6.S096

Introduction to C and C++

Why?

1

You seek performance

1

You seek performance

“zero-overhead principle”

2

You seek to interface directly with hardware

3

That’s kinda it

C

a nice way to avoid writing assembly language directly

C++

responds to the demands of maintaining large C projects

C++11

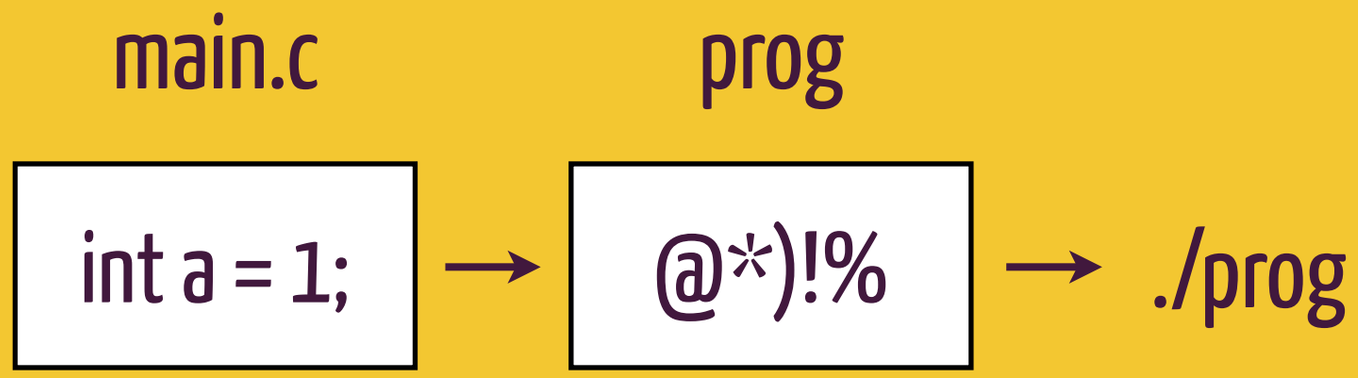
responds to the demands of maintaining large C++ projects

Maintain power and flexibility of what came before

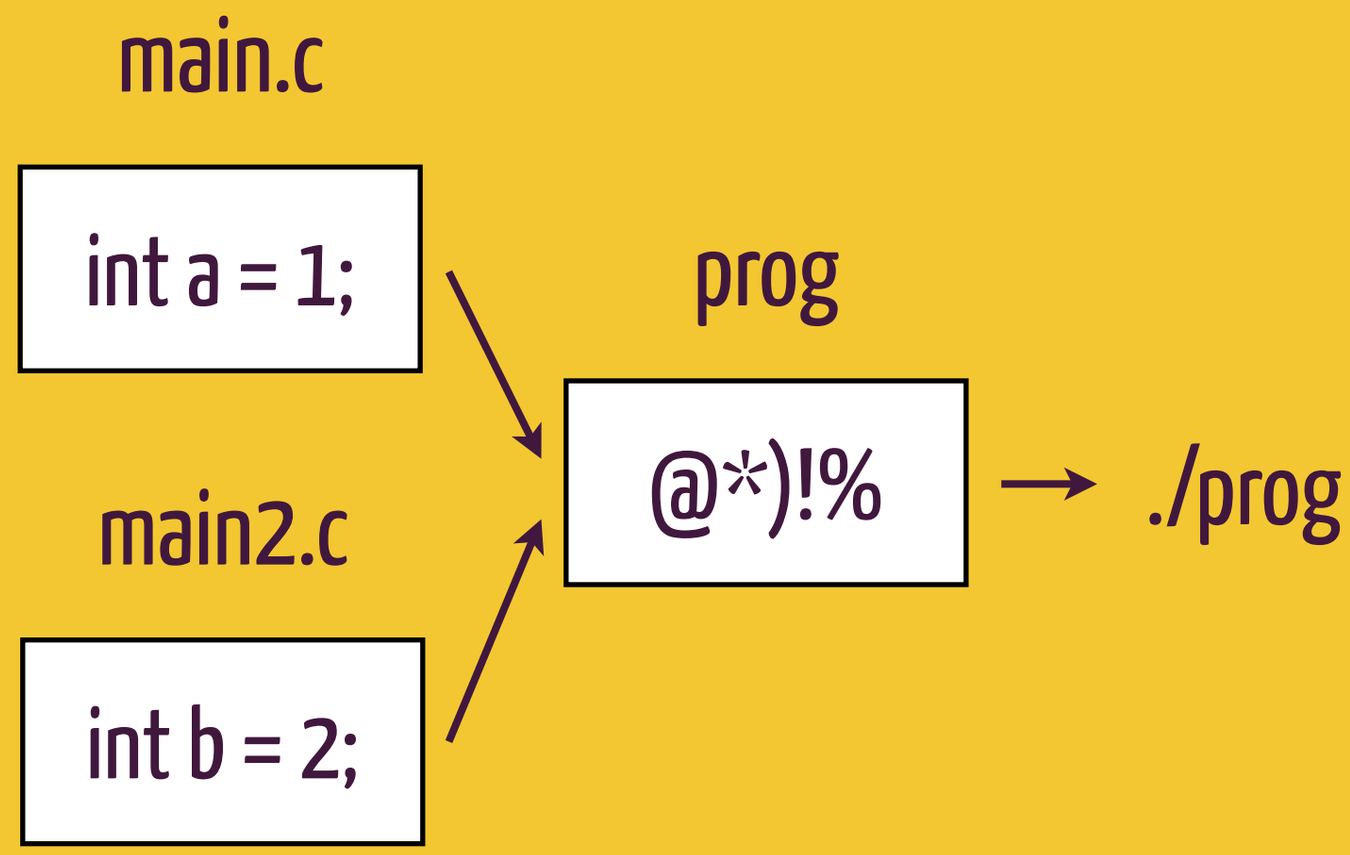
Today: Compilation Pipeline

Source Code

Program




```
gcc -o prog main.c
```




```
gcc -o prog main.c main2.c
```

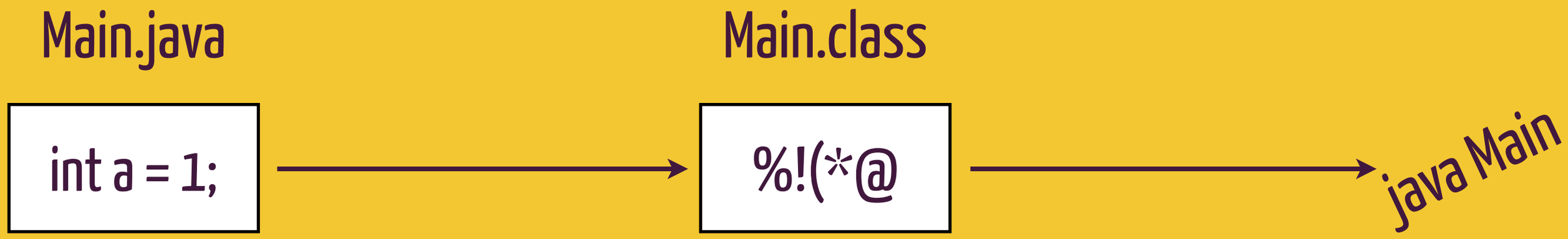
```
$ gcc -o prog main.c
$ ./prog
Hello, World!
$
```

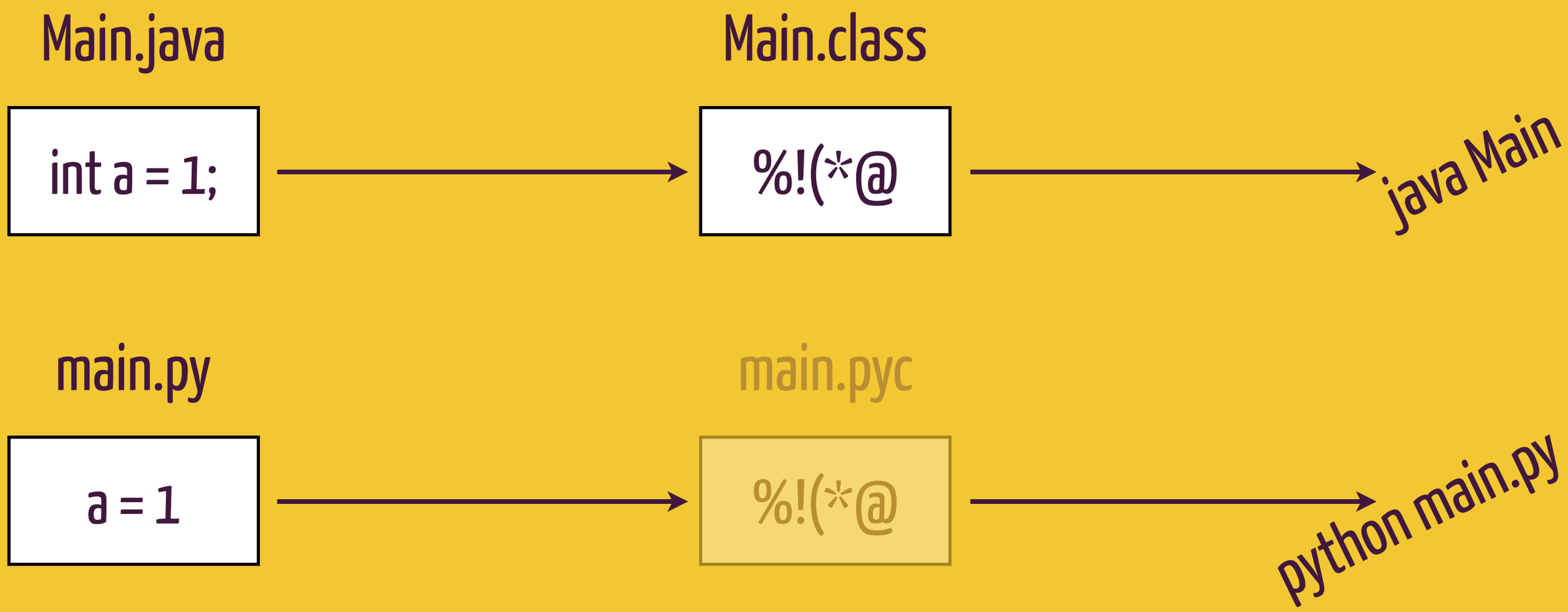
```
$ gcc -o prog main.c
$ ./prog
Hello, World!
$
```

