
  (if (eqv? cls-name 'object)
      '()
      (let ([c-decl (lookup-class cls-name)])
        (cons
         (make-first-part c-decl)
         (new-object (class-decl->super-name
                      c-decl)))))))
```

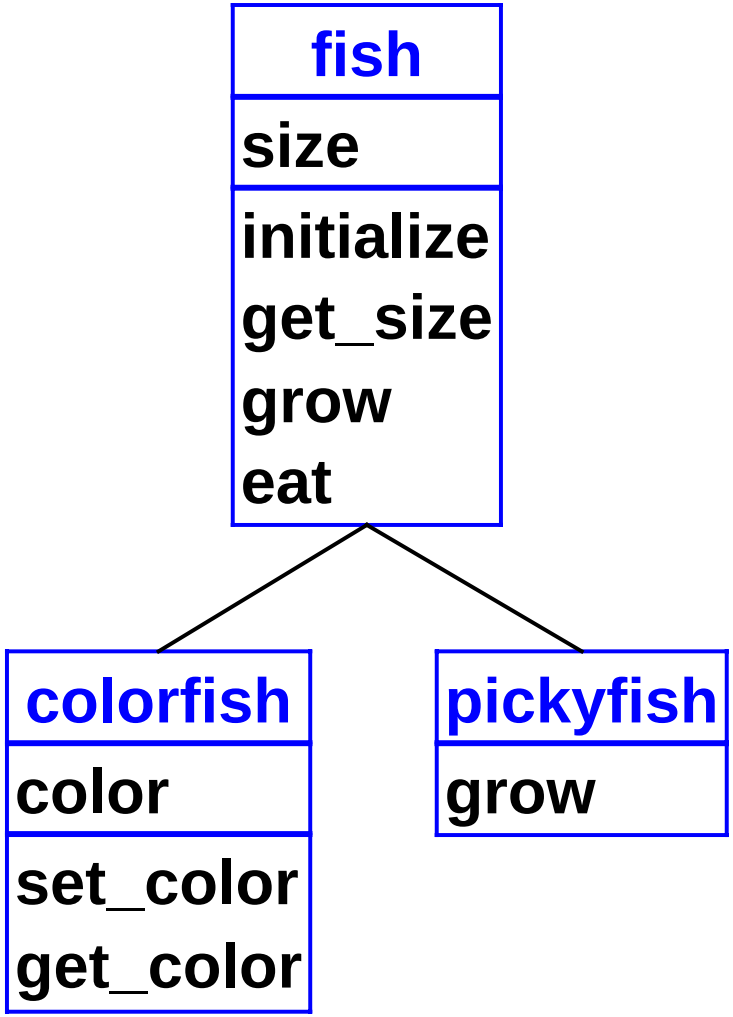
Object Representation

```
;; make-first-part : class-decl -> part
(define (make-first-part c-decl)
  (a-part
   (class-decl->class-name c-decl)
   (make-vector
    (length (class-decl->field-ids
             c-decl)))))
```



Method Search

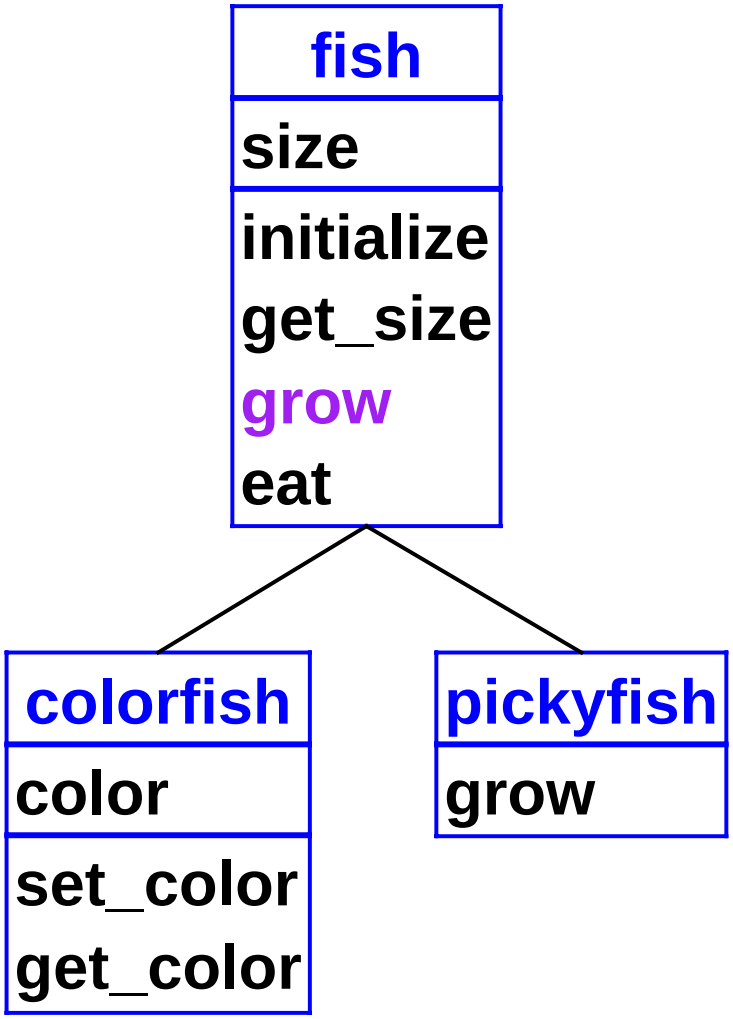
- **get_size** in **colorfish**: Check **colorfish**'s methods, then methods in the superclass **fish**, etc.

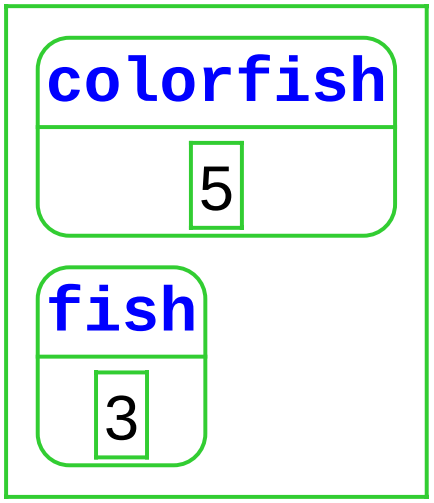


Method Search

