# COMP 348
# PRINCIPLES OF PROGRAMMING LANGUAGES

**Tutorial #4**

Functional Programming

LISP

# LISP - LIST PROCESSING LANGUAGE

- An AI language developed in 1958 (J. McCarty at MIT)
- Special focus on symbolic processing and symbol manipulation
  - ❑Linked list structures
  - ❑Programs, functions are represented as lists

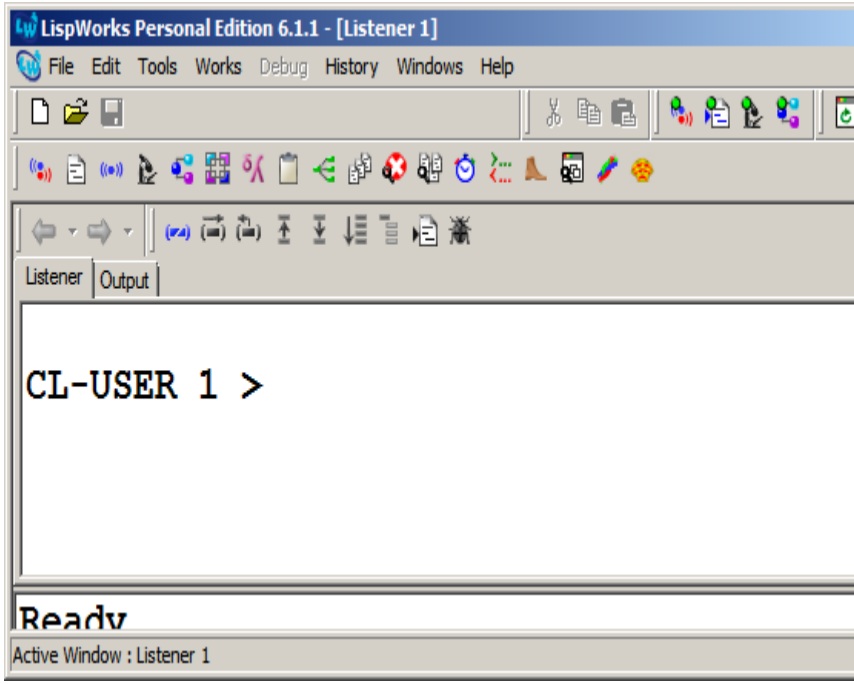
- Many AI programs now are written in C, C++, Java
  - ❑List manipulation libraries are available

- LISP programming languages
  - ❑Scheme – widely-known general-purpose Lisp dialects; supports functional and imperative programming
  - ❑Common Lisp – supports a combination of procedural, functional, and object-oriented programming (includes CLOS)

# INTERACTIVE PROGRAMMING

- Lisp prompt
- Lisp reads Lisp expressions, evaluates them according to the rules of Lisp, and prints the result.
- It's called the read-eval-print loop, or REPL for short.

It's also referred to as the top-level, the top-level listener, or the Lisp listener.



