# Language Processors

COMS W4115

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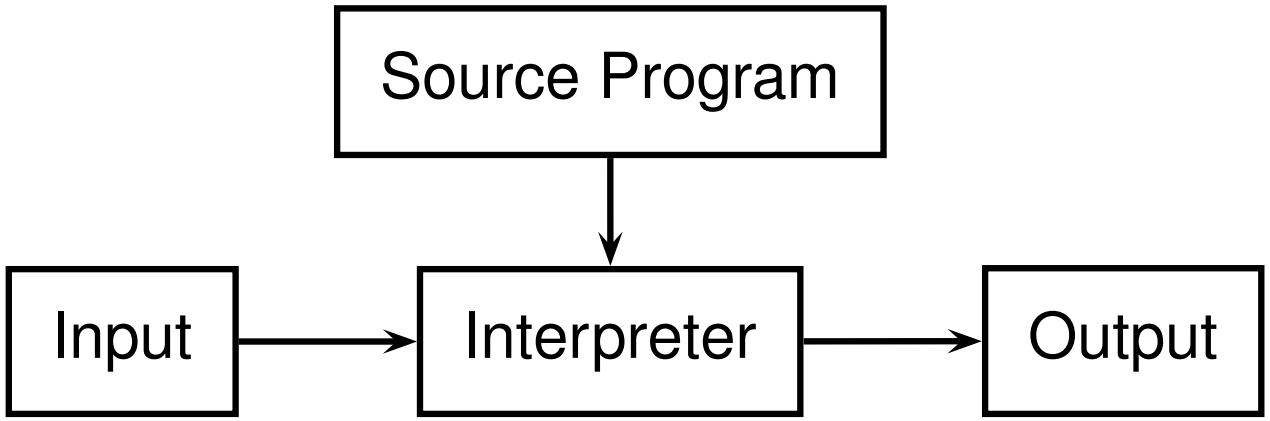
