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# PAIP EXERCISES



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# Introduction to Common Lisp

## Using Functions

- 1     $\langle \text{titles } 1 \rangle \equiv$  (7)  
      (defparameter \*titles\*  
        '(Mr Mrs Miss Ms Sir Madam Dr Admiral Major General)  
        "A list of titles that can appear at the start of a name.")  
      Defines:  
        \*titles\*, used in chunk 4.
- 2     $\langle \text{abstract first-name } 2 \rangle \equiv$   
      ( $\langle \text{function first-name(name): } 3 \rangle$   
        ( $\langle \text{if the first element of name is a title } 4 \rangle$   
           $\langle \text{then return the first-name of the rest of the name } 5 \rangle$   
           $\langle \text{else return the first element of the name } 6 \rangle$ ))
- 3     $\langle \text{function first-name(name): } 3 \rangle \equiv$  (2)  
      defun first-name (name)  
        "Select the first name from a name represented as a list."
- 4     $\langle \text{if the first element of name is a title } 4 \rangle \equiv$  (2)  
      if (member (first name) \*titles\*)  
      Uses \*titles\* 1.
- 5     $\langle \text{then return the first-name of the rest of the name } 5 \rangle \equiv$  (2)  
      (first-name (rest name))
- 6     $\langle \text{else return the first element of the name } 6 \rangle \equiv$  (2)  
      (first name)

*Exercises*

```

7  <intro.lisp 7>≡
    (ql:quickload :lisp-unit)

    (defpackage #:intro
      (:use #:common-lisp #:lisp-unit))

    (in-package #:intro)

    <titles 1>

    ;; Exercise 1.1
    <Exercise 1.1 8>

    ;; Exercise 1.2
    <Exercise 1.2 17>

    ;; Exercise 1.3
    <Exercise 1.3 24>

```

*Exercise 1.1*

Define a version of **last-name** that handles “Rex Morgan MD,” “Morton Downey, Jr.,” and whatever other cases you can think of.

```

8  <Exercise 1.1 8>≡ (7)
    <suffixes 13>

    <last-name 9>

    <Exercise 1.1 tests 14>

9  <last-name 9>≡ (8)
    (defun last-name (name)
      "Select the last name from a name represented as a list."
      (if <the last element of a name is a suffix 10>
          <then return the last-name of all but the last element of the name 11>
          <else return the last element of the name 12>)))

```

Defines:

last-name, used in chunks 11, 15, and 16.

First, we check to see if the last element of the **name** is a suffix, i.e. whether it's a member of **\*suffixes\***.

```

10 <the last element of a name is a suffix 10>≡ (9)
    (member (first (last name)) *suffixes*)
    Uses *suffixes* 13.

```

If it is, then drop it from the **name** and return the **last-name** of the result.

```

11 <then return the last-name of all but the last element of the name 11>≡ (9)
    (last-name (butlast name))
    Uses last-name 9.

```

Otherwise, it's the last name, so return it.

12  $\langle \text{else return the last element of the name } 12 \rangle \equiv$  (9)  
`(first (last name))`

13  $\langle \text{suffixes } 13 \rangle \equiv$  (8)  
`(defparameter *suffixes*`  
`'(MD Jr)`  
`"A list of suffixes that can appear at the end of a name.")`

Defines:

`*suffixes*`, used in chunk 10.

14  $\langle \text{Exercise 1.1 tests } 14 \rangle \equiv$  (8)  
`(define-test test-last-name`  
 `$\langle \text{Rex Morgan MD } 15 \rangle$`   
 `$\langle \text{Morton Downey, Jr } 16 \rangle$ )`

15  $\langle \text{Rex Morgan MD } 15 \rangle \equiv$  (14) Assert that the `last-name` of Rex Morgan MD is Morgan.  
`(assert-equal 'Morgan (last-name '(Rex Morgan MD)))`  
 Uses last-name 9.