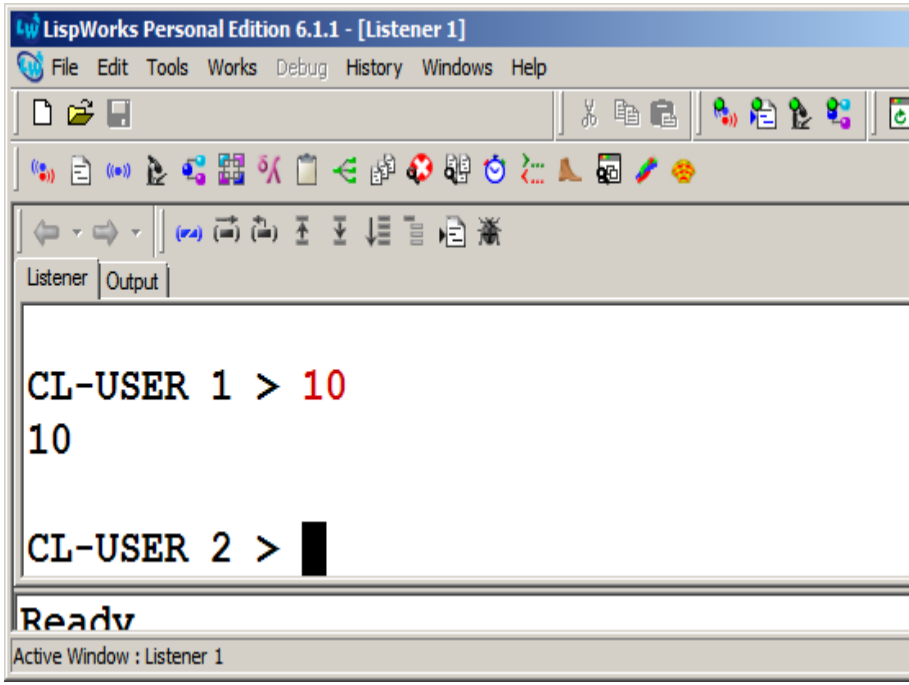
# REPL CONCEPT

- A user type 10 followed by Return and should see the output as shown in the Fig.

- The Lisp reader, the R in REPL, reads the text "10" and creates a Lisp object representing the number 10.

- This object is a self-evaluating object, which means that when given to the evaluator, the E in REPL, it evaluates to itself.

- This value is then given to the printer, which prints the 10 on the line by itself.



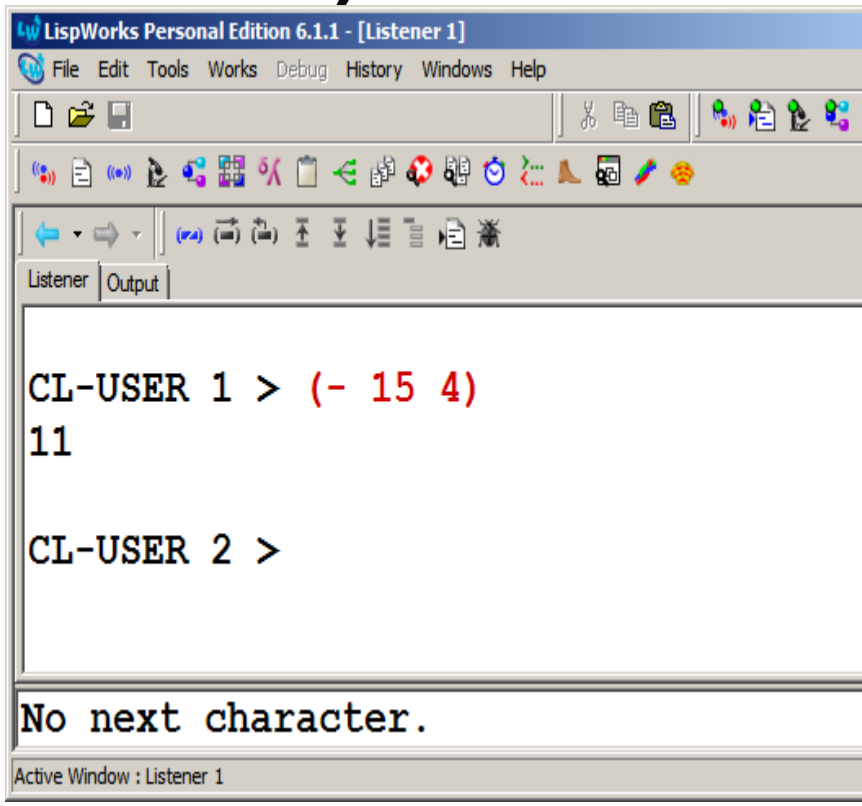
# REPL CONCEPT (CONT.)

- When a user type (- 15 4) at the Lisp prompt.

- Here we have a list of three elements, the symbol -, and the numbers 15 and 4.

- Lisp, in general, evaluates lists by treating the first element as the name of a function and the rest of the elements as expressions to be evaluated to yield the arguments to the function.