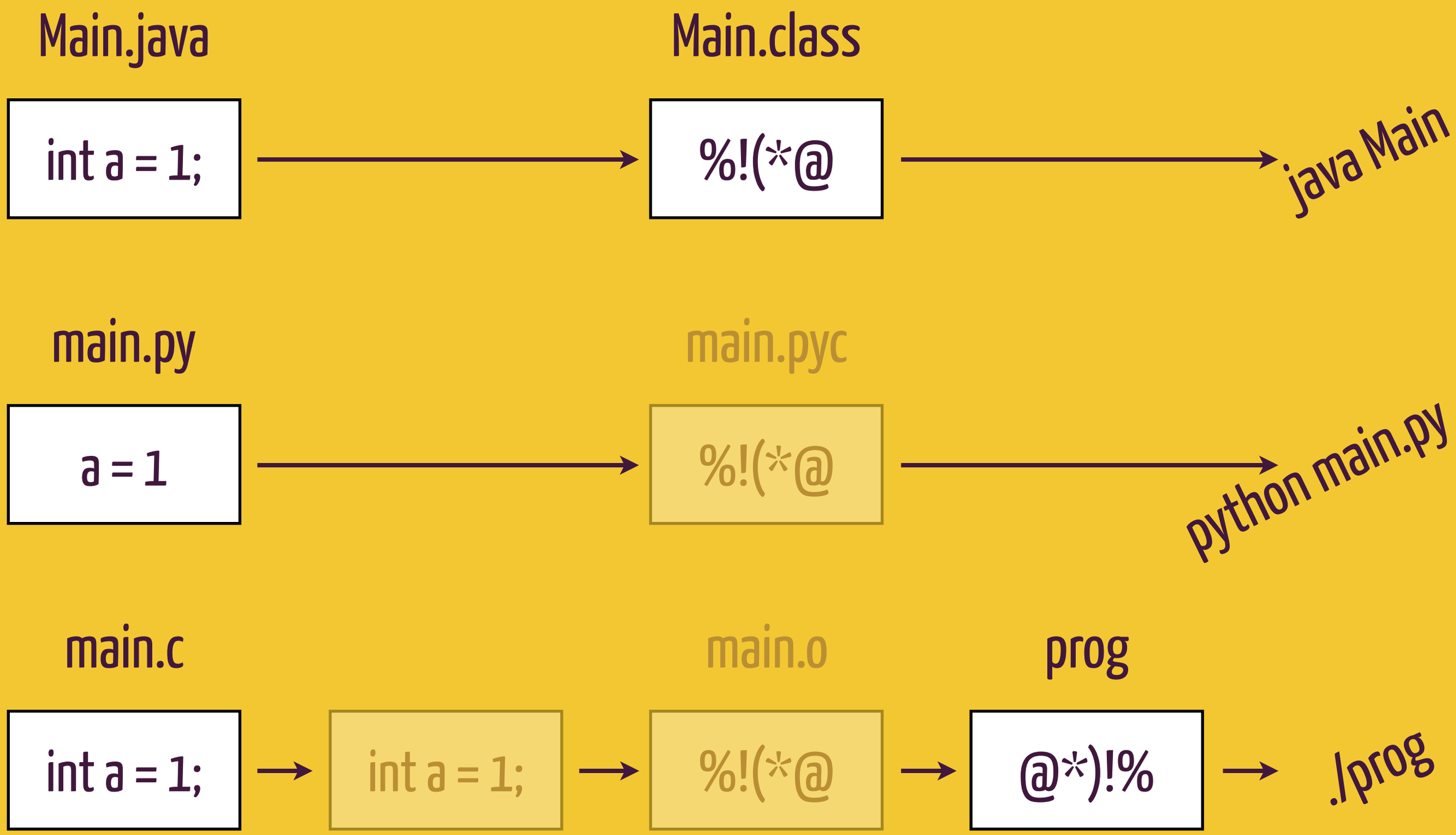
DONE

“To debug the sausage, one must see how it is made.”

—Someone, probably


Main.java
int a = 1;
Main.class
%!(*@
java Main


Main.java
int a = 1;
Main.class
%!(*@
java Main
main.py
a = 1
main.pyc
%!(*@
python main.py


Main.java
int a = 1;
Main.class
%!(*@
java Main
main.py
a = 1
main.pyc
%!(*@
python main.py
main.c
int a = 1;
int a = 1;
main.o
%!(*@
prog
@*)!%
./prog

Pre-Process

main.c

int a = 1;

→

int a = 1;

