Linker Symbols

- **Global symbols**
  - Symbols defined by module *m* that can be referenced by other modules.
  - E.g.: non-**`static`** C functions and non-**`static`** global variables.

- **External symbols**
  - Global symbols that are referenced by module *m* but defined by some other module.

- **Local symbols**
  - Symbols that are defined and referenced exclusively by module *m*.
  - E.g.: C functions and global variables defined with the **`static`** attribute.
  - **Local linker symbols are *not* local program variables**

Step 1: Symbol Resolution

```c
int sum(int *a, int n);

int array[2] = {1, 2};

int main()
{
    int val = sum(array, 2);
    return val;
}
```

main.c

```c
int sum(int *a, int n)
{
    int i, s = 0;

    for (i = 0; i < n; i++) {
        s += a[i];
    }
    return s;
}
```

sum.c

Step 1: Symbol Resolution

Referencing a global…

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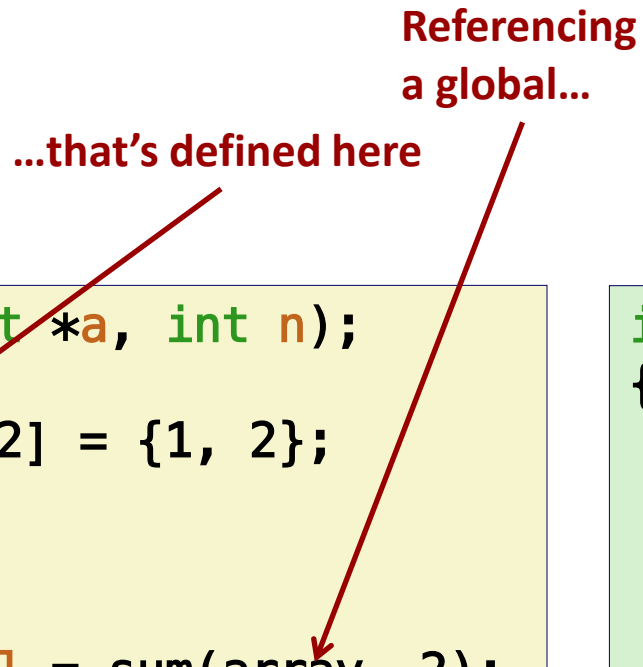
Step 1: Symbol Resolution

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