16  $\langle \text{Morton Downey, Jr } 16 \rangle \equiv$  (14)  
`(assert-equal 'Downey (last-name '(Morton Downey Jr)))`  
 Uses last-name 9.

### Exercise 1.2

Write a function to exponentiate, or raise a number to an integer power.  
 For example  $(\text{power } 3 \ 2) = 3^2 = 9$ .

17  $\langle \text{Exercise 1.2 } 17 \rangle \equiv$  (7)  
 $\langle \text{square } 22 \rangle$   
 $\langle \text{power } 18 \rangle$   
 $\langle \text{Exercise 1.2 tests } 23 \rangle$

18  $\langle \text{power } 18 \rangle \equiv$  (17)  
`(defun power (x n)`  
`"Raise x to the power of n."`  
`(cond  $\langle \text{if n is zero return } 1 \ 19 \rangle$`   
 `$\langle \text{if n is even return x to the power of n over two, squared } 20 \rangle$`   
 `$\langle \text{otherwise return x times x to the power of n minus one } 21 \rangle$ ))`

Defines:

`power`, used in chunks 20, 21, and 23.

19  $\langle \text{if n is zero return } 1 \ 19 \rangle \equiv$  (18)  $x^0 = 1$   
`((zerop n) 1)`

20  $\langle \text{if n is even return x to the power of n over two, squared } 20 \rangle \equiv$  (18)  
`((evenp n) (square (power x (/ n 2))))`  
 Uses power 18 and square 22.

$$x^n = \begin{cases} 1 & \text{if } n = 0, \\ (x^{n/2})^2 & \text{if } n \text{ is even,} \\ x \times x^{n-1} & \text{otherwise.} \end{cases}$$

21  $\langle \text{otherwise return } x \text{ times } x \text{ to the power of } n \text{ minus one } 21 \rangle \equiv$  (18)  
 (t (\* x (power x (- n 1))))

Uses power 18.

22  $\langle \text{square } 22 \rangle \equiv$  (17)  $\text{square}(x) = x^2$   
 (defun square (x) (expt x 2))

Defines:

square, used in chunk 20.

23  $\langle \text{Exercise 1.2 tests } 23 \rangle \equiv$  (17)  
 (define-test test-power  
 (assert-equal 9 (power 3 2)))

Uses power 18.

### Exercise 1.3

Write a function that counts the number of atoms in an expression.

For example: (count-atoms '(a (b) c)) = 3. Notice that there is something of an ambiguity in this: should (a nil c) count as three atoms, or as two, because it is equivalent to (a () c)?

24  $\langle \text{Exercise 1.3 } 24 \rangle \equiv$  (7)  
 (defun count-atoms (exp)  
 "Return the total number of non-nil atoms in the expression."  
 (cond  $\langle \text{if exp is nil there are no atoms } 25 \rangle$   
 $\langle \text{if exp is an atom there is only one } 26 \rangle$   
 $\langle \text{otherwise add the count of the atoms in the first and rest of exp } 27 \rangle$ ))

Defines:

count-atoms, used in chunk 27.

25  $\langle \text{if exp is nil there are no atoms } 25 \rangle \equiv$  (24)  
 ((null exp) 0)

26  $\langle \text{if exp is an atom there is only one } 26 \rangle \equiv$  (24)  
 ((atom exp) 1)

27  $\langle \text{otherwise add the count of the atoms in the first and rest of exp } 27 \rangle \equiv$  (24)  
 (t (+ (count-atoms (first exp))  
 (count-atoms (rest exp))))

Uses count-atoms 24.



## Overview of Lisp

```
28  <find-all 28>≡ (29)
      (defun find-all (item sequence &rest keyword-args
                        &key (test #'eql) test-not &allow-other-keys)
        "Find all those elements of sequence that match item,
        according to the keywords. Doesn't alter sequence."
        (if test-not
            (apply #'remove item sequence
                    :test-not (complement test-not) keyword-args)
            (apply #'remove item sequence
                    :test (complement test) keyword-args)))
```

Defines:

find-all, used in chunk 34.