→

main.o

%!(*@

→

prog

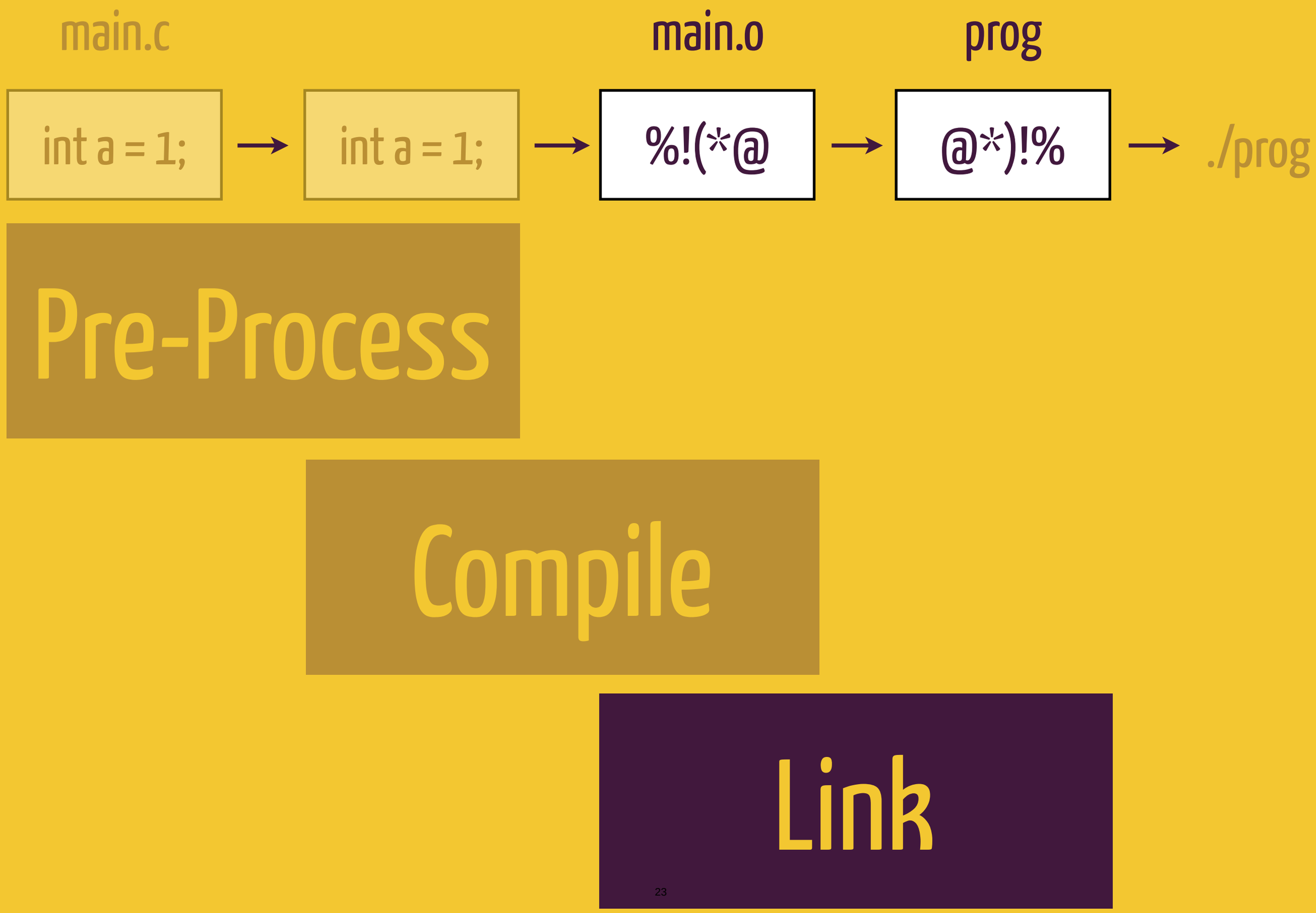
@*)!%

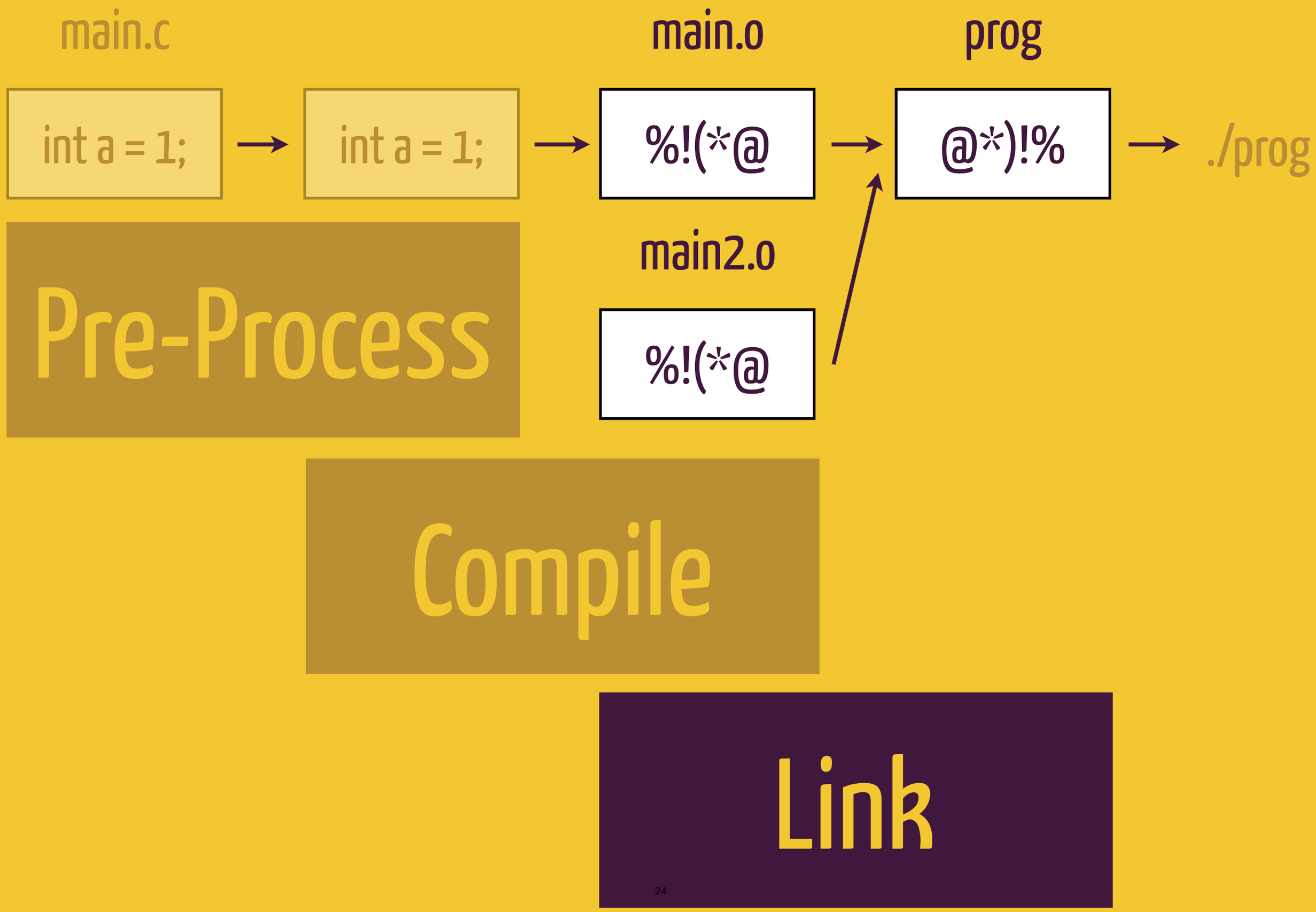
→

./prog

Pre-Process

Compile


main.c
int a = 1;
int a = 1;
main.o
%!(*@
prog
@*)!%
./prog
Pre-Process
Compile
Link


main.c
int a = 1;
int a = 1;
Pre-Process
Compile
main.o
%!(*@
main2.o
%!(*@
Link
prog
@*)!%
./prog

Pre-Process

Compile

Link

Pre-Process

Compile

Link

#include

#define

#ifdef

rimshot.txt

```
ba-dum chh
```

joke.txt

```
A man walks into
a bar. Ouch!
#include "rimshot.txt"
```

```
cpp -P joke.txt
```

output:

```
A man walks into
a bar. Ouch!
ba-dum chh
```

```
cpp -P joke.txt
```

double.py

```
#define fosho def
#define kthx return
#define wutz print

fosho double(x):
    kthx x * 2
wutz double(6)
```

These are called "macros"

```
cpp -P double.py
```

output:

```
def double(x):
    return x * 2
print double(6)
```

```
cpp -P double.py
```

output:

```
def double(x):
    return x * 2
print double(6)
```

cpp -P double.py | python

```
12
```

AWESOME

```
cpp -P double.py
```

beer.txt

```
#define beer(x) x bottles of \
beer on the wall...

beer(99)
beer(98)
beer(97)
...
```

```
cpp -P beer.txt
```

beer.txt

```
#define beer(x) x bottles of \
beer on the wall...

beer(99)
beer(98)
beer(97)
...
```

```
cpp -P beer.txt
```

output:

```
99 bottles of beer on the wall...
98 bottles of beer on the wall...
97 bottles of beer on the wall...
...
```

```
cpp -P beer.txt
```

answer.txt

```
What’s 7 times 6?
#ifdef REVEAL
42
#endif
```

```
cpp -P answer.txt
```

output:

```
What’s 7 times 6?
```

```
cpp -P answer.txt
```

output:

```
What’s 7 times 6?
```

```
cpp -P answer.txt
```

```
#define REVEAL
```

```
cpp -P answer.txt
```

```
#define REVEAL
```

or:

```
cpp -P -D REVEAL answer.txt
```

```
cpp -P answer.txt
```

output:

```
What’s 7 times 6?
42
```

```
cpp -P -D REVEAL answer.txt
```

answer.txt

```
What’s 7 times 6?
#ifndef REVEAL
42
#endif
```

```
cpp -P answer.txt
```

(Fancy) String Substitution

How is this used in C?

hello.c

```c
#include <stdio.h>

int main() {
    printf("Hello, World!\n");
    return 0;
}
```

```
gcc -E hello.c
```

hello.c * angle brackets -> use the system search path

```c
#include <stdio.h>

int main() {
    printf("Hello, World!\n");
    return 0;
}
```

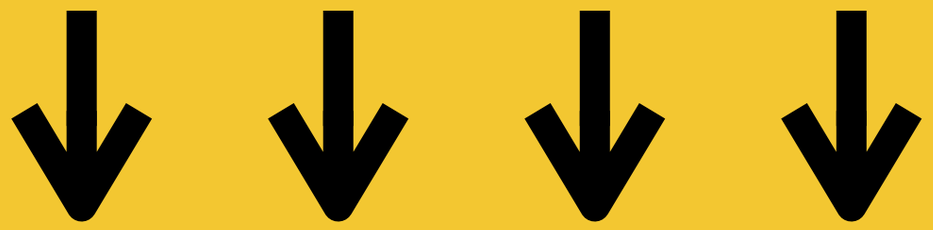
```
gcc -E hello.c
```

hello.c

* angle brackets -> use the system search path

```c
#include <stdio.h>

int main() {
    printf("Hello, World!\n");
    return 0;
}
```



```
gcc -E hello.c
```

output:

```
int printf(const char * , ...)
__attribute__((__format__
(__printf__, 1, 2)));

int main() {
    printf("Hello, World!\n");
}
```

* pretending printf is all that's defined in stdio.h

```
gcc -E hello.c
```

output:

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

int main() {
    printf("Hello, World!\n");
}
```

* pretending printf is all that's defined in stdio.h

```
gcc -E hello.c
```

#include is not

```
import pickle

import java.io.*;
```

fib.c

```
#define MAX_FIB 20
int fib[MAX_FIB];

int main() {
  fib[0] = 0;
  fib[1] = 1;
  for(int i = 2; i < MAX_FIB; i++)
    fib[i] = fib[i-1] + fib[i-2];
  return 0;
}
```

```
gcc -E fib.c
```

output:

```
int fib[20];

int main() {
  fib[0] = 0;
  fib[1] = 1;
  for(int i = 2; i < 20; i++)
    fib[i] = fib[i-1] + fib[i-2];
}
```

```
gcc -E fib.c
```

debug.c

```
#include <stdio.h>

int main() {
#ifdef DEBUG
    printf("Hello, World!\n");
#endif
    return 0;
}
```