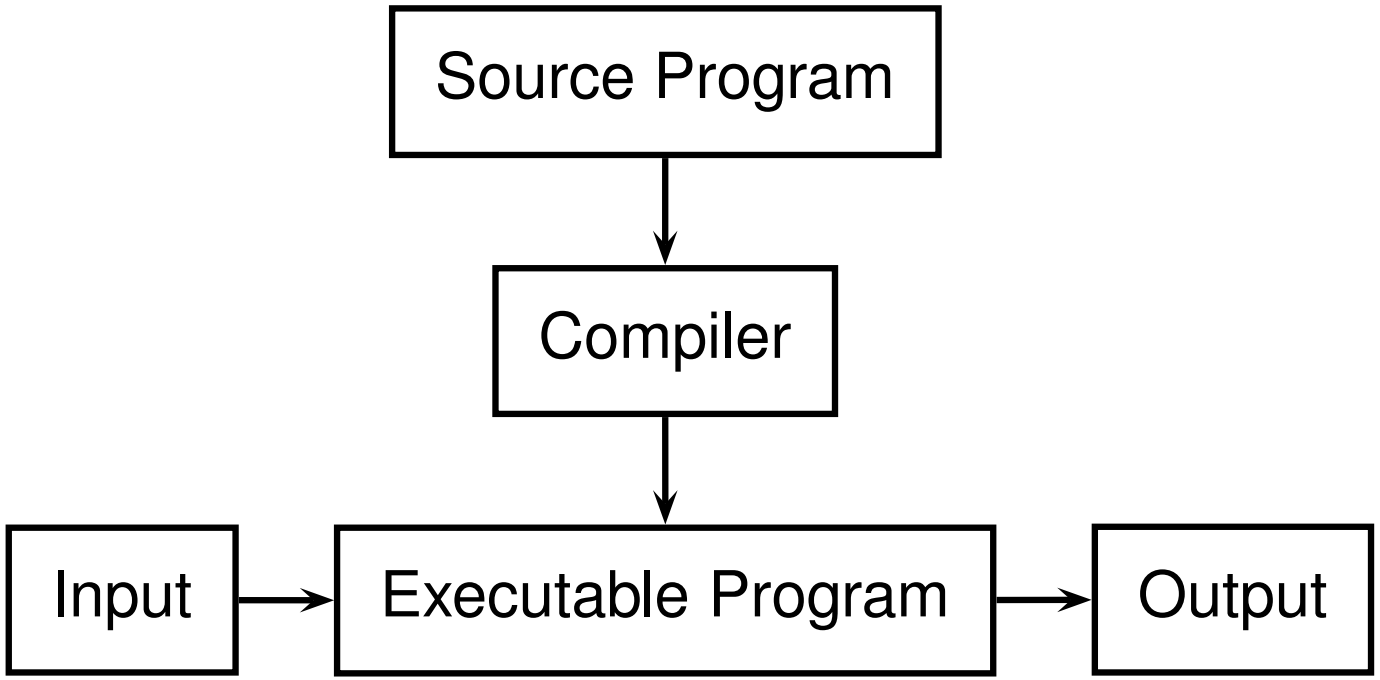
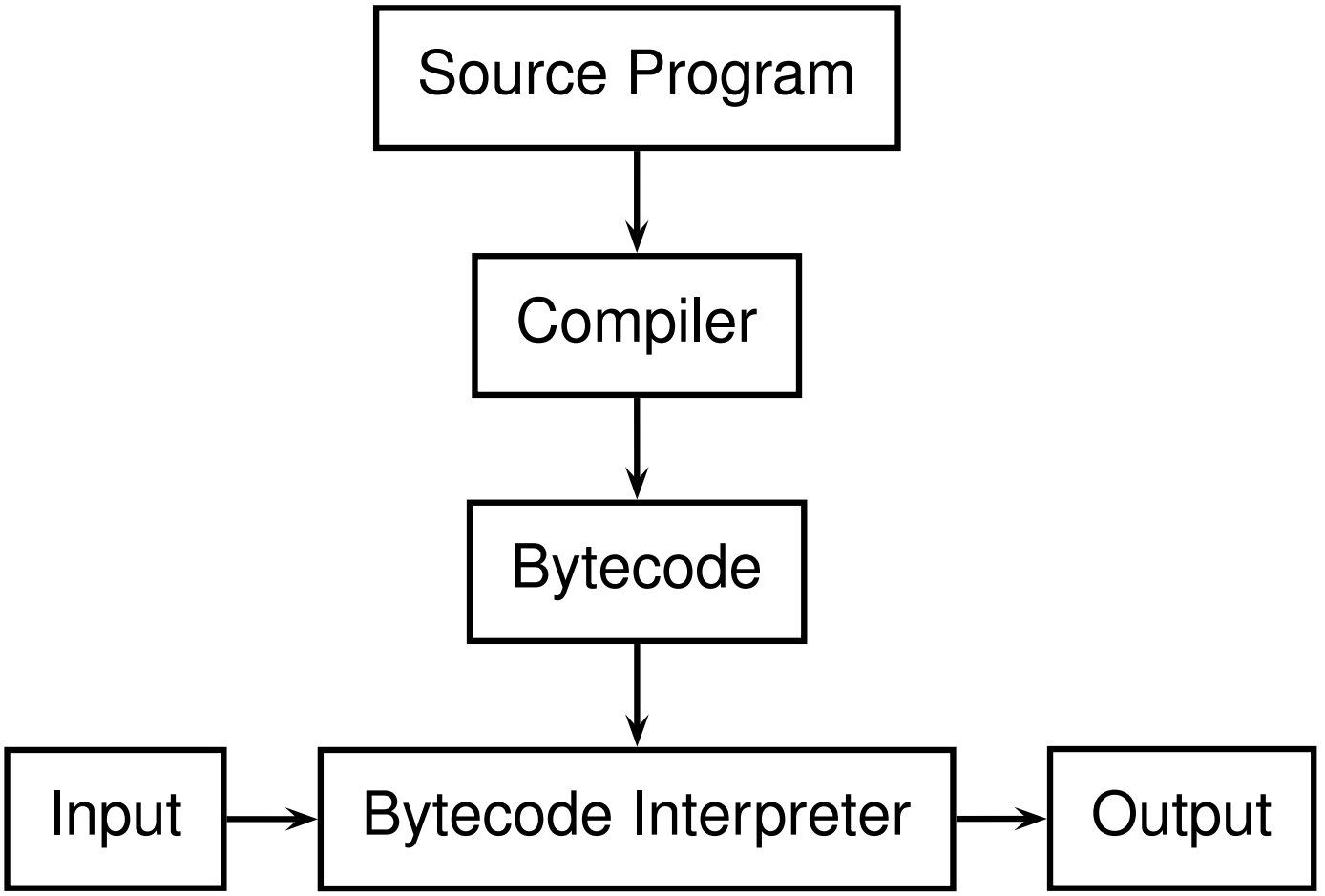
# Interpreter



