Lecture 10: Expression Evaluation

COMP 524 Programming Language Concepts
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Based on slides by A. Block, notes by N. Fisher, F. Hernandez-Campos, and D. Stotts

Goal of Talk

- The goal of this talk is to talk about expressions and the flow of programs

Control Flow

- **Control flow** is the order in which a program executes.
- For imperative languages (e.g., Java), this is fundamental.
- For other programing paradigms (e.g., functional), the compilers/interpreters take care of ordering.

Expression Evaluation

- An **expressions** consist of a **simple object** (e.g., a variable), an **operator**, or a **function** applied to a collection of objects and/or operators.
- Expression evaluation is a **crucial** component of **functional** languages.

Functional languages are very “math-like” and in math a primary concept is evaluating expressions.

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- Expression evaluation is a **crucial** component of **functional** languages.

Operators

- Operators are used in
    - **Prefix** notation: operators come first
        - **(* (+ 1 3) 2)**
    - **Infix** notation: operators in middle
        - **(1+3)*2**
    - **Postfix** notation: operators last
        - **a++**

Operators-Precedence

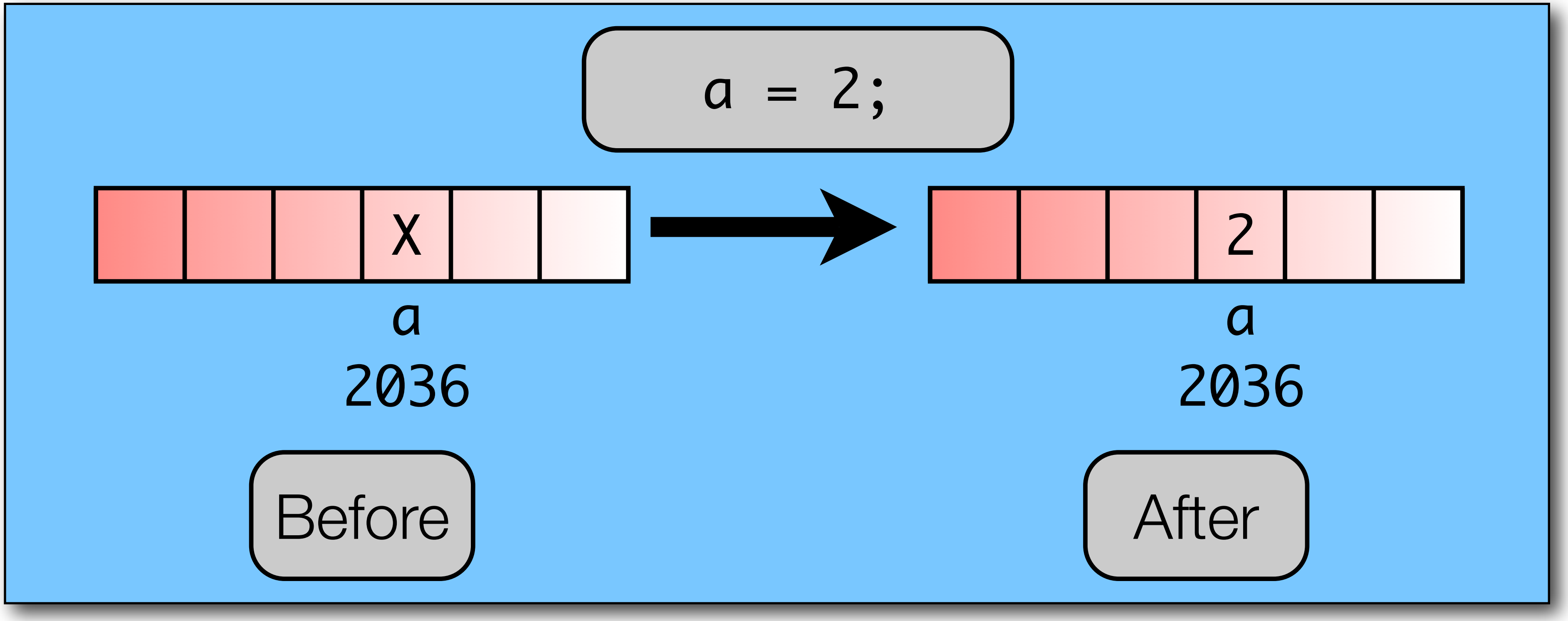
- **Precedence** rules specify the order in which operators of **different** precedence levels are evaluated.
  - e.g. Multiplication before addition.
- Precedence in **boolean** expressions **very** important
  - The phrase "`if A<B and C<D`" can be read as:
  - `if (A<B) and (C<D)`
  - `if (A< (B and C)) <D`