```
gcc -DDEBUG debug.c -o debug
```

debug.c

```c
#include <stdio.h>

int main() {
    printf("Hello, World!\n");
    return 0;
}
```

```
gcc -DDEBUG debug.c -o debug
```

debug.c

```
#include <stdio.h>

int main() {
    return 0;
}
```

```
gcc debug.c -o debug
```

Pre-Process

Compile

Link

main.c

int a = 1;

→

int a = 1;

→

main.o

%!(*@

→

prog

@*)!%

→

./prog

Compile

Compile

Type-checking
Linear processing

Type-checking

```
int reptile() {
    return "frog";
}
```

Type-checking

```
int reptile() {
    return "frog";
}
```

```
reptile.c: In function ‘reptile’:
reptile.c:2:5: warning: return makes
integer from pointer without a cast
```

Type-checking

```
def vegetable(day):
    if day != "Tuesday":
        return "tomato"
    else:
        return 1000
```

Type-checking

```
def vegetable(day):
    if day != "Tuesday":
        return "tomato"
    else:
        return 1000
```

Python says: no problem

```
int reptile() {
    return "frog";
}
```

```
int () {
    return char*;
}
```

```
int vegetable(char *day) {
  if (strcmp(day, "Tuesday") != 0){
    return "tomato";
  } else {
    return 1000;
  }
}
```

```
int (char*) {
  if (int){
    return char*;
  } else {
    return int;
  }
}
```

```
int (char*) {
  if (int){
    return char*;
  } else {
    return int;
  }
}
```

```
int (char*) {
  if (int){
    return char*;
  } else {
    return int;
  }
}
```

Everything has
a single, fixed type

```
def foo(a, b):
    return a + b

foo(2, 3)
foo("2", "3")
```

Variable Declarations

```
int foo;
float foo;
double foo;
char foo;
```

```
int foo[42];
int *foo;
struct Bar foo;
```

Function Declarations

```
double fmin(double, double);
```

return type

argument types

Function Declarations

```
void exit(int);
```

returns nothing

```
int rand(void);
```

takes no arguments

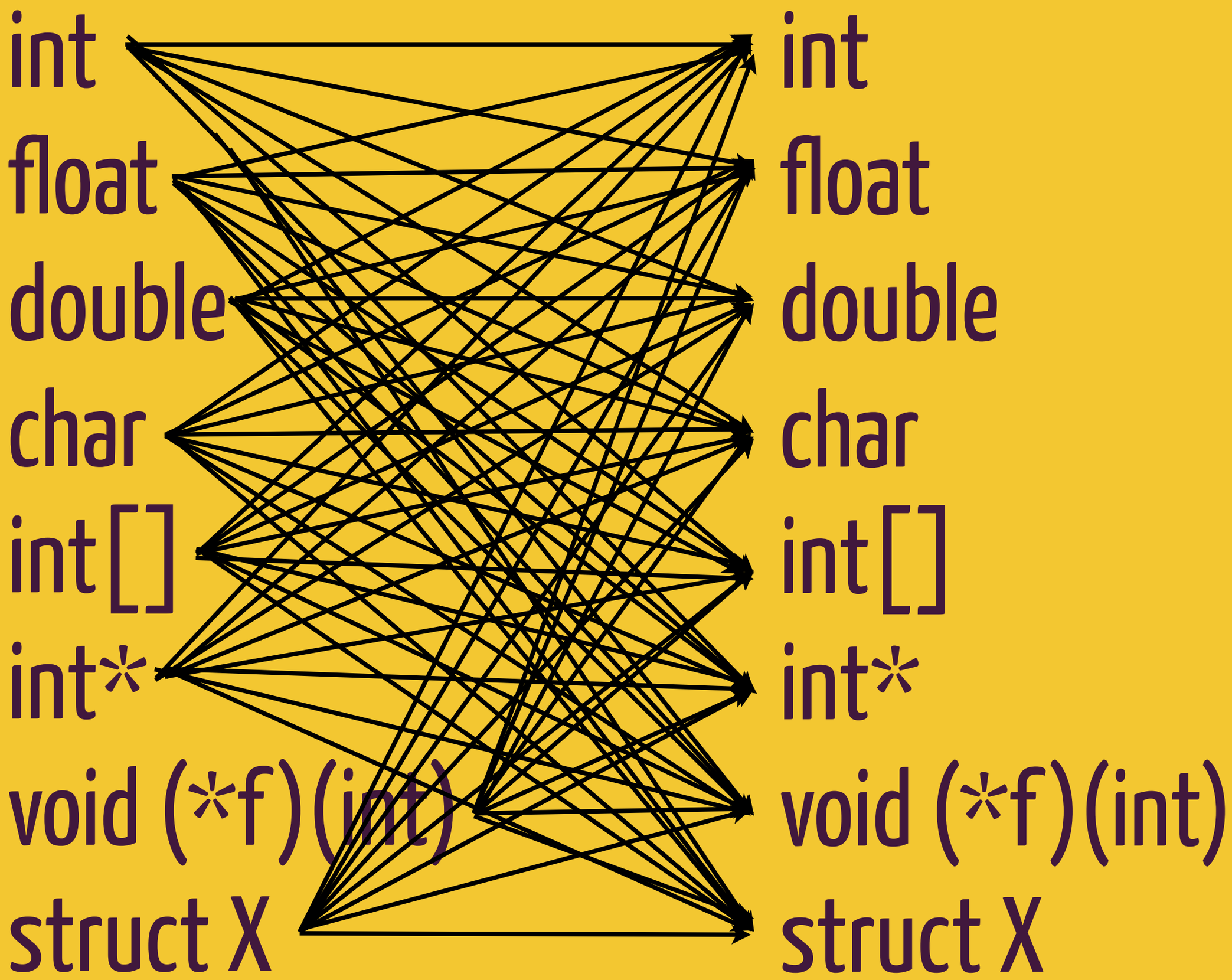
```
int foo(int a, int b){
    return a + b;
}
```

