# Subprograms: Parameters

***Programming Languages***

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# Outline

- Terminology
  - Signature
  - Formal vs. Actual
  - Parameter Correspondence
- Passing Modes
  - Semantic
  - Actual
- Passing Arrays

# Terminology

**Signature**

*Portion of the Subprogram that tells us its interface but not its implementation.*

*Contains:*

1. Return type (if any)
2. Name
3. Count, order, and type of all Parameters

***The type signature omits the name***

# Parameters

Within a definition:

```
int magic(int a, int b, int c) {
    return b * b - 4 * a * c;
}
```

Within a call:

```
int d = magic(a, a + 1, a * 4);
```

# Parameters

Within a definition:

Called a **formal parameter**

- A “dummy” variable listed in the signature
- Used within the function’s implementation

Within a call:

Called an **actual parameter**

- Represents a value or address
- Determined at the point of execution

# Parameter Correspondence

**Actual Parameters** must map to **Formal Parameters**

***How do you think we should be able to map these?***

# Parameter Correspondence

**Actual Parameters** must map to **Formal Parameters**

*Positional*

- The first actual parameter corresponds to the first formal parameter, the second actual parameter corresponds to the second formal parameter, and so on…
- Very easy to check/implement

*Keyword*

- The *name* associated with the formal parameter must be used at the call site (where a subprogram is called)
- Parameters can appear in any order
- Intent can be clearer, but it harder to check/implement

# Passing Modes

# Semantic Modes

- In mode

  *Information is sent to the subprogram*

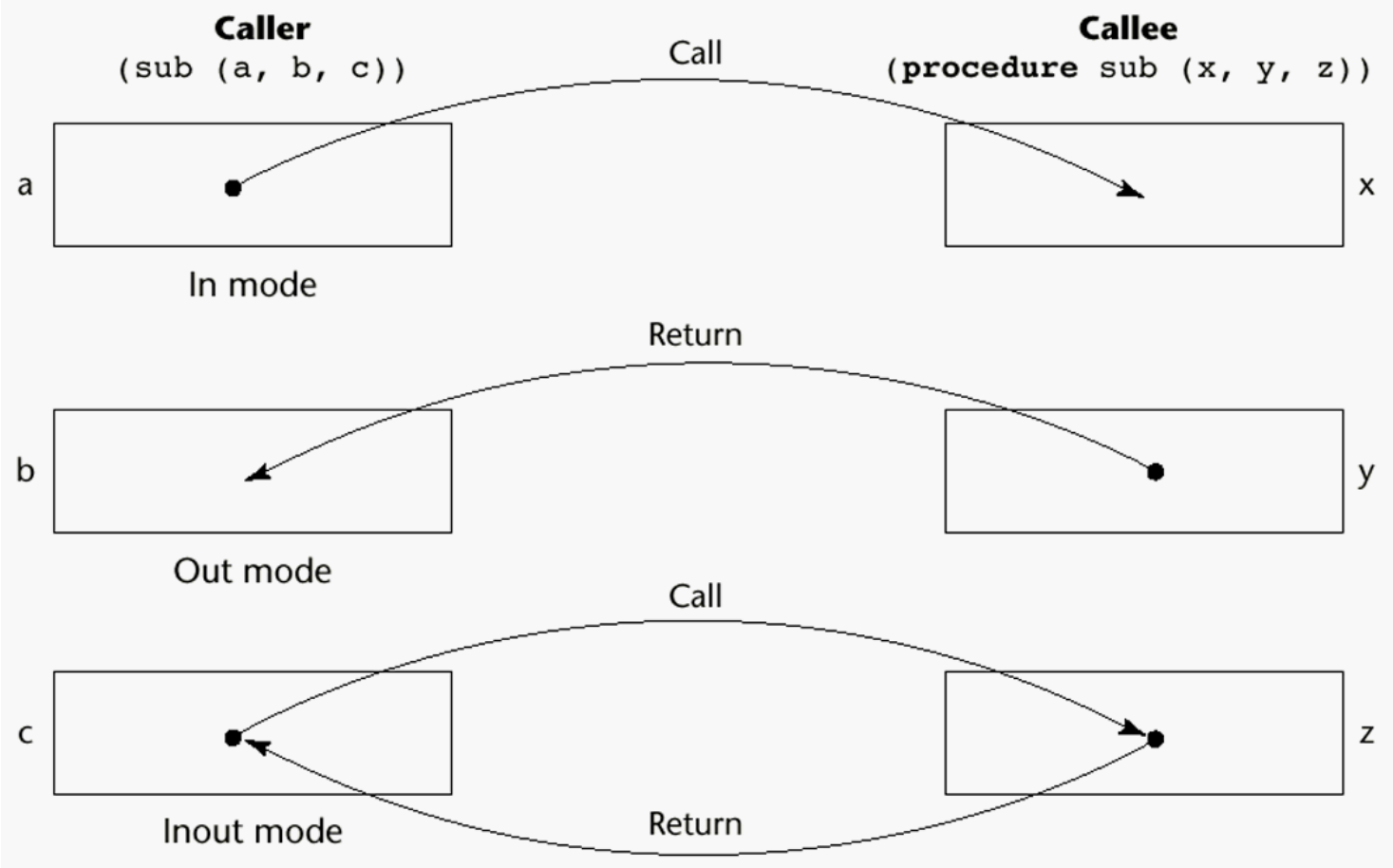
- Out mode

  *Information is retrieved from the subprogram*

- In-Out mode

  *Information is sent/received to/from the subprogram*

# Semantic Modes



# Actual Modes

- Pass-by-Value
- Pass-by-Result
- Pass-by-Value-Result
- Pass-by-Reference
- Pass-by-Name