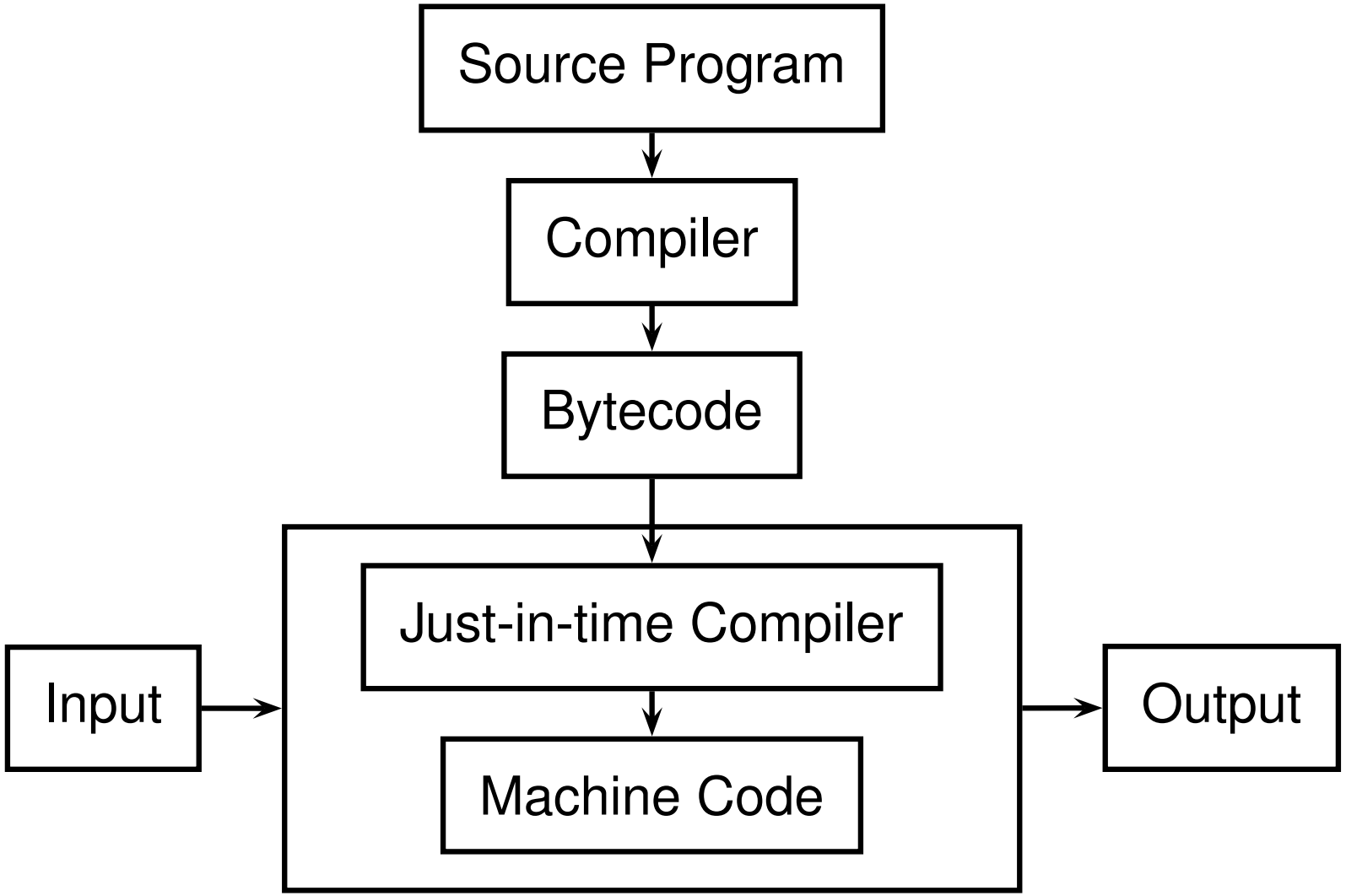
# Compiler



# Bytecode Interpreter

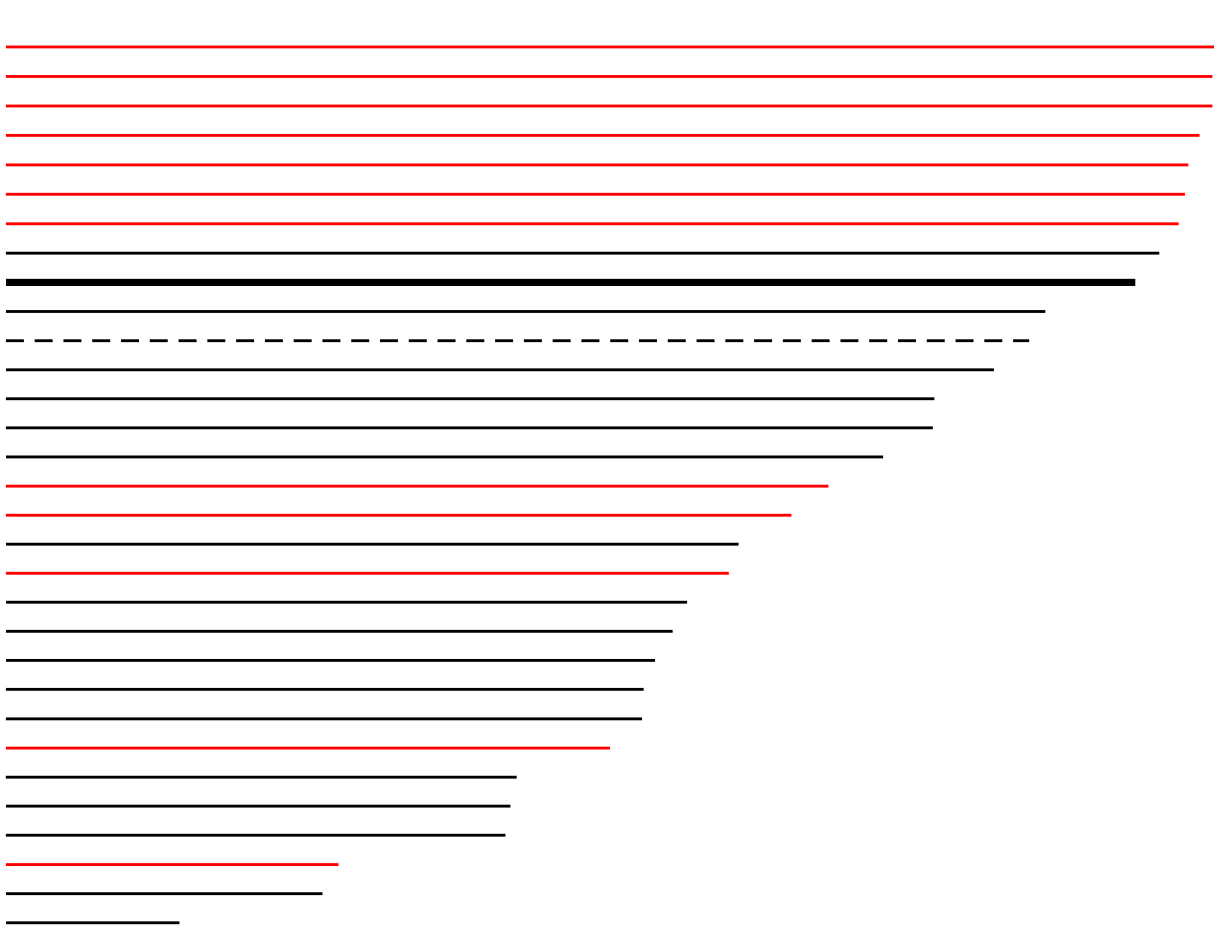


# Just-in-time Compiler



# Language Speeds Compared

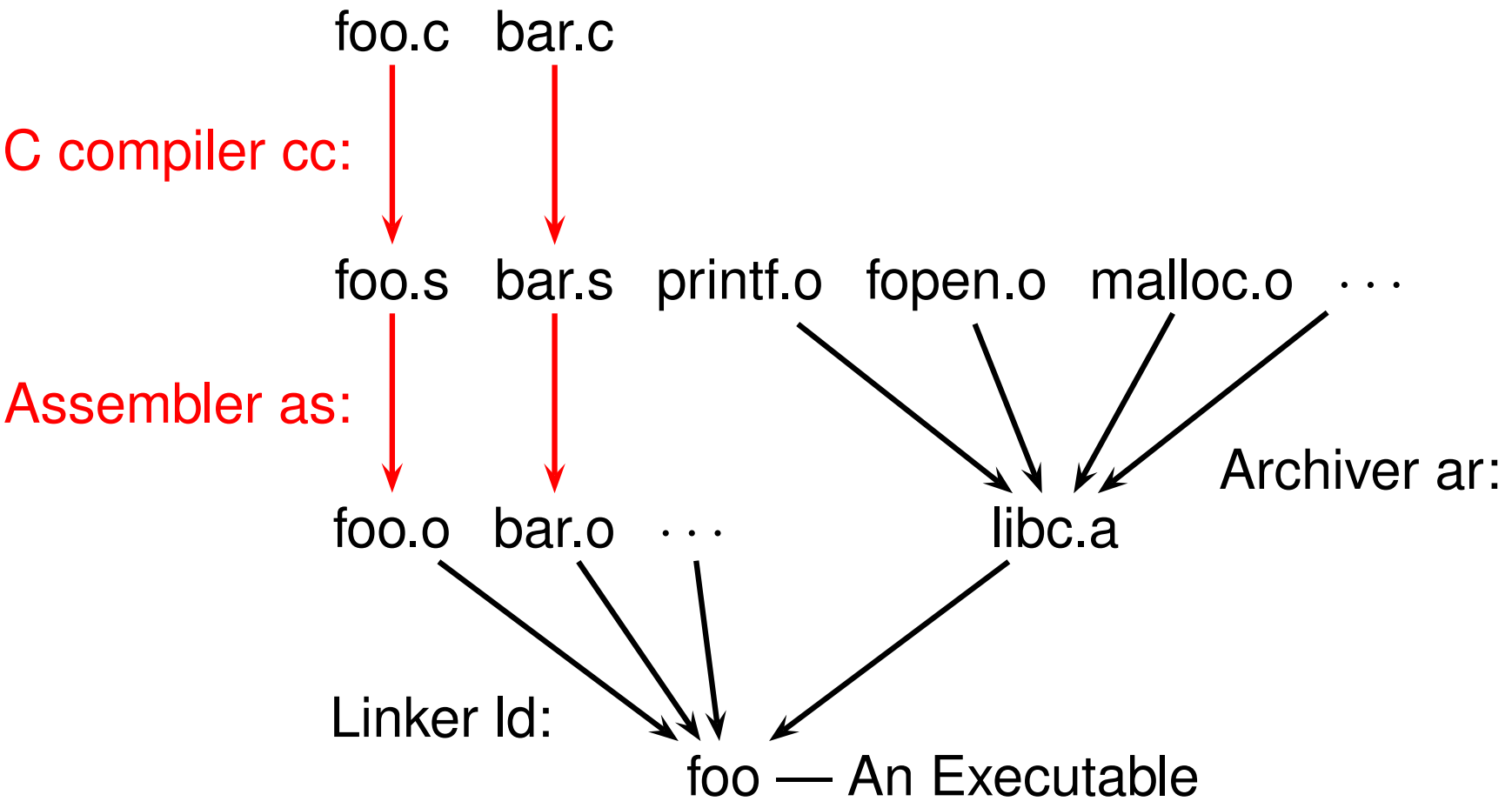
| Language | Impl. |
|---|---|
| C | **gcc** |
| Ocaml | **ocaml** |
| SML | **mlton** |
| C++ | **g++** |
| SML | **smlnj** |
| Common Lisp | **cmucl** |
| Scheme | **bigloo** |
| Ocaml | ocamlb |
| Java | **java** |
| Pike | pike |
| Forth | *gforth* |
| Lua | lua |
| Python | python |
| Perl | perl |
| Ruby | ruby |
| Eiffel | **se** |
| Mercury | **mercury** |
| Awk | mawk |
| Haskell | **ghc** |
| Lisp | rep |
| Icon | icon |
| Tcl | tcl |
| Javascript | njs |
| Scheme | guile |
| Forth | **bigforth** |
| Erlang | erlang |
| Awk | gawk |
| Emacs Lisp | xemacs |
| Scheme | **stalin** |
| PHP | php |
| Bash | bash |