```
(define find-method-and-apply
  (lambda (m-name host-name self args)
    (if (eqv? host-name 'object)
      (eopl:error ...) ; not found
      (let ([m-decl
             (lookup-method-decl
              m-name
              (class-name->method-decls
               host-name))])
        (if (method-decl? m-decl)
            (apply-method m-decl host-name
                          self args)
            (find-method-and-apply m-name
             (class-name->super-name
              host-name)
             self args))))))
```

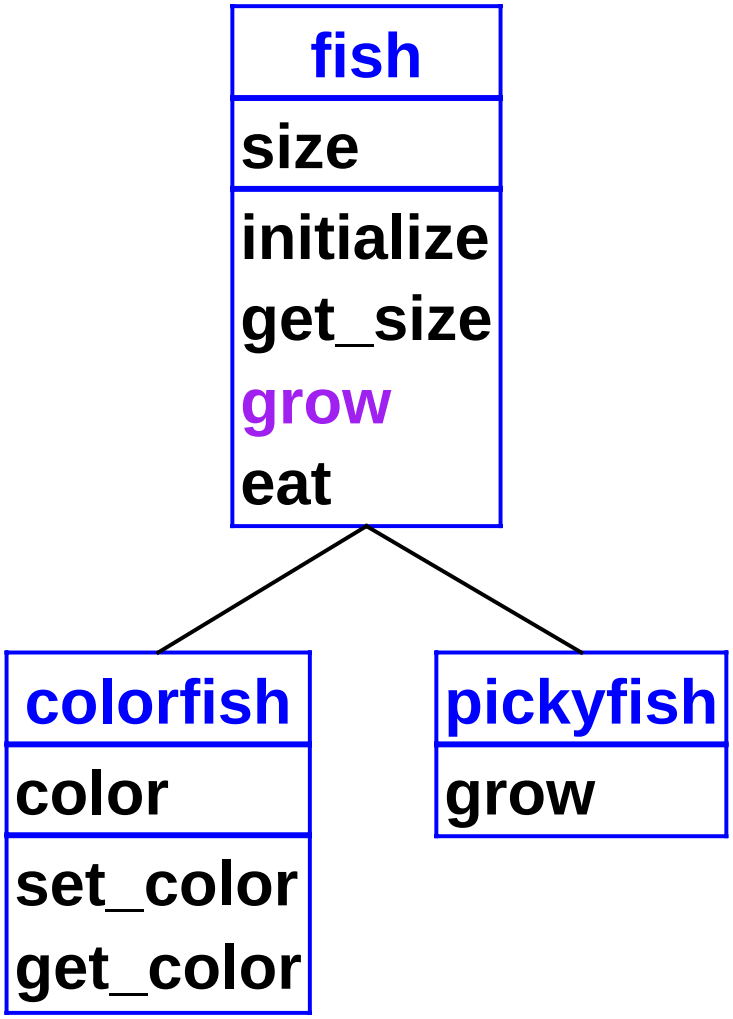
Method Application

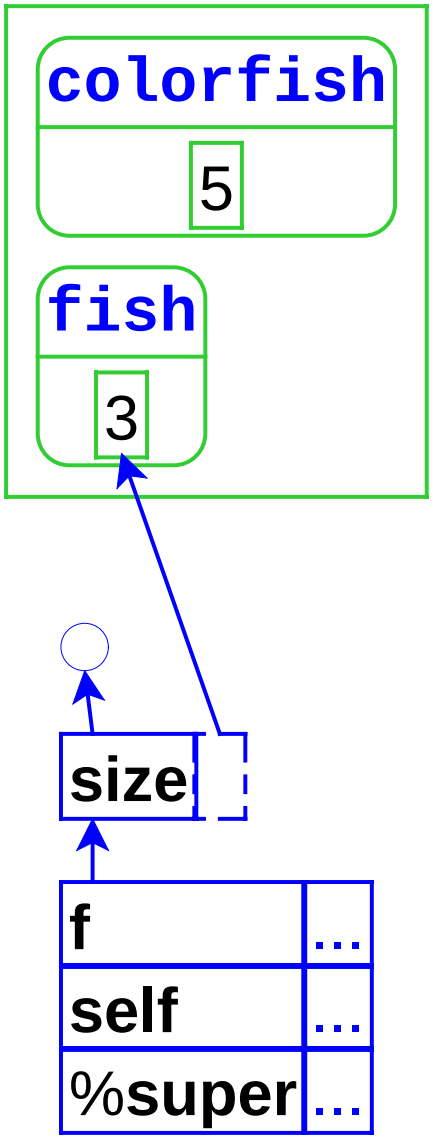




grow(f)
set size=+(size,f)

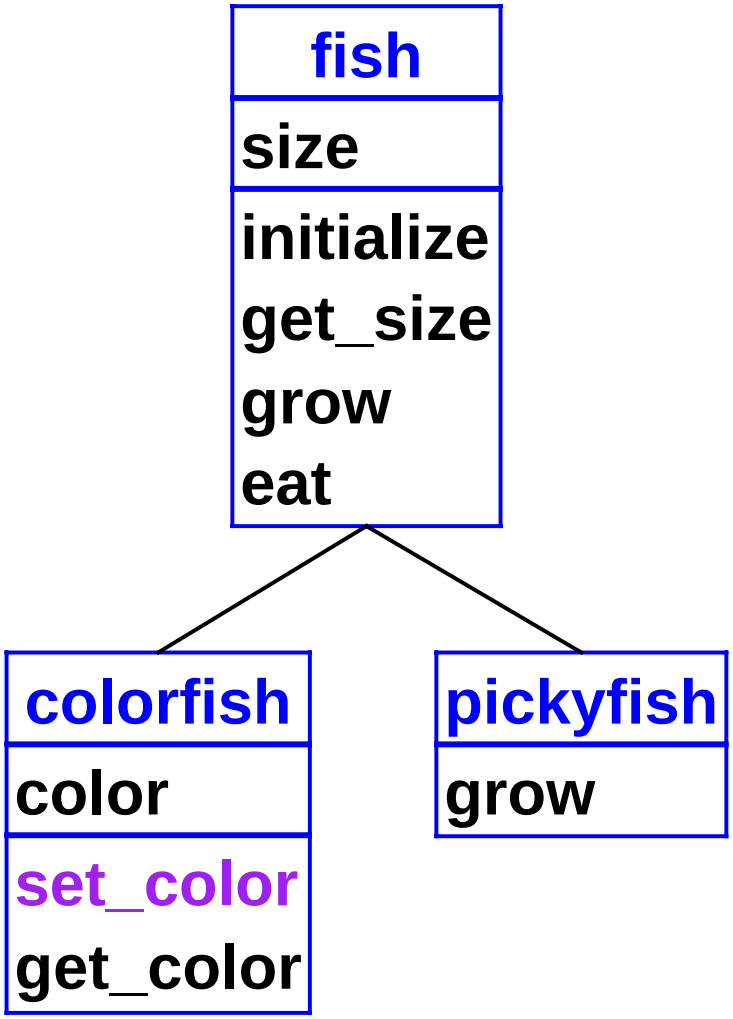