# Pass-by-Value (In mode)

- The **value** of the actual parameter is used to initialize its corresponding formal parameter
- The underlying value is usually copied from one memory cell to another
- *Advantages:*
  - Simple
- *Disadvantages:*
  - Additional storage required
  - Copied value can be large (in space)

# Pass-by-Value

```
int by_value (int x) {
   int y = 4;
   x += 4;
   return y + x;
}
int y = 3;
int z = by_value (y);
// y =
// z =
```

# Pass-by-Value

Most languages do pass-by-value default:

- C
- C++
- Java
- C#
- Javascript
- Python* (for immutable types)

# Pass-by-Result (Out mode)

- There is no passed initial value, but the formal parameter acts like a local variable.
- When control flow returns to the caller, copy the result back to a memory cell.
- *Advantages:*
  - Useful for when you have multiple “outputs”
- *Disadvantages:*
  - For `fun(x, list[x])` should the address of `list[x]` be determined before or after execution?
  - Special semantics need to be determined for calls that use the same memory cell twice: `fun(a, a)`

# Pass-by-Result

```
void by_result (int x) {
   int y = 2;
   x = y + 4;
}

int y = 3;
by_result (y);
// y =
```

# Pass-by-Value-Result (In-Out mode)

- The expected combination of pass-by-value and pass-by-result
- Also called pass-by-copy (copy ALL THE THINGS)
- Formal parameters all have local storage

# Pass-by-Value-Result

Very few languages can pass-by-value-result:

- FORTRAN

# Pass-by-Value-Result

```
void by_value_result (int x) {
   int y = 4;
   x = y + 4;
}

int y = 3;
by_value_result (y);
// y =
```

# Pass-by-Reference (In-Out mode)

- Instead of passing a value, pass an *access path* (or memory address).
- Also called pass-by-sharing
- *Advantages:*
  - Lower memory footprint
- *Disadvantages:*
  - Slower access (must deference to retrieve value)
  - Potential side effects (multiple reference updates)
  - Aliasing isn't a lot of fun

# Pass-by-Reference

```
void by_reference (int x) {
   int y = 4;
   x = y + 4;
}

int y = 3;
by_reference (y);
// y =
```

# Pass-by-Reference

Most languages can pass-by-reference:

- C++
- Java (reference semantics for objects)
- C# (**ref** keyword)
- Python* (for mutable types)

# Pass-by-Name (In-Out mode)

- Literal Text Substitution
- Formals bound at time of call
- Values bound at time of reference or assignment
- *Advantages:*
  - Provides the latest possible binding
  - Extremely flexible
- *Disadvantages:*
  - No obvious semantics by looking at it

*It was possible to do this natively in ALGOL; harder to do today due to language design decisions.*

# Pass-by-Name (Jensen's Device)

```
#define SUM(Type, Var, Low, High, Term) \
 ({ \
    int low = (Low); \
    int high = (High); \
    Type sum = (Type)0; \
    for (Var = low; Var <= high; ++Var) { \
      sum += (Term); \
    } \
    sum;
 })
```

# Pass-by-Name (Jensen's Device)

```
double sum = SUM(double, i, 1, 100, 1.0 / i)

// expands to:
double sum = ({
  int low = (1);
  int high = (100);
  double sum = (double)0;
  for (i = low; i <= high; ++i) {
    sum += (1.0 / i);
  }
  sum;
});
```

# Pass-by-Name (Jensen's Device)

```
double prod = SUM(double, i, 1, 100, SUM(double, j, i, 100, i * j))

// expands to
double prod = ({
  int low = (1);
  int high = (100);
  double sum = (double)0;
  for (i = low; i <= high; ++i) {
    sum += (({
      int low = (i);
      int high = (100);
      double sum = (double)0;
      for (j = low; j <= high; ++j) {
        sum += (i * j);
      }
      sum;
    }));
  }
  sum;
});
```

# Passing Arrays as Parameters

# Languages Where Passing Arrays is Fine and Works as Expected

| | | | |
|---|---|---|---|
| C# | D | Java | Python |
| JavaScript | Ruby | Perl | PHP |
| Lisp | OCaml | F# | FORTRAN |

# Languages Where Passing Arrays is Weird

# Array Passing in C/C++

**Definition of a stack-based array in C:**

```
int arr[5];
```

The type of `arr` is `int[5]`

Passing `arr` as a parameter will *decay* its type.

Decay means automatic conversion (loss of information)

`int*`

# Array Passing in C/C++

**Definition of a heap-based array in C++:**

```
int* arr = new int[5];
```

The type of `arr` is `int*`

Passing `arr` as a parameter doesn't change its type: `int*`

# Array Passing in C/C++

*We don't want heap-based and stack-based arrays to interact differently, so they need to be converted to a common type*

- Though it is possible to accept only stack-based arrays!

# Multi-Dimensional Array Passing in C++

```
double m[3][4];

// valid
void mat_inverse (double (&m)[3][4])
void mat_inverse (double* m[4])
// invalid
void mat_inverse (double** m)
```

We decay the outer-most dimension **only**