bytecodes **native code** **JIT** *Threaded code*

http://www.bagley.org/~doug/shootout/

# Separate Compilation



# Preprocessor

“Massages” the input before the compiler sees it.

- Macro expansion
- File inclusion
- Conditional compilation

# The C Preprocessor

```
#include <stdio.h>
#define min(x, y) \
   ((x)<(y))?(x):(y)
#ifdef DEFINE_BAZ
int baz();
#endif
void foo()
{
   int a = 1;
   int b = 2;
   int c;
   c = min(a,b);
}
```

`cc -E example.c` gives

```
extern int
printf(char*,...);
```

... many more declarations from stdio.h

```
void foo()
{
   int a = 1;
   int b = 2;
   int c;
   c = ((a)<(b))?(a):(b);
}
```

# Compiling a Simple Program

```
int gcd(int a, int b)
{
  while (a != b) {
    if (a > b) a -= b;
    else b -= a;
  }
  return a;
}
```

# What the Compiler Sees

```
int gcd(int a, int b)
{
  while (a != b) {
    if (a > b) a -= b;
    else b -= a;
  }
  return a;
}
```

```
i  n  t sp  g  c  d  (  i  n  t sp  a  , sp  i
n  t sp  b  ) nl  { nl sp sp  w  h  i  l  e sp
(  a sp  !  = sp  b  ) sp  { nl sp sp sp sp  i
f sp  (  a sp  > sp  b  ) sp  a sp  -  = sp  b
; nl sp sp sp sp  e  l  s  e sp  b sp  -  = sp
a  ; nl sp sp  } nl sp sp  r  e  t  u  r  n sp
a  ; nl  } nl
```