# GPS: The General Problem Solver

```
29 <gps.lisp 29>≡
    (ql:quickload :lisp-unit)

    (defpackage #:gps
      (:use #:common-lisp #:lisp-unit)
      (:export #:GPS))

    (in-package #:gps)

    <find-all 28>

    <The current state: a list of conditions 30>

    <A list of available operators 31>

    <An operation with preconds, add-list and del-list 32>

    <Solve a goal from a state using a list of operators 33>

    <Achieve an individual goal 34>

    <Decide if an operator is appropriate for a goal 35>

    <Apply operator to current state 36>

    <Define a list of operations 38>

    <Assert that a given problem is solvable 39>

    <GPS Tests 40>
    Uses GPS 33.

30 <The current state: a list of conditions 30>≡ (29)
    (defvar *state* nil "The current state: a list of conditions.")
    Defines:
    *state*, used in chunks 33, 34, and 36.

31 <A list of available operators 31>≡ (29)
    (defvar *ops* nil "A list of available operators.")
    Defines:
    *ops*, used in chunks 33 and 34.
```

32  $\langle$ An operation with preconds, add-list and del-list 32 $\rangle \equiv$  (29)

```
(defstruct op
  "An operation"
  (action nil)
  (preconds nil)
  (add-list nil)
  (del-list nil))
```

33  $\langle$ Solve a goal from a state using a list of operators 33 $\rangle \equiv$  (29)

```
(defun GPS (*state* goals *ops*)
  "General Problem Solver: achieve all goals using *ops*."
  (if (every #'achieve goals) 'solved))
```

Defines:

GPS, used in chunk 29.

Uses \*ops\* 31, \*state\* 30, and achieve 34.

34  $\langle$ Achieve an individual goal 34 $\rangle \equiv$  (29)

```
(defun achieve (goal)
  "A goal is achieved if it already holds,
  or if there is an appropriate op for it that is applicable."
  (or (member goal *state*)
      (some #'apply-op
        (find-all goal *ops* :test #'appropriate-p))))
```

Defines:

achieve, used in chunks 33 and 36.

Uses \*ops\* 31, \*state\* 30, apply-op 36, appropriate-p 35, and find-all 28.

35  $\langle$ Decide if an operator is appropriate for a goal 35 $\rangle \equiv$  (29)

```
(defun appropriate-p (goal op)
  "An op is appropriate to a goal if it is in its add list."
  (member goal (op-add-list op)))
```

Defines:

appropriate-p, used in chunk 34.

36  $\langle$ Apply operator to current state 36 $\rangle \equiv$  (29)

```
(defun apply-op (op)
  "Print a message and update *state* if op is applicable."
  (when (every #'achieve (op-preconds op))
    (print (list 'executing (op-action op)))
    (setf *state* (set-difference *state* (op-del-list op)))
    (setf *state* (union *state* (op-add-list op)))
    t))
```

Defines:

apply-op, used in chunk 34.

Uses \*state\* 30 and achieve 34.

To drive the son to school, the son must start at home and the car must work.

37  $\langle$ Drive son to school 37 $\rangle \equiv$  (38)

```
(make-op :action 'drive-son-to-school
  :preconds '(son-at-home car-works)
  :add-list '(son-at-school)
  :del-list '(son-at-home))
```

38 *⟨Define a list of operations 38⟩*≡ (29)

```
(defparameter *school-ops*
  (list
    ⟨Drive son to school 37⟩
    (make-op :action 'shop-installs-battery
      :preconds '(car-needs-battery shop-knows-problem shop-has-money)
      :add-list '(car-works))
    (make-op :action 'tell-shop-problem
      :preconds '(in-communication-with-shop)
      :add-list '(shop-knows-problem))
    (make-op :action 'telephone-shop
      :preconds '(know-phone-number)
      :add-list '(in-communication-with-shop))
    (make-op :action 'look-up-number
      :preconds '(have-phone-book)
      :add-list '(know-phone-number))
    (make-op :action 'give-shop-money
      :preconds '(have-money)
      :add-list '(shop-has-money)
      :del-list '(have-money))))
```

