Parameter Passing Modes

Our programs are littered with function calls like $f(x, 5)$.

This is a way of passing information from the call site (where the code $f(x, 5)$ appears) to the function itself.

The parameter passing mode tells us how the information about the arguments (e.g. $x$ and 5) is communicated from the call site to the function.

Pass by Value

C/C++ use pass by value by default. Java uses it for primitive types (int, boolean, etc.).

```cpp
void f(int a) {
    a = 2*a;
    print(a);
}

int main() {
    int x = 5;
    f(x);
    print(x);
    return 0;
}
```

What does this C++ program print?

Pass by Value

In this scheme, the function receives copies of the actual parameters.

The function cannot modify the originals, only its copies, which are destroyed when the function returns.

Function arguments represent one-way communication from call site to function.

(How can the function communicate back?)
Pass by Reference

C++ supports reference parameters. Perl and VB use this mode by default.

```perl
sub foo {
    $_[0] = "haha_changed_by_foo";
}
my $y = "this_is_mine!";
foo($y);
print $y, "\n";
```

You can guess what this Perl program prints...

Similar behavior happens if we wrote void f(int &a) {...} in the previous C++ example.

Pass by Reference

The formal parameters of the function become aliases for the actual parameters!
Normally the actual parameters must be variable names (or more generally, l-values...).

Function arguments now represent two-way communication.

Most common reasons to use reference parameters:

Variations

- **Pass by Value/Result**
The initial value is passed in as a copy, and the final value on return is copied back out to the actual parameter.
Behaves like pass-by-reference, unless the actual parameter is accessed during the function call.

- **Pass by Sharing**
This is what happens with objects in Java.
Actual and formal parameters both reference some shared data (i.e., the object itself).
But they are not aliases; functions can change the object that is referenced, but cannot set which object is referenced.
Parameter Passing Modes

Pass by Value/Result
This is the default in Fortran, and for “in out” parameters in Ada:

```plaintext
-- in file f.adb
procedure f(x : in out Integer) is
begin
  x := 10;
end f;
```

```plaintext
-- in file test.adb
procedure test is
  y : Integer := 5;
begin
  f(y);
  Ada.Integer_Text_IO.Put(y);
end test;
```

Calling test prints 10, not 5!

Parameter Passing Modes

Pass by Sharing
This is the default in languages like Java, for non-primitive types:

```plaintext
class Share {
  static class Small {
    public int x;
    public Small(int thex) { x = thex; }
  }

  public static void test(Small s) {
    s.x = 10;
    s = new Small(20);
  }

  public static void main(String[] args) {
    Small mainsmall = new Small(5);
    test(mainsmall);
    System.out.println(mainsmall.x);
  }
}
```

Does this program print 5, 10, or 20?

Parameter Passing Modes

Parameter Passing in Functional Languages
Why haven’t we talked about parameter passing in Haskell, Scheme, etc.?
Argument evaluation

**Question**: When are function arguments evaluated?

There are three common options:

- **Applicative order**: Arguments are evaluated just before the function body is executed. This is what we get in C, C++, Java, and even SPL.

- **Call by name**: Arguments are evaluated every time they are used. (If they aren’t used, they aren’t evaluated!)

- **Normal order**: next slide.

Lazy Evaluation

(A.K.A. normal order evaluation)

Combines the best of both worlds:

- Arguments are not evaluated until they are used.
- Arguments are only evaluated at most once.

(Related idea to memoization.)

Lazy Examples

Note: lazy evaluation is great for functional languages (why?).

- Haskell uses lazy evaluation for everything, by default. Allows wonderful things like infinite arrays!

- Scheme lets us do it manually with delayed evaluation, using she built-in special forms delay and force.
Method calls in objects

What does a call like `obj.foo(x)` do in an OOP language such as C++ or Java?

`foo` must be a method defined in the class of `obj`. The method also has access to what object it was called on (called `this` in C++ and Java).

This is syntactic sugar for having a globally-defined method `foo`, with an extra argument for "this". So we can think of `obj.foo(x)` as `foo(obj,x)`.

Overloading

Function overloading: one name, many functions. Which function to call is determined by the types of the arguments.

```cpp
class A { void print() { cout << "in A" << endl; };
class B { void print() { cout << "in B" << endl; };

void foo(int a) { cout << a << " is an int\n"; }
void foo(double a) { cout << a << " is a double\n"; }

int main() {
    cout << (5 << 3) << endl;
    A x; B y;
    x.print();
    y.print();
    foo(5); foo(5.0);
}
```

How does overloading occur in this C++ example?

Polymorphism

Subtype polymorphism is like overloading, but the called function depends on the object’s actual type, not its declared type!

Each object stores a virtual methods table (vtable) containing the address of every virtual function. This is inspected at run-time when a call is made.

See section 9.4 in your book if you want the details.
Polymorphism example in C++

class Base { virtual void aha() = 0; };

class A : public Base {
    void aha() { cout << "I'm an A!" << endl; }
};

class B : public Base {
    void aha() { cout << "I'm a B!" << endl; }
}

int main(int argc) {
    Base* x;
    if (argc == 1) // can't know this at compile-time!
        x = new A;
    else
        x = new B;
    x.aha(); // Which one will it call?
}

Operators, Built-ins

Different kinds of functions

The code f(5) here is definitely a function call:

int f(int x) { return x + 6; }

int main() {
    cout << f(5) << endl;
    return 0;
}

- What else is a function call?

Operators, Built-ins

Operators

Say we have the following C++ code:

int mod (int a, int b) {
    return a - (a/b)*b;
}

What is the difference between
23 % 5
and
mod(23, 5)
Are Operators Functions?

It's language dependent!

- **Scheme**: Every operator is clearly just like any other function. Yes, they can be re-defined at will.
- **C/C++**: Operators are functions, but they have a **special syntax**. The call x + y is **syntactic sugar** for either operator+(x, y) or x.operator+(y).
- **Java**: Can't redefine operators; they only exist for some built-in types. So are they still function calls?

Built-ins

A **built-in function** looks like a normal function call, but instead makes something special happen in the compiler/interpreter.

- Usually system calls are this way.
- C/C++ are an important exception!
- What is the difference between a built-in and a library function?

Macros

Recall that C/C++ has a **preprocessor** stage that occurs before compilation. These are the commands like #include, #ifndef, etc.

#define defines a **macro**. It corresponds to textual substitution **before** compilation.
**Macros**

**Constant Macros**

Here’s an example of a basic macro that you might see somewhere:

The program

```c
#define PI 3.14159

double circum (double radius)
{ return 2*PI*radius; }
```

gets directly translated by the preprocessor to

```c
double circum (double radius)
{ return 2*3.14159*radius; }
```

before compilation!

**Macro Issues #1**

What if we wrote the last example differently:

```c
#define PI 3.14159
#define TWOPI PI + PI

double circum (double radius)
{ return TWOPI * radius; }
```

**Function-like Macros**

We can also do things like this in C++:

```c
#define CIRCUM (radius) 2*3.14159*radius
...
cout << CIRCUM(1.5) + CIRCUM(2.5) << endl;
...
```

gets translated to

```c
...
cout << 2*3.14159*1.5 + 2*3.14159*2.5 << endl;
...
```

(still prior to compilation)
Macro Issues #2

What if we made the following function to print out the larger number:

```c
#define PRINTMAX (a,b) \
    if (a >= b) {cout << a << endl;} \
    else {cout << b << endl;}
```

This will work fine for `PRINTMAX(5,10)`, but what happens with the following:
```
int x = 5;
PRINTMAX (++x, 2)
```

Thoughts on Macros

- The advantage is SPEED - pre-compilation!
- Notice: no types, syntactic checks, etc.
  — lots of potential for nastiness!
- The literal text of the arguments is pasted into the function wherever the parameters appear.
  This is called ...
- The `inline` keyword in C++ is a compiler suggestion that may offer a compromise.
- Scheme has a very sophisticated macro definition mechanism — allows one to define "special forms".

Class Outcomes

You should know:

- The way parameter passing works in pass by value, by reference, by value/result, and by sharing
- Relative advantages of those parameter passing modes
- The way arguments are evaluated under applicative order, normal order, and call by name
- Why lazy evaluation (normal order) can be terrific
- What function overloading is and where it gets used
- What subtype polymorphism is and how virtual tables are used to implement it
- Differences between operators, built-ins, library routines, and user-defined functions
- What constant macros and function-like macros are, and what are their advantages and drawbacks.