Text file is a sequence of characters

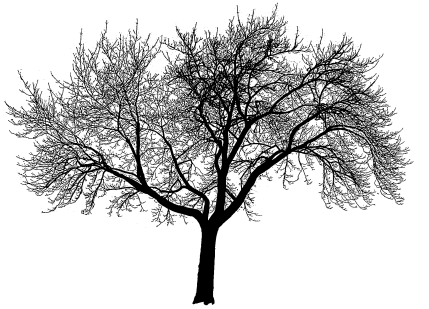
# Lexical Analysis Gives Tokens

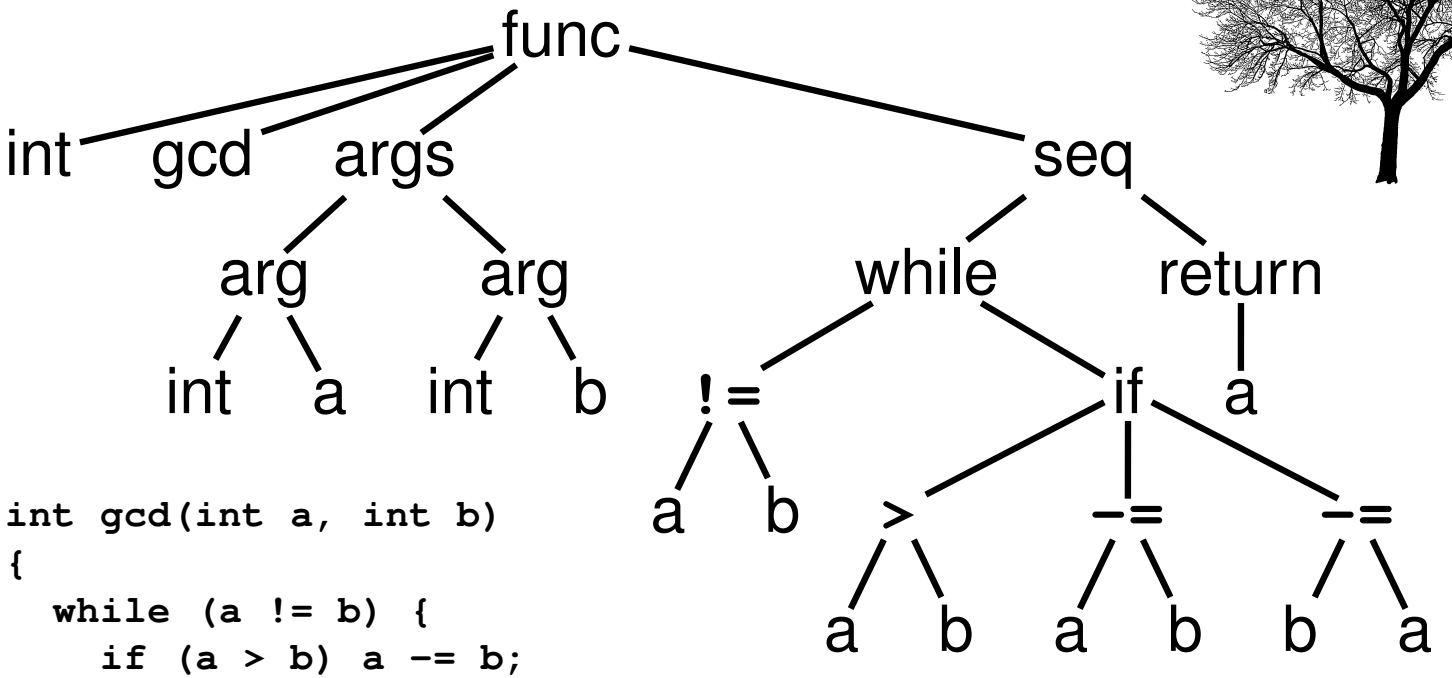
```
int gcd(int a, int b)
{
  while (a != b) {
    if (a > b) a -= b;
    else b -= a;
  }
  return a;
}
```

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| int | gcd | ( | int | a | , | int | b | ) | { | |
| while | ( | a | != | b | ) | { | if | ( | a | |
| > | b | ) | a | -= | b | ; | else | b | -= | a |
| ; | } | return | a | ; | } | | | | | |

A stream of tokens. Whitespace, comments removed.