### Tests

39 *⟨Assert that a given problem is solvable 39⟩*≡ (29)

```
(defmacro assert-solved (form)
  '(assert-equal 'solved ,form))
```

Defines:  
 assert-solved, used in chunk 40.

```

40  <GPS Tests 40>≡ (29)
    (define-test complex
      (assert-equal
        (format nil "~%~{(EXECUTING ~A) ~^~%~}"
          '(look-up-number
            telephone-shop
            tell-shop-problem
            give-shop-money
            shop-installs-battery
            drive-son-to-school))
        (with-output-to-string (*standard-output*)
          (assert-solved
            (gps '(son-at-home car-needs-battery have-money have-phone-book)
              '(son-at-school)
              *school-ops*))))))

    (define-test unsolvable
      (assert-nil (gps '(son-at-home car-needs-battery have-money)
        '(son-at-school)
        *school-ops*)))

    (define-test simple
      (assert-solved (gps '(son-at-home car-works)
        '(son-at-school)
        *school-ops*)))

    (define-test money-leftover
      (assert-solved (gps '(son-at-home have-money car-works)
        '(have-money son-at-school)
        *school-ops*)))

    (define-test clobbered-sibling
      (assert-nil (gps '(son-at-home car-needs-battery have-money have-phone-book)
        '(have-money son-at-school)
        *school-ops*)))

```

Uses assert-solved 39.

# *Test Runner*

```
41 <runtests 41>≡
    #! /usr/bin/env nix-shell
    #! nix-shell -i sh -p sbcl

    # N.B. quicklisp must be installed and configured.

    sbcl -non-interactive \
        -load src/paip/$1.lisp \
        -eval "(let* ((results (lisp-unit:run-tests :all :$1))
                      (failures (lisp-unit:failed-tests results))
                      (status   (if (null failures) 0 1)))
              (sb-posix:exit status))"
```





# Chunks

*<A list of available operators 31>*  
*<abstract first-name 2>*  
*<Achieve an individual goal 34>*  
*<An operation with preconds, add-list and del-list 32>*  
*<Apply operator to current state 36>*  
*<Assert that a given problem is solvable 39>*  
*<Decide if an operator is appropriate for a goal 35>*  
*<Define a list of operations 38>*  
*<Drive son to school 37>*  
*<else return the first element of the name 6>*  
*<else return the last element of the name 12>*  
*<Exercise 1.1 8>*  
*<Exercise 1.1 tests 14>*  
*<Exercise 1.2 17>*  
*<Exercise 1.2 tests 23>*  
*<Exercise 1.3 24>*  
*<find-all 28>*  
*<function first-name(name): 3>*  
*<GPS Tests 40>*  
*<gps.lisp 29>*  
*<if exp is an atom there is only one 26>*  
*<if exp is nil there are no atoms 25>*  
*<if n is even return x to the power of n over two, squared 20>*  
*<if n is zero return 1 19>*  
*<if the first element of name is a title 4>*  
*<intro.lisp 7>*  
*<last-name 9>*  
*<Morton Downey, Jr 16>*  
*<otherwise add the count of the atoms in the first and rest of exp 27>*  
*<otherwise return x times x to the power of n minus one 21>*  
*<power 18>*  
*<Rex Morgan MD 15>*  
*<runtests 41>*  
*<Solve a goal from a state using a list of operators 33>*

*⟨square 22⟩*  
*⟨suffixes 13⟩*  
*⟨The current state: a list of conditions 30⟩*  
*⟨the last element of a name is a suffix 10⟩*  
*⟨then return the last-name of all but the last element of the name 11⟩*  
*⟨then return the first-name of the rest of the name 5⟩*  
*⟨titles 1⟩*

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