Operators--Associativity

- **Associativity** rules specify the order in which operators of the **same** precedence level are evaluated.
  - Usually they are evaluated “left-to-right”
- In Fortran, ****** associates from **right-to-left**
  - x ** y = x^y
  - Thus 2**3**4 is read as 2^(3^4) rather than (2^3)^4.
- Also assignment in C
  - a = b = c

Assignment

- The basic operation language is **assignment**.
- An assignment places a **value** into a **specific memory location**.



Ass

As a result, assignments have longevity and can exist beyond their **original context**.

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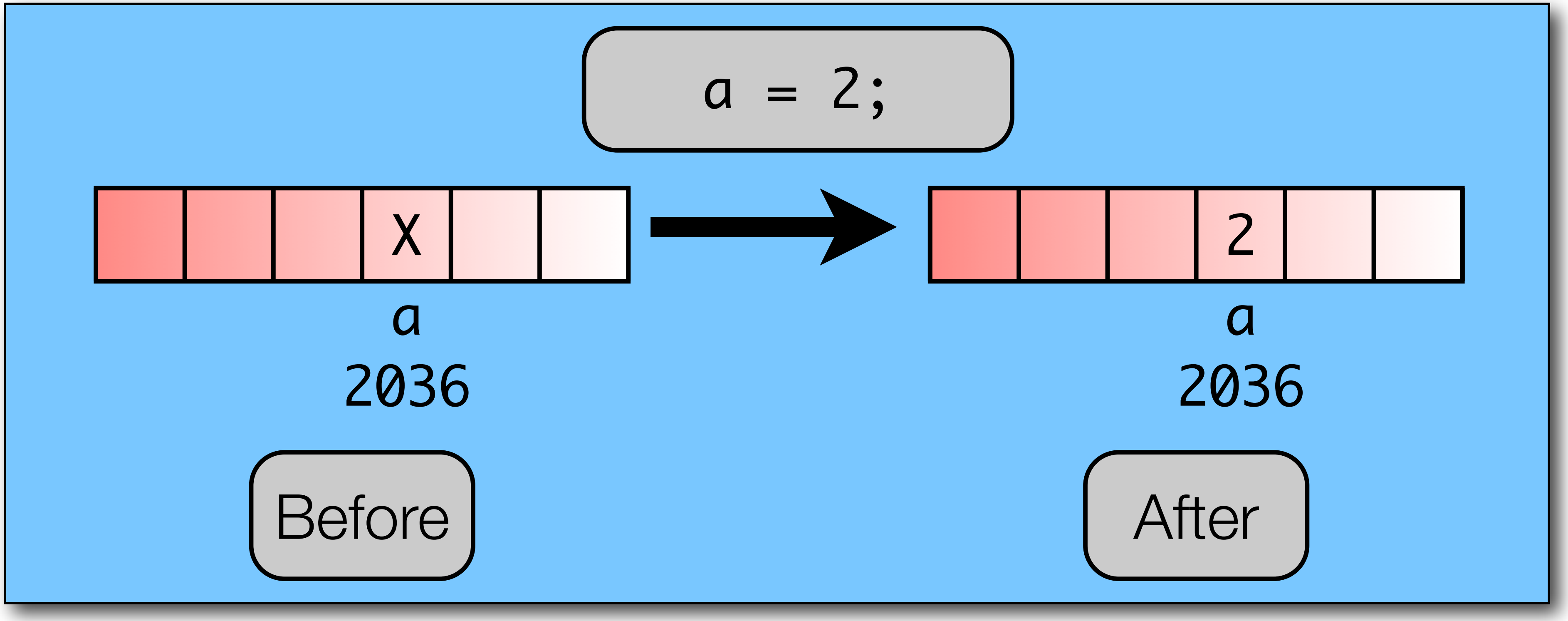
- An y **location**.



```
a = 2;
```