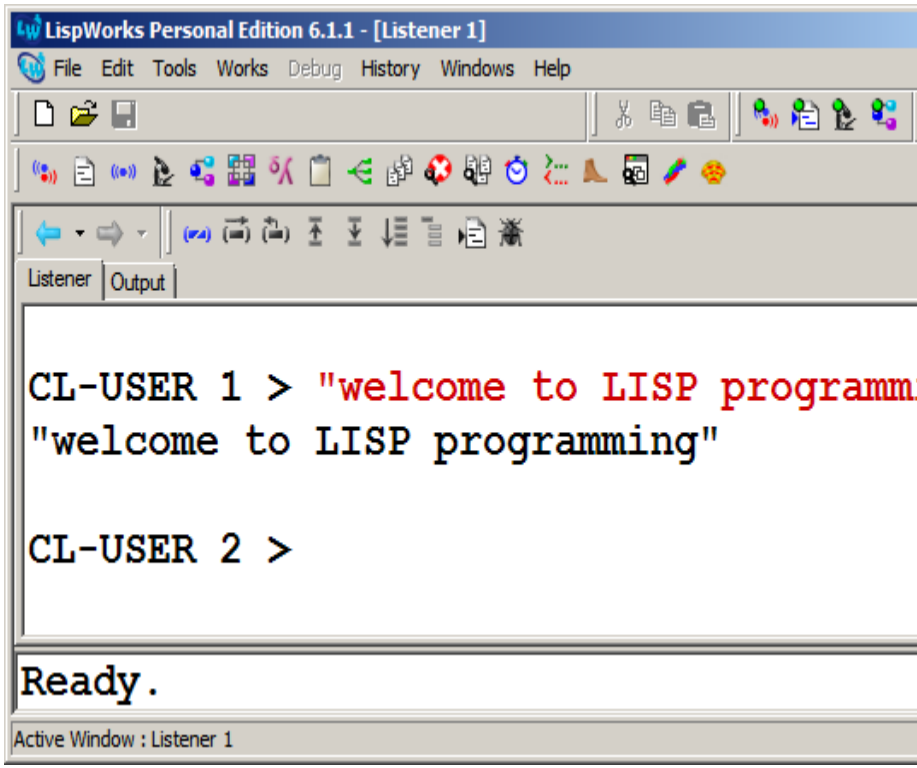
- So here, the symbol - names a function that performs subtraction. 15 and 4 evaluate to themselves and are then passed to the subtraction function, which returns 11. The value 11 is passed to the printer, which prints it.



# REPL CONCEPT (CONT.)

- Lisp reads the double-quoted string and instantiates a string object in memory that, when evaluated, evaluates to itself and is then printed in the same literal syntax.

- The quotation marks aren't part of the string object in memory--they're just the syntax that tells the reader to read a string.