```
reptile.c: In function ‘reptile’:
reptile.c:2:5: warning: return makes
integer from pointer without a cast
```

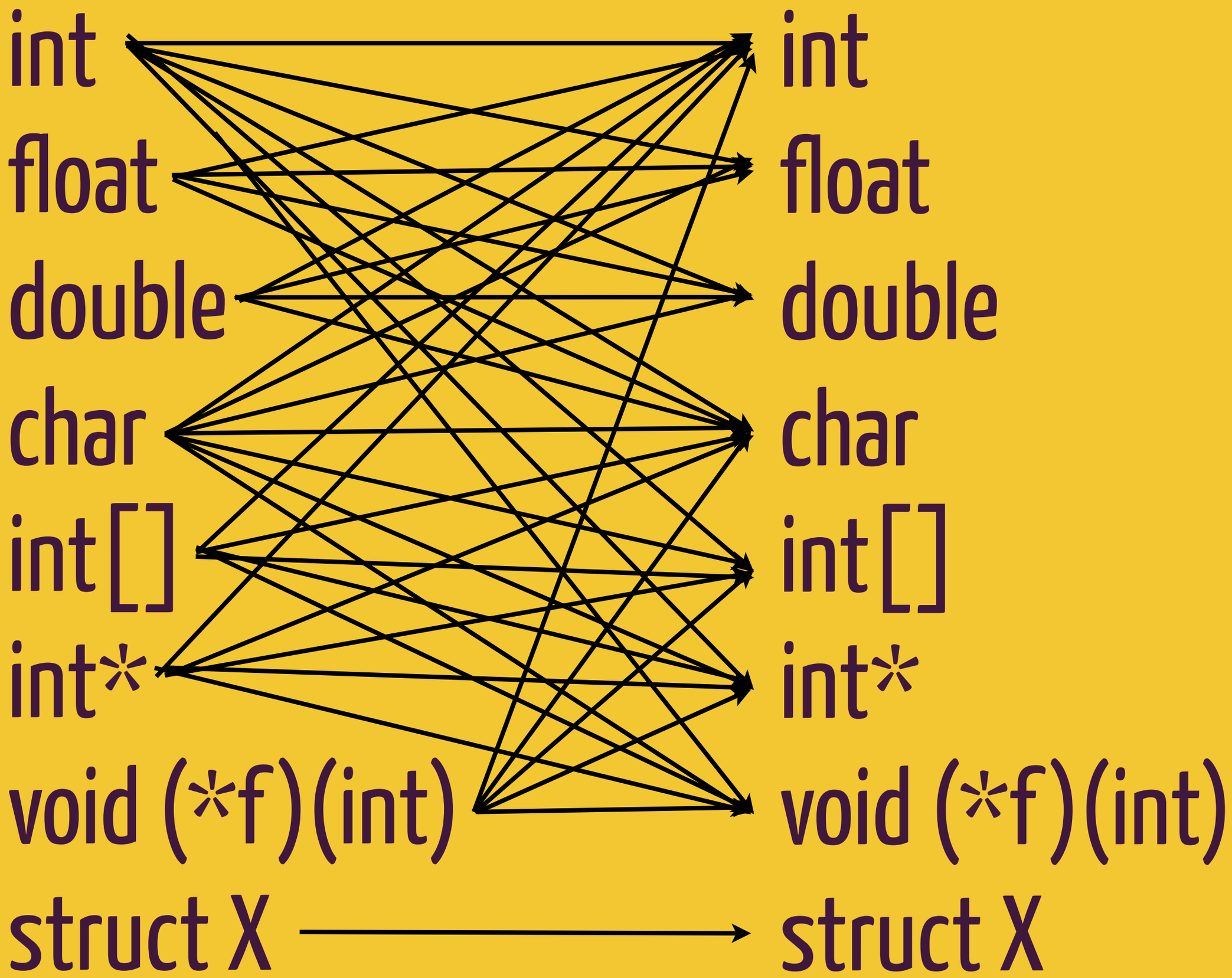
```
reptile.c: In function ‘reptile’:
reptile.c:2:5: warning: return makes
integer from pointer without a cast
```

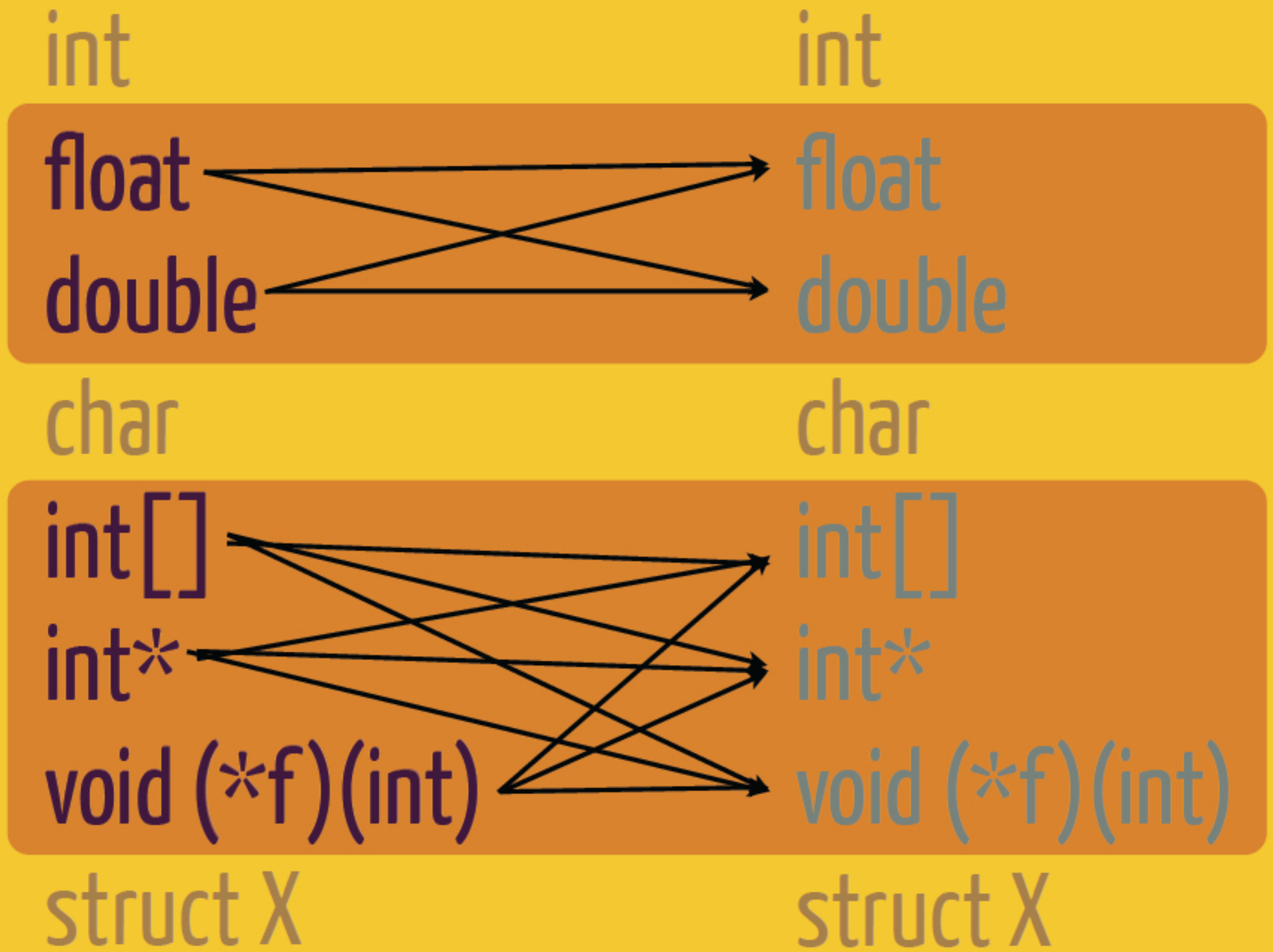
```
int a = 4;
float b = (float)a;
```

all theoretical casts