Context

- To see the difference between context consider the two following statements.

```
int sum(int n){
  int val=0;
  for(int i=0,i<=n;i++){
    val+=i;
  }
  return val;
}
```

Imperative

```
int sum(int n){
  if (n<=0) then
    return 0
  else
    return n+sum(n-1)
}
```

Functional

Context

In the imperative code the value of **`val`** changes within the context of **`sum`**

- To see th r the two following statements.

```
int sum(int n){
  int val=0;
  for(int i=0,i<=n;i++){
    val+=i;
  }
  return val;
}
```

```
int sum(int n){
  if (n<=0) then
    return 0
  else
    return n+sum(n-1)
}
```

Imperative

Functional

Context

In the functional code the value of **n** changes but only between contexts of **sum**

- To see th r the two following statements.

```
int sum(int n){
  int val=0;
  for(int i=0,i<=n;i++){
    val+=i;
  }
  return val;
}
```

Imperative

```
int sum(int n){
  if (n<=0) then
    return 0
  else
    return n+sum(n-1)
}
```

Functional

Variables

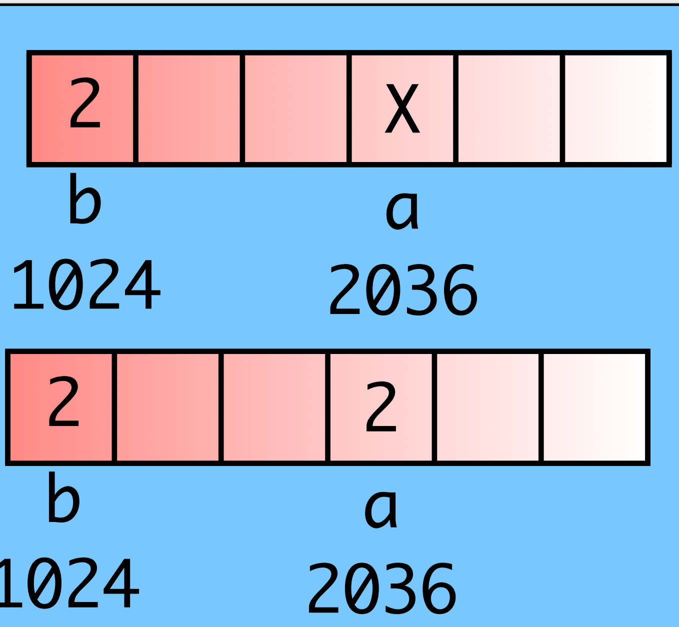
- Two ways to model variables:
    - **Value model**
    - **Reference model**

Value Model

- Under the **value model** variables on the **left-hand side** (called **l-values**) of equations denote **references**, and variables on the **right-hand side** (called **r-values**) denote **values**.

```
b = 2;
a = b;
```

```
mem(1024)= 2;
mem(2036)= 2;
```