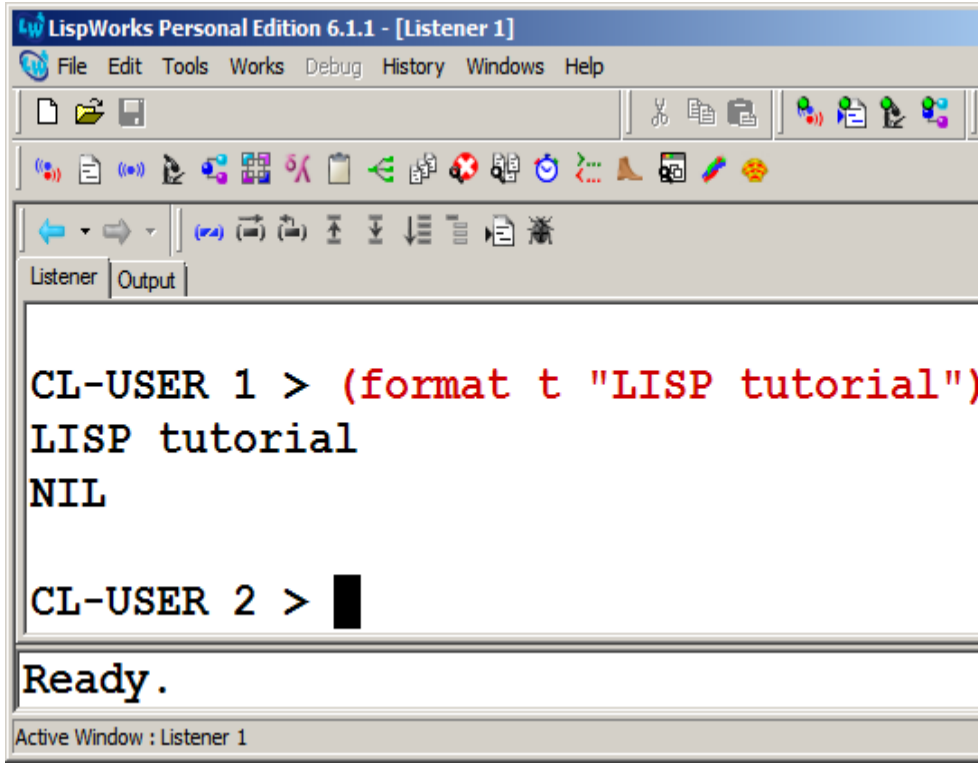
# FORMAT FUNCTION

- FORMAT takes a variable number of arguments, but the only two required arguments are the place to send the output and a string.

- If you pass t as its first argument, it sends its output to standard output.

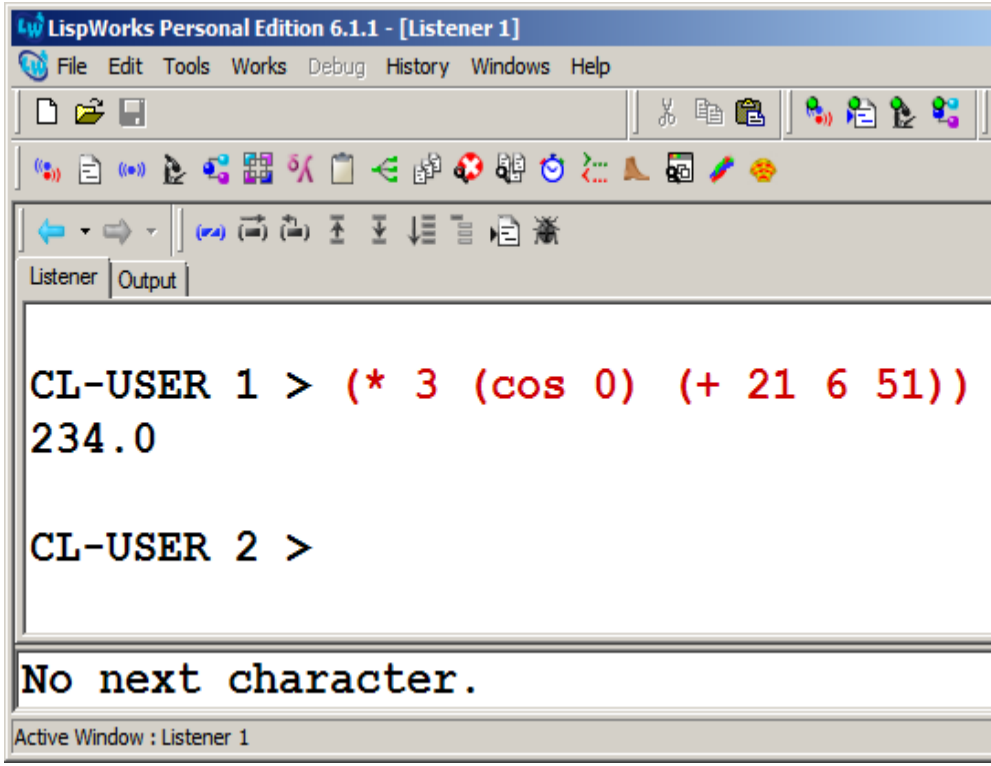
- NIL is the result of evaluating the FORMAT expression, printed by the REPL. (NIL is Lisp's version of false and/or null)

- There are other ways as well to emit output.