Method Application

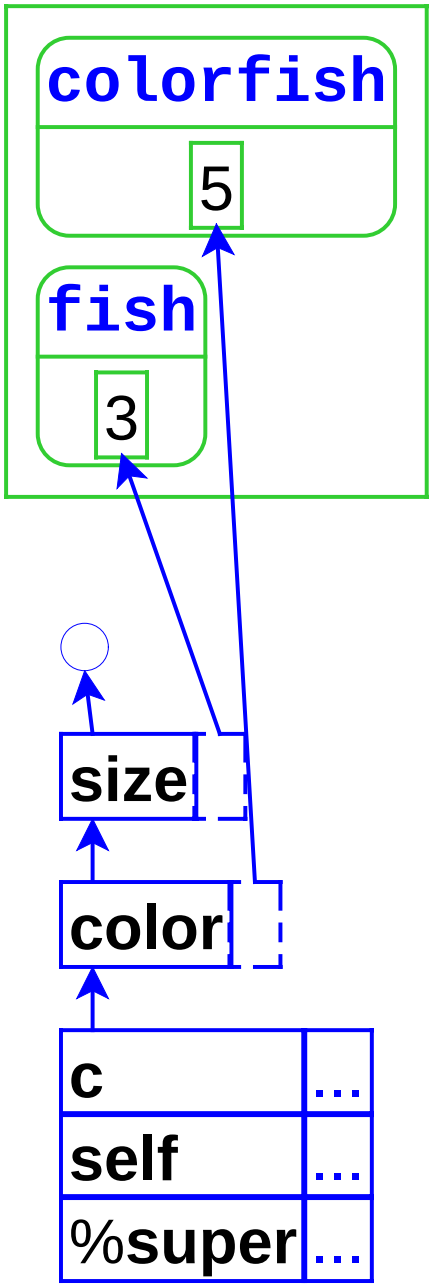




grow(f)
set size=+(size,f)

Method Application





set_color(c)

set color = c

Method Application

```
;; apply-method : method-decl sym object
;;                lstof-expval -> expval
(define apply-method
  (lambda (m-decl host-name self args)
    (let ([ids (method-decl->ids m-decl])
          [body (method-decl->body m-decl])
          [super-name
           (class-name->super-name host-name)])
      (eval-expression
       body
       (extend-env
        (cons '%super (cons 'self ids))
        (cons super-name (cons self args))
        (build-field-env
         (view-object-as self
                         host-name))))))
```

Method Application

```
;; view-object-as : object sym -> lstof-parts
(define (view-object-as parts class-name)
 (if (eqv? (part->class-name (car parts))
           class-name)
    parts
    (view-object-as (cdr parts) class-name)))

;; build-field-env : lstof-parts -> env
(define (build-field-env parts)
  (if (null? parts)
      (empty-env)
      (extend-env-refs
       (part->field-ids (car parts))
       (part->fields    (car parts))
       (build-field-env (cdr parts)))))
```

Object Implementation Overview

- **Inheritance**: superclass chain for fields and methods, part chain
- **Overriding**: method dispatch uses object tag
- **Super calls**: %**super** hidden variable contains superclass name