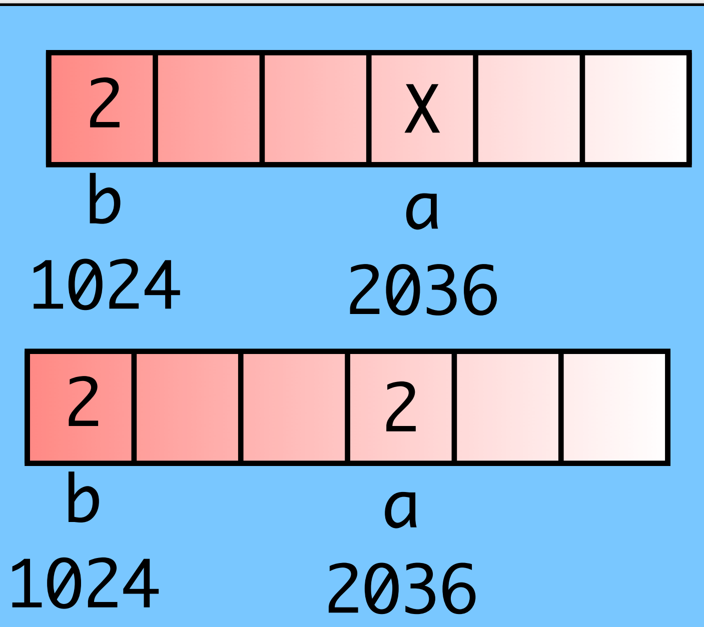
Val

Pascal and C use this model

- U **le**
  (c
  va
  denote **values**.

```
b = 2;
a = b;
```

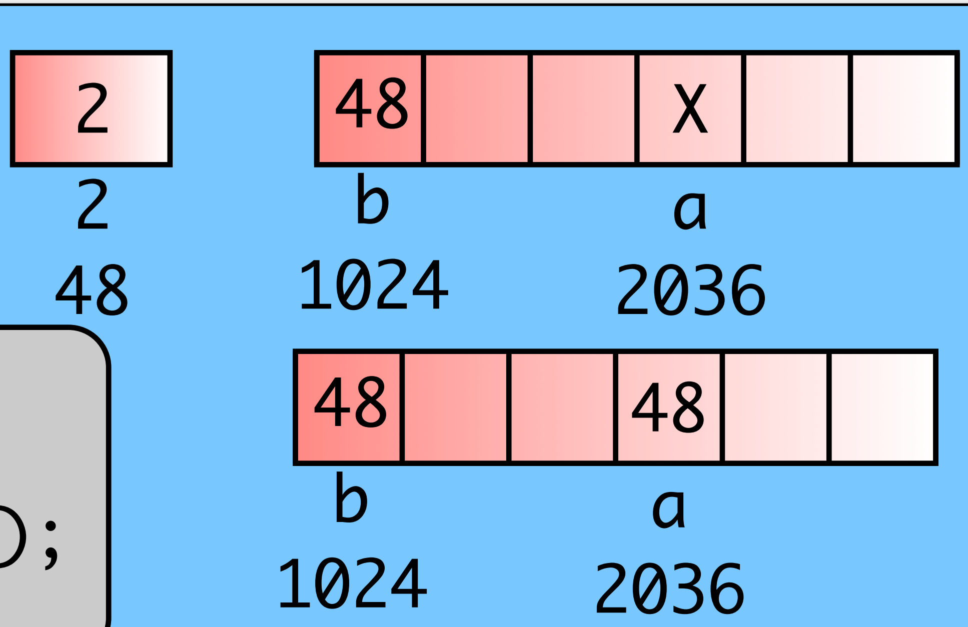
```
mem(1024)= 2;
mem(2036)= 2;
```



Reference Model

- Under the **reference model** variables on both the left- and right-hand side **are references**.

```
b = 2;
a = b;
```



```
 mem(1024)= loc(2);
mem(2036)= mem(1024);
```