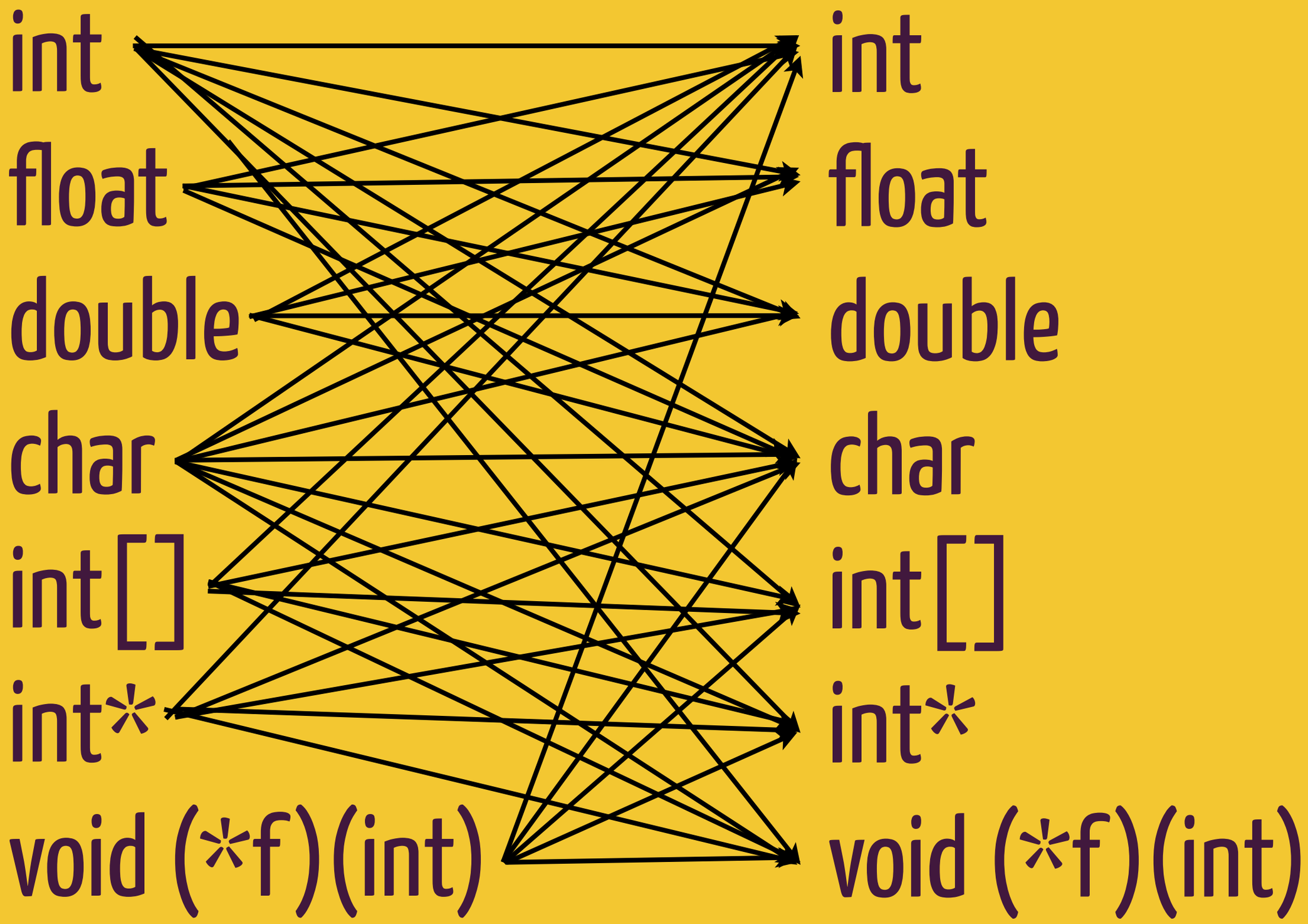


allowed casts



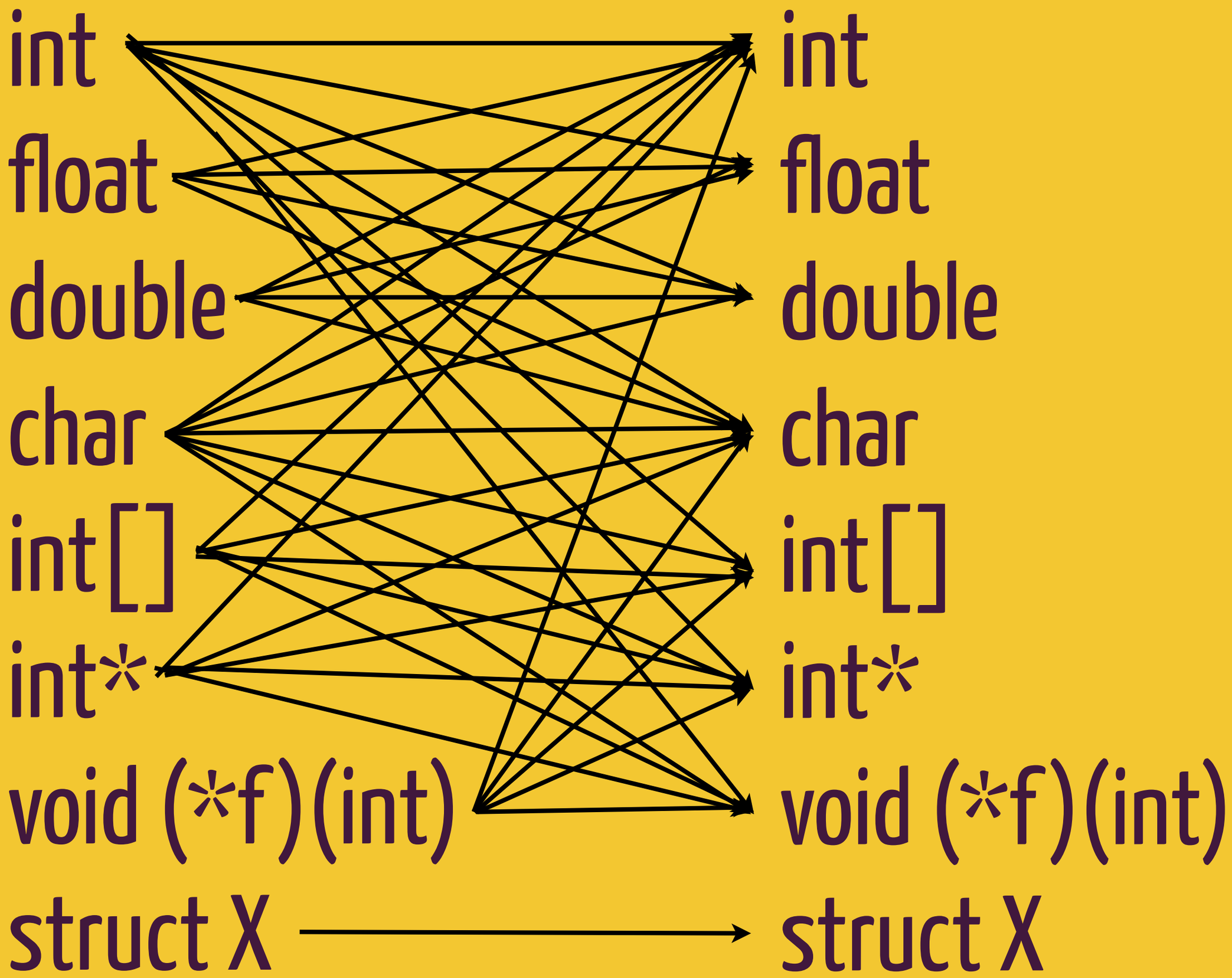

int
int
float
float
double
double
char
char
int[]
int[]
int*
int*
void (*f)(int)
void (*f)(int)
struct X
struct X

allowed casts

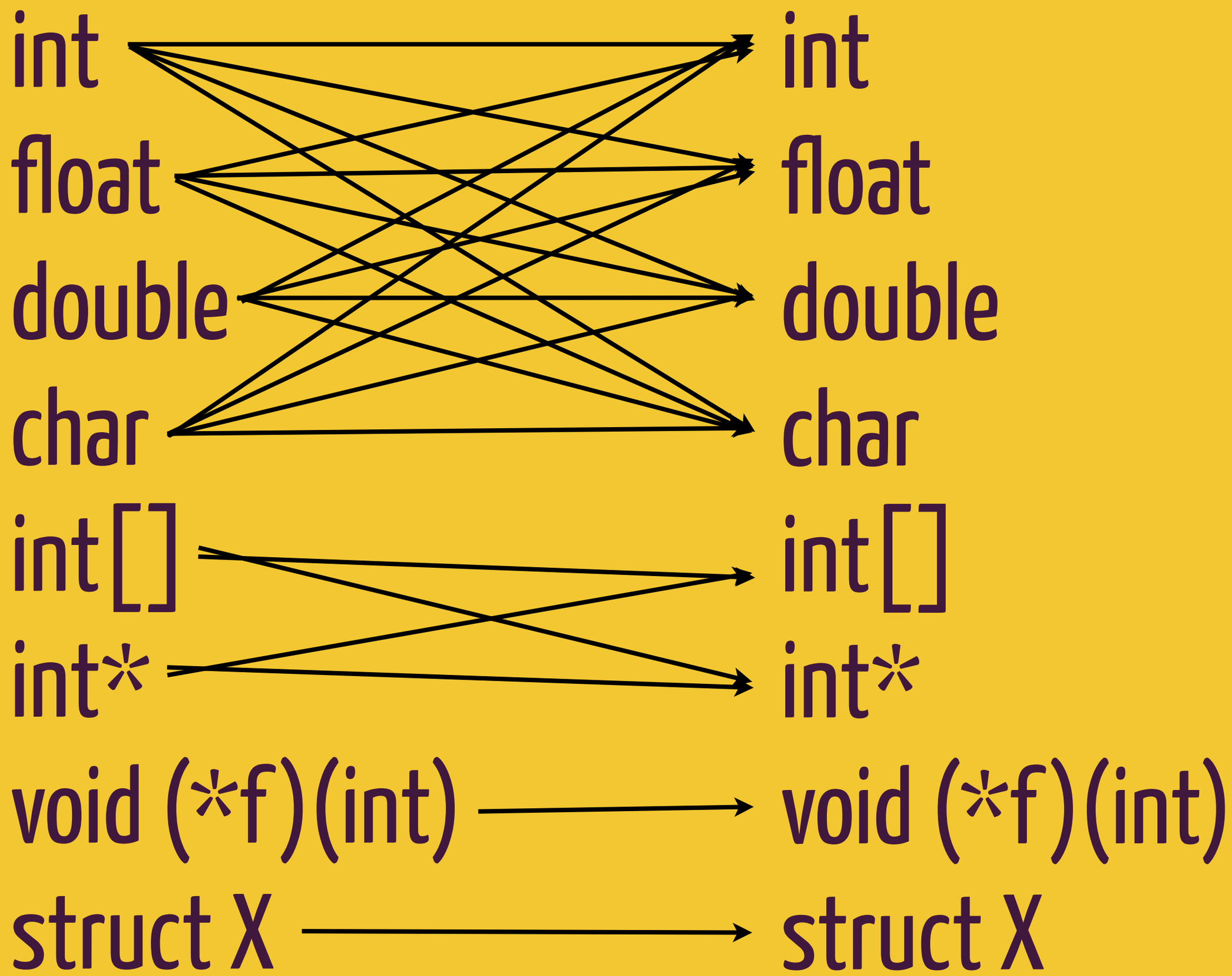


struct X → struct X

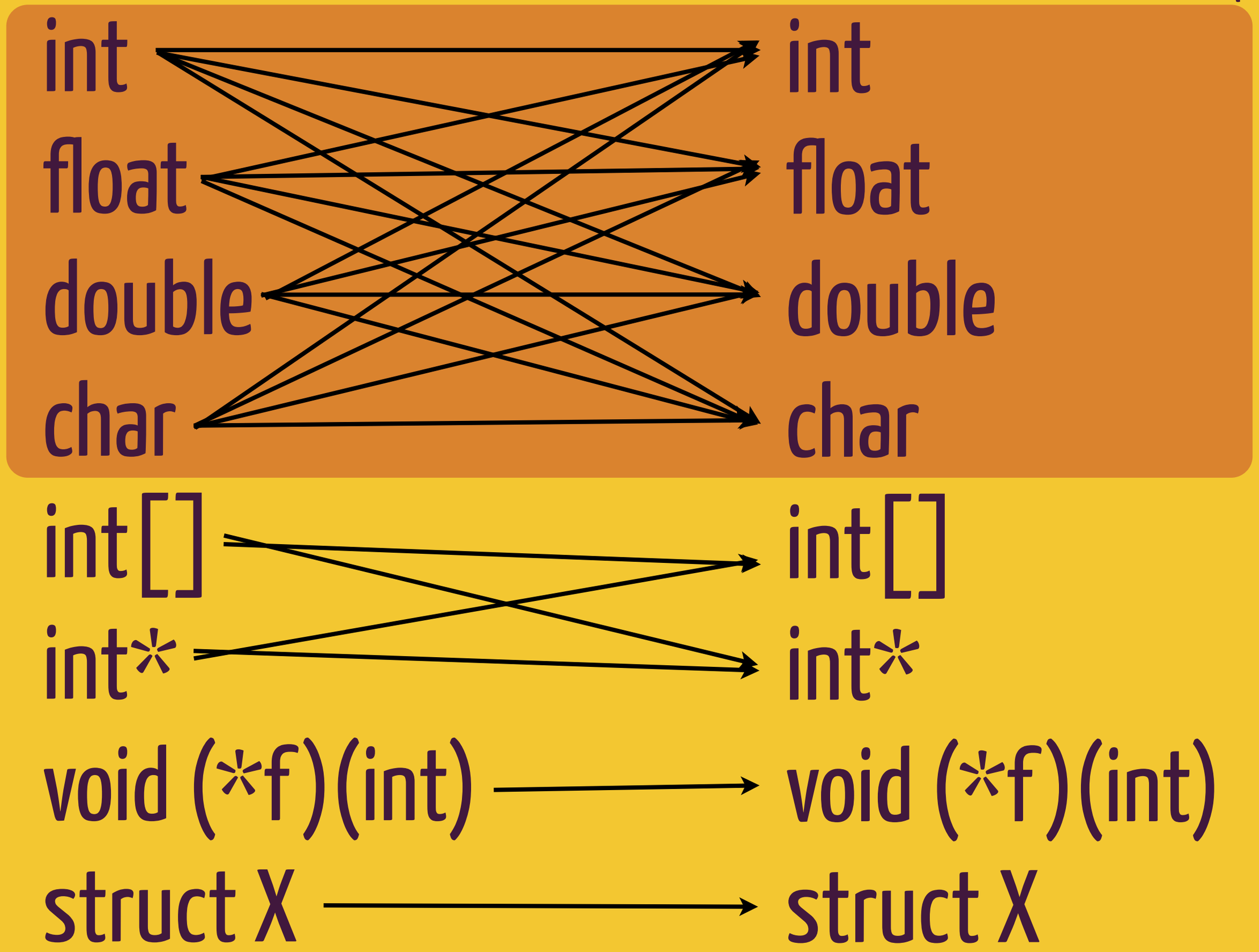
allowed casts



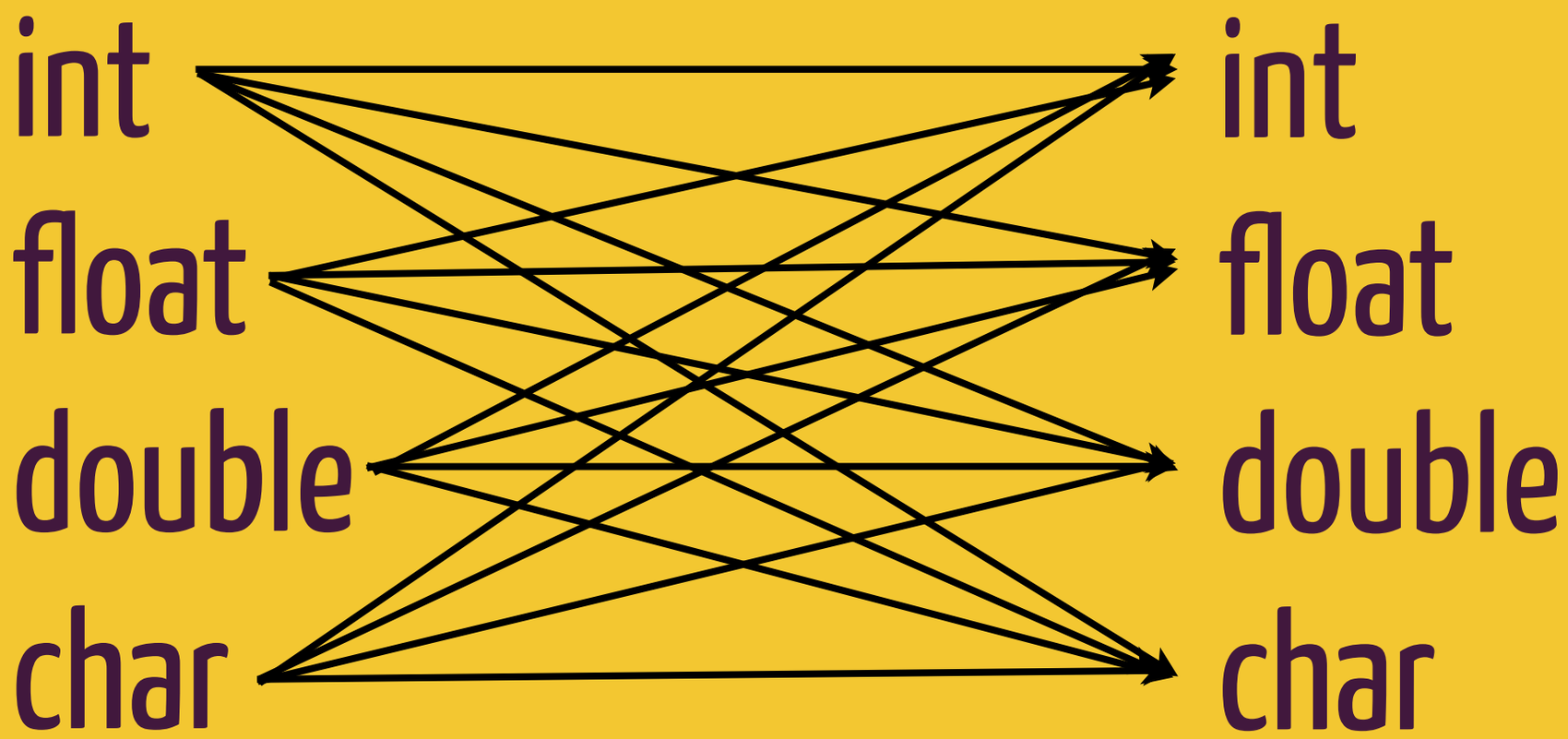