# LISP EXPRESSIONS

- The most common LISP form is function application.
- LISP represents a function call f(x) as (f x). For example, cos(0) is written as (cos 0).
- LISP expressions are case-insensitive. It makes no difference whether we type (cos 0) or (COS 0).
- functions, like "+" and "*", could take an arbitrary number of arguments
- Math representation: 3*Cos(0)*(21+6+51)



# LISP EXPRESSIONS (CONT.)

LispWorks Personal Edition 6.1.1 - [Listener 1]

File Edit Tools Works Debug History Windows Help

Listener | Output

```
CL-USER 1 > (+ 2/4 2/8)
3/4

CL-USER 2 > (* 2.5 1.25 -9.5 2/4)
-14.84375

CL-USER 3 > (sqrt 9)
3.0

CL-USER 4 > (reverse "sunny day")
"yad ynnus"

CL-USER 5 > (length "hello world")
11

CL-USER 6 > (not (and (= (+ 1 2) 3) (< 4 3) (= (+ 2 3) 7) ))
T

CL-USER 7 >
```

Ready.

Active Window : Listener 1

# BOOLEAN OPERATIONS

```
CL-USER 1 > (not nil)
T

CL-USER 2 > (not t)
NIL

CL-USER 3 > (and t t nil)
NIL

CL-USER 4 > (or t nil t)
T

CL-USER 5 > (and t t ())
NIL

CL-USER 6 > (and t t (or t nil))
T
```

# BOOLEAN OPERATIONS (CONT.)

```
CL-USER 7 > (setq Z '(a1 a2 a3))
(A1 A2 A3)

CL-USER 8 > (and (member 'a3 z)(member 'a2 z))
(A2 A3)

CL-USER 9 > (not (member 'a4 z))
T

CL-USER 10 > (member 'a5 Z)
NIL

CL-USER 11 > (or (member 'a4 z)(member 'a5 z))
NIL

CL-USER 12 > (or (member 'a4 z)(member 'a3 z))
(A3)

CL-USER 13 > (and (member 'a3 z)(member 'a5 z))
NIL
```

# CONSTRUCTING LISTS

Three built-in functions to create a list.

- cons: creates a list by adding an element as the head of an existing list
- list: creates a list comprised of its arguments.
- append: creates a list by concatenating existing lists.

# FUNCTION CONS

A list in Lisp is singly-linked where each node is a pair of two pointers, the first one pointing to a data element and the second one pointing to the tail of the list with the last node's second pointer pointing to the empty list.

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# FUNCTION LIST

Lists can be created directly with the list function, which takes any number of arguments, and it returns a list composed of these arguments.

```
CL-USER 1 > (list 1 2 'a 3)
(1 2 A 3)

CL-USER 2 > (list 1 '(2 3) 4)
(1 (2 3) 4)

CL-USER 3 > (list '(+ 2 1) (+ 2 1))
((+ 2 1) 3)

CL-USER 4 > (list 1 2 3 (list 'a 'b 4) 5)
(1 2 3 (A B 4) 5)

CL-USER 5 > (list '(+ (2 + 4))(* 5 4))
((+ (2 + 4)) 20)
```

# FUNCTION APPEND

The append function takes any number of list arguments and it returns a list which is the concatenation (join) of its arguments:

```
CL-USER 1 > (append '(1 2) '(3 4))
(1 2 3 4)

CL-USER 2 > (append '(1 2 3) '() '(a) '(5 6))
(1 2 3 A 5 6)

CL-USER 3 > (append '(1 2 3 '(a b c)) '() '(d) '(4 5))
(1 2 3 (QUOTE (A B C)) D 4 5)

CL-USER 4 > (append '(1 '2 3 a) '() '(d) '(4 5))
(1 (QUOTE 2) 3 A D 4 5)

CL-USER 5 > (append a '(1 b 2))

Error: The variable A is not of type LIST

CL-USER 6 > (append (list 'a) '(4 5 6))
(A 4 5 6)
```

We must transform **a** into a list

# ACCESSING A LIST

Only two operations are available. We can only access either the head of a list, or the tail of a list.

Operation car (also: first) takes a list as an argument and returns the head of the list.

```
CL-USER 1 > (car '((a b d) c f))
(A B D)

CL-USER 2 > (car '(a e f))
A
```

Operation cdr (also: rest) takes a list as an argument and returns the tail of the list.

```
CL-USER 3 > (cdr '((a b d) c f))
(C F)

CL-USER 4 > (cdr '(a e f))
(E F)

CL-USER 5 > (cdr '((a 1) (b 2) (c 3)))
((B 2) (C 3))
```