Re

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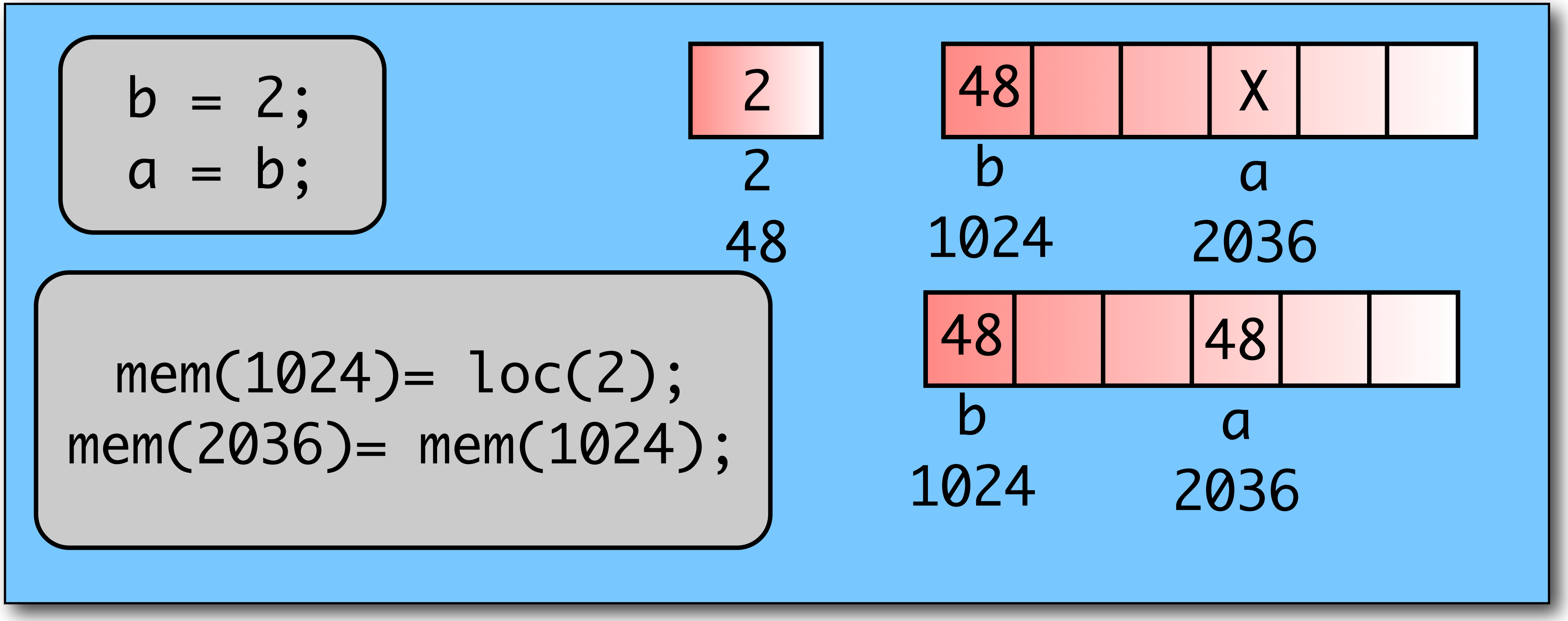
Lisp, Clu use this model.



```
b = 2;
a = b;
```

```
mem(1024)= loc(2);
mem(2036)= mem(1024);
```

Expressions: Initialization

- Variable initialization can be **implicit** or **explicit**.
  - **Implicit**: variables are initialized as they are used (e.g., Perl).

```
$a += 3;
```

  - **Explicit**: variables are initialized by the programmer (e.g., C).

```
int a = 0;
a += 3;
```

- Java, C# require **definite assignment**
  - Variables must be assigned a value before they are used in expressions

Expressions: Orthogonality

- **Orthogonality** means that features can be used in **any combination** and **the meaning is consistent** regardless of the surrounding features
  - Good idea in principle, but requires careful thought
  - e.g. assignment as an expression
    - unfortunate when combined with poor syntactic choices, as in C:

```
if(a=b){ }
```

```
if(a==b){ }
```

Expressions: Complication

- Execution ordering within expressions is **complicated by side effects** (and code improvements)
  - e.g., in C

```
b=1;
int inc(int a) {
  b+=1;
  return a+1;
}
c = (3*b) * inc(b);
```

- If inc(b) is evaluated before (3*b), the final value of c is 12. If the (3*b) is evaluated first, then the value is c is 6.