implicit casts

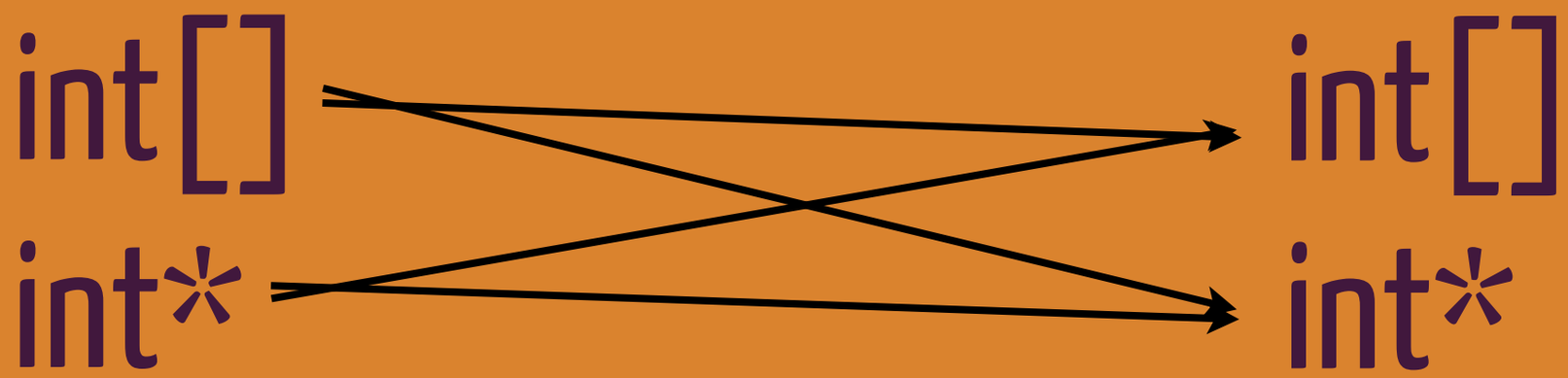


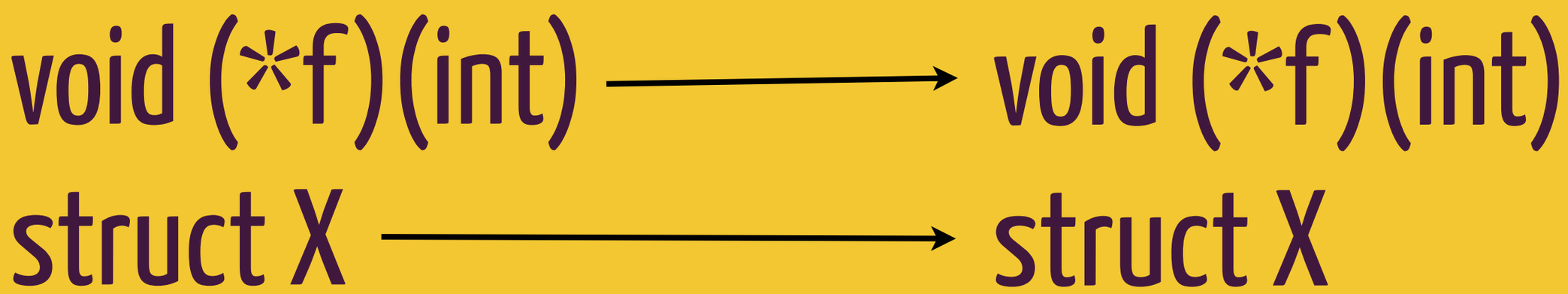
implicit casts



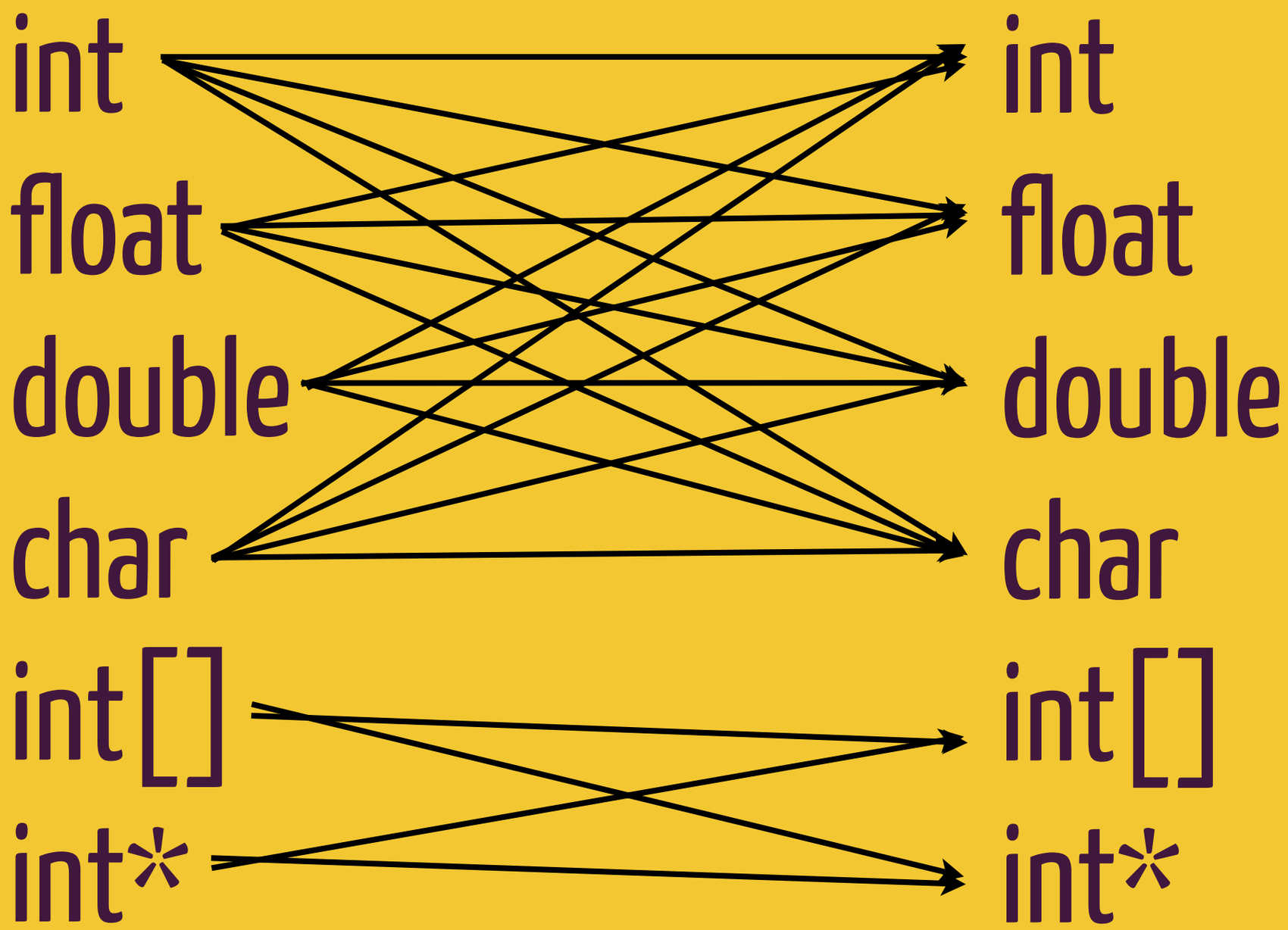
implicit casts







implicit casts



void (*f)(int) → void (*f)(int)

struct X → struct X

Compile

Type-checking
Linear processing

Linear processing
(just a small note)

You can only use what's declared above

