

Programming Paradigms

Functional Languages

(Part 2)

Prof. Dr. Michael Pradel

Software Lab, University of Stuttgart

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Plan for Today

- Introduction
- A Bit of Scheme ←
- Evaluation Order

Function Application

- **Pair of parentheses: Function application**

- First expression inside: Function
- Remaining expressions: Arguments

- **Examples:**

(+ 3 4)

((+ 3 4))

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`(+ 3 4)`

`((+ 3 4))`

**Applies + function
to 3 and 4.**

Evaluates to 7.

Function Application

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- First expression inside: Function
- Remaining expressions: Arguments

- **Examples:**

`(+ 3 4)`

**Applies + function
to 3 and 4.**

Evaluates to 7.

`((+ 3 4))`

**Tries to call 7 with zero
arguments.**

Gives runtime error.

Creating Functions

- Evaluating a **lambda expression** yields a function

- First argument to `lambda`: Formal parameters
- Remaining arguments: Body of the function

- **Example:**

```
(lambda (x) (* x x))
```

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Yields the “square” function

Bindings

- **Names bound to values with `let`**
 - First argument: List of name-value pairs
 - Second argument: Expressions to be evaluated in order

- **Example:**

```
(let ((a 3)
      (b 4)
      (square (lambda (x) (* x x)))
      (plus +))
      (sqrt (plus (square a) (square b))))
```


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      (plus +))
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```

Yields 5.0

Conditional Expressions

- **Simple conditional expression with `if`**

- First argument: Condition
- Second/third argument: Value returned if condition is true/false

- **Multiway conditional expression with `cond`**

- **Examples:**

```
(if (< 2 3) 4 5)
```

```
(cond  
  ((< 3 2) 1)  
  ((< 4 3) 2)  
  (else 3))
```

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Yields 4

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Yields 4

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```

Dynamic Typing

- **Types** are determined and checked **at runtime**
- **Examples:**

```
(if (> a 0) (+ 2 3) (+ 2 "foo"))
```

```
(define min (lambda (a b) (if (< a b ) a b)))
```

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**Evaluates to 5 if a is positive;
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**Implicitly polymorphic:
Works both for integers and floats.**

Quiz: Functions in Scheme

Which of the following yields 9?

```
; Program 1  
( (lambda (x) (* x x)) 3)
```

```
; Program 2  
(- (+ 12 3) (+ 2 4))
```

```
; Program 3  
(9)
```

```
; Program 4  
( (lambda (x y) (- x y)) (+ 10 0) (- 4 2))
```

Please vote via Ilias.

Quiz: Functions in Scheme

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; Program 1
((lambda (x) (* x x)) 3) ✓

; Program 2
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; Program 3
(9) ✗

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Lists

- **Central data structure with various operations**

- `car` extracts first element
- `cdr` extracts all elements but first
- `cons` joins a head to the rest of a list

- **Examples:**

`(car ' (2 3 4))`

`(cdr ' (2 3 4))`

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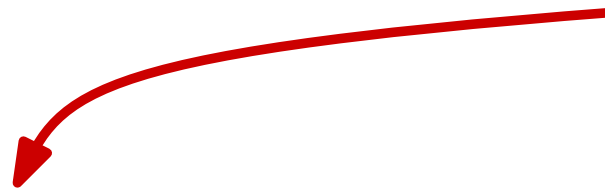
Yields 2

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Yields (3 4)

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Yields (2 3 4)



Assignments

■ Side effects via

- `set!` for assignment to **variables**
- `set-car!` for assigning **head of list**
- `set-cdr!` for assigning **tail of list**

■ **Example:**

```
(let ((x 2)
      (l '(a b)))
  (set! x 3)
  (set-car! l '(c d))
  (set-cdr! l '(e))
  (cons x l))
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Yields (3 (c d) e)

Sequencing

- Cause interpreter to evaluate multiple **expressions one after another** with `begin`

- **Example:**

```
(let
  (n "there")
  (begin
    (display "hi ")
    (display n)))
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Prints "hi there"

Iteration

- Several forms of **loops**, e.g., with `do`
- Example:

```
( (lambda (n)
  (do ((i 0 (+ i 1))
      (a 0 b)
      (b 1 (+ a b)))
    ((= i n) b)
    (display b)
    (display " "))) 5)
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- expression to compute next value

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Computes first n Fibonacci numbers

Programs as Lists


- **Programs and lists: Same syntax**
 - Both are **S-expressions**: String of symbols with balanced parentheses
- **Construct and manipulate an unevaluated program as a list**
- **Evaluate with `eval`**
- **Example:**

```
(eval (cons '+ (list '2 '3)))
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Yields 5