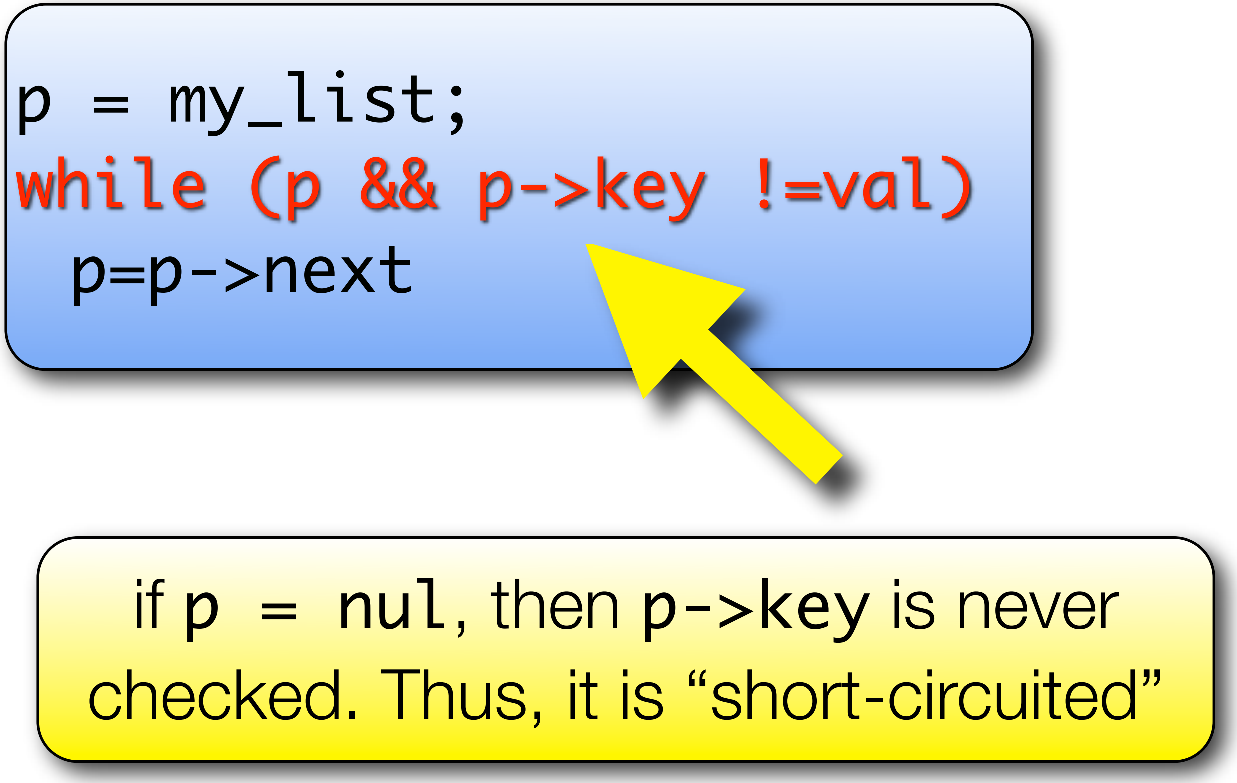
Expressions: Short-Circuit

- Expressions may be executed using short-circuit evaluation

```
p = my_list;
while (p && p->key !=val)
  p=p->next
```

Expressions: Short-Circuit

- Expressions may be executed using short-circuit evaluation



```
p = my_list;
while (p && p->key !=val)
  p=p->next
```

if `p = nul`, then `p->key` is never checked. Thus, it is “short-circuited”

Expressions: Short-Circuit

- Expressions may be executed using short-circuit evaluation

```
p = my_list;
while (p && p->key !=val)
  p=p->next
```

```
 p := my_list;
while (p<>nil) and
   (p^.key <> val) do
      p:=p^.next
```

Since Pascal does not have short circuiting, this will check both. Thus, if `p=nil`, then `p^.key` will **return an error.**