```c
int main() {
    printf("%d\n", answer());
    return 0;
}

int answer() {
    return 1337;
}
```

```
int main() {
    printf("%d\n", answer());
    return 0;
}

int answer() {
    return 1337;
}
```

```c
int answer() {
    return 1337;
}

int main() {
    printf("%d\n", answer());
    return 0;
}
```

```
int answer();

int main() {
    printf("%d\n", answer());
    return 0;
}

int answer() {
    return 1337;
}
```

declaration

definition

HMM

```
int answer();

int main() {
    printf("%d\n", answer());
    return 0;
}

int answer() {
    return 1337;
}
```

declaration

definition

```
int answer();

int main() {
    printf("%d\n", answer());
    return 0;
}
```

declaration

```
int answer() {
    return 1337;
}
```

definition

```
int answer();
```

← declaration

```
#include "answer.h"

int main() {
    printf("%d\n", answer());
    return 0;
}
```

```
int answer() {
    return 1337;
}
```

← definition

Pre-Process

Compile

Link

main.o

int main()

int answer()

main.o

```
int main()
```

```
answer.c: In function ‘main’:
answer.c:4: warning: implicit declaration of
function ‘answer’
Undefined symbols for architecture x86_64:
  "_answer", referenced from:
      _main in ccuzmRrm.o
ld: symbol(s) not found for architecture x86_64
collect2: ld returned 1 exit status
```

```
answer.c: In function ‘main’:
answer.c:4: warning: implicit declaration of
function ‘answer’
Undefined symbols for architecture x86_64:
  "_answer", referenced from:
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answer.c: In function ‘main’:
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Undefined symbols for architecture x86_64:
  "_answer", referenced from:
      _main in ccuzmRrm.o
ld: symbol(s) not found for architecture x86_64
collect2: ld returned 1 exit status
```

Compiler: “I don’t know what `answer` is.
I’ll assume it returns an `int`.”

```
answer.c: In function ‘main’:
answer.c:4: warning: implicit declaration of
function ‘answer’
Undefined symbols for architecture x86_64:
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answer.c: In function ‘main’:
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Undefined symbols for architecture x86_64:
  "_answer", referenced from:
      _main in ccuzmRrm.o
ld: symbol(s) not found for architecture x86_64
collect2: ld returned 1 exit status
```

Linker: “I looked in all the object files,
but I couldn’t find `answer`.”

main.o

```
int main()
```

main.o

int main()

answer.o

int answer()

main.o

int main()

answer.o

int answer()

```
int main() {
    printf("%d\n", answer());
    return 0;
}
```

```
int answer() {
    return 1337;
}
```

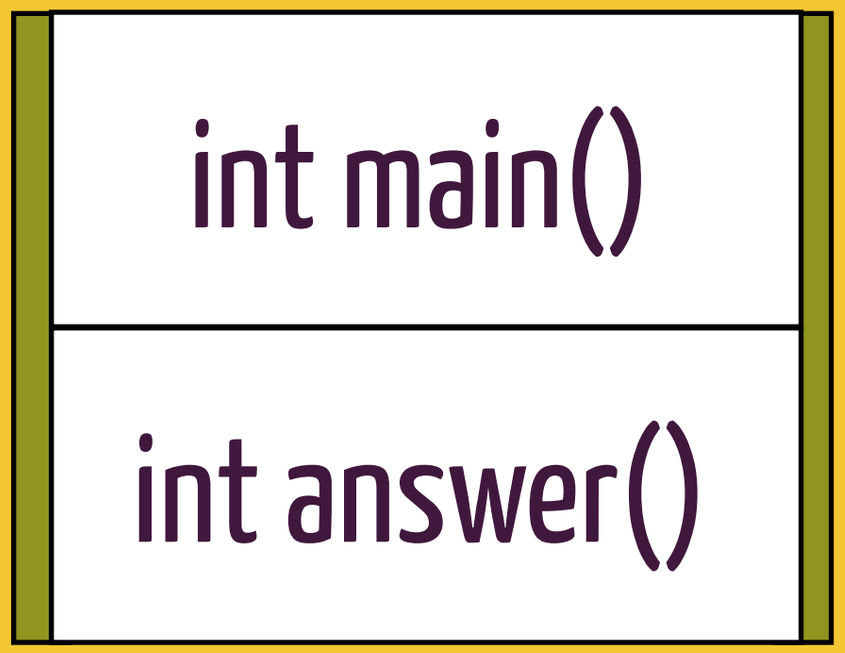
main.o

```
int main()
```

answer.o

```
int answer()
```

prog




```
gcc -o prog main.c answer.c
```

```
answer.c: In function ‘main’:
answer.c:4: warning: implicit declaration of
function ‘answer’
```

```
answer.c: In function ‘main’:
answer.c:4: warning: implicit declaration of
function ‘answer’
```

Compiler: “I don’t know what `answer` is.
I’ll assume it returns an `int`.”

answer.h

```
int answer();
```

main.c

```
#include "answer.h"

int main() {
    printf("%d\n", answer());
    return 0;
}
```

answer.h

```
int answer();
```

answer.c

```
#include "answer.h"

int answer() {
    return 1337;
}
```

Summary

answer.h

```
int answer();
```

main.c

```
#include "answer.h"

int main() {
    printf("%d\n", answer());
    return 0;
}
```

Preprocess: `gcc -E main.c`

```
int answer();

int main() {
    printf("%d\n", answer());
    return 0;
}
```

Compile: `gcc -c main.c main.c`

main.o

```
%!(*@
```

answer.o

```
%!(*@
```

Link: `gcc -o prog main.o main.o`

prog

```
%!(*@
```

Pre-Process

Compile

Link

6.S096 Introduction to C and C++

IAP 2013