# Parsing Gives an AST

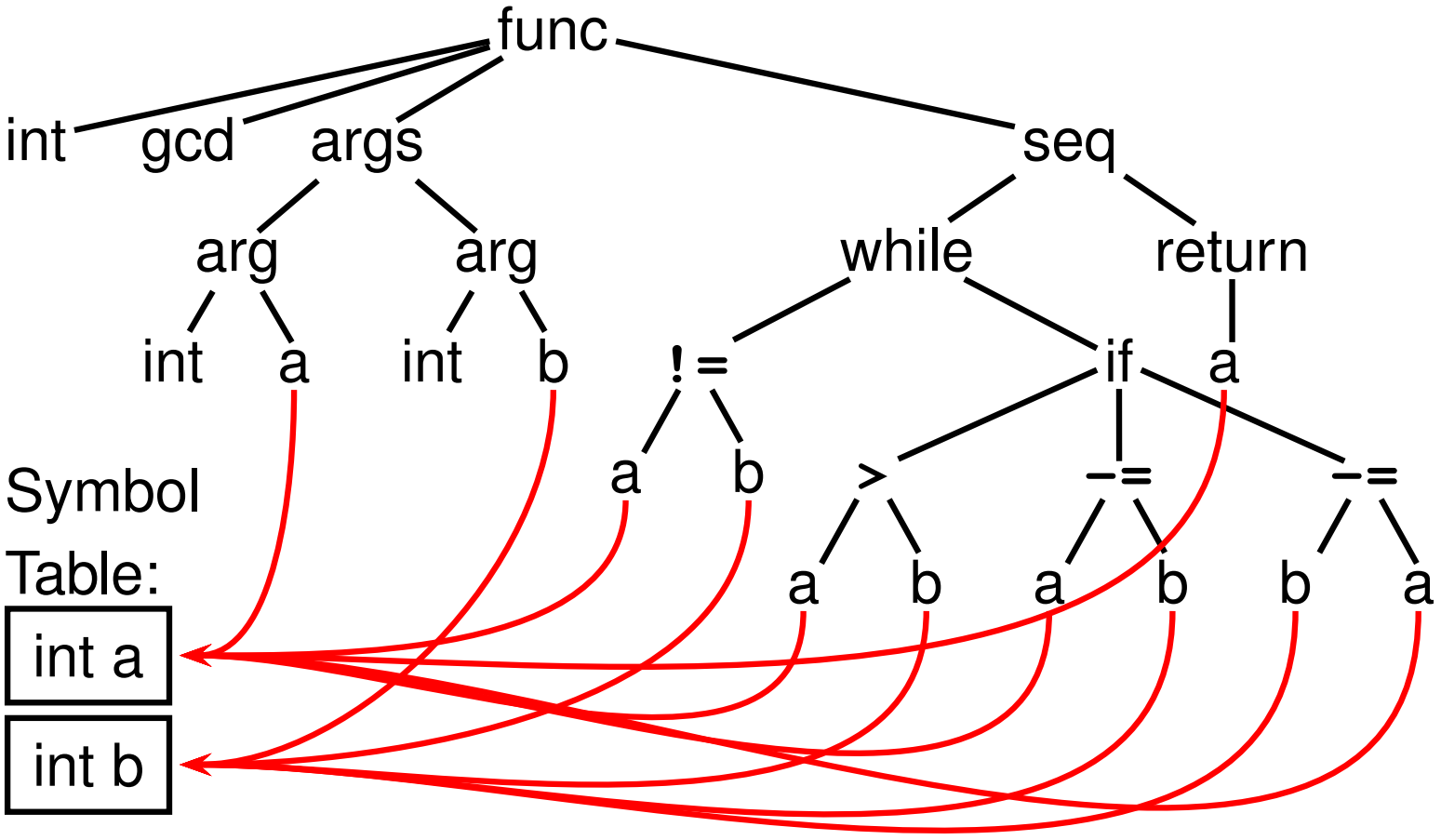





```
int gcd(int a, int b)
{
  while (a != b) {
    if (a > b) a -= b;
    else b -= a;
  }
  return a;
}
```

Abstract syntax tree built from parsing rules.

# Semantic Analysis Resolves Symbols




Types checked; references to symbols resolved

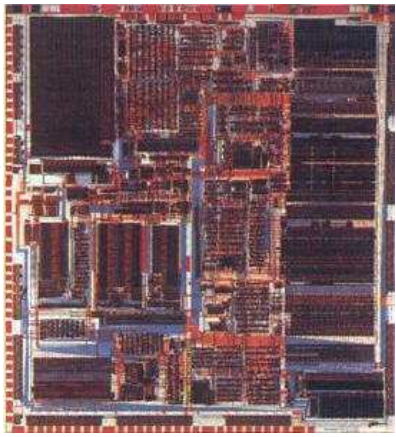
# Translation into 3-Address Code

```
L0: sne   $1,  a, b
    seq   $0, $1, 0
    btrue $0, L1     % while (a != b)
    sl    $3,  b, a
    seq   $2, $3, 0
    btrue $2, L4     % if (a < b)
    sub   a,   a, b % a -= b
    jmp   L5
L4: sub   b,   b, a % b -= a
L5: jmp   L0
L1: ret    a
```

```
int gcd(int a, int b)
{
  while (a != b) {
    if (a > b) a -= b;
    else b -= a;
  }
  return a;
}
```

Idealized assembly language w/ infinite registers

# Generation of 80386 Assembly



```
gcd:   pushl  %ebp                % Save FP
       movl   %esp,%ebp
       movl   8(%ebp),%eax        % Load a from stack
       movl   12(%ebp),%edx       % Load b from stack
.L8:   cmpl   %edx,%eax
       je     .L3                 % while (a != b)
       jle    .L5                 % if (a < b)
       subl   %edx,%eax           % a -= b
       jmp    .L8
.L5:   subl   %eax,%edx           % b -= a
       jmp    .L8
.L3:   leave                      % Restore SP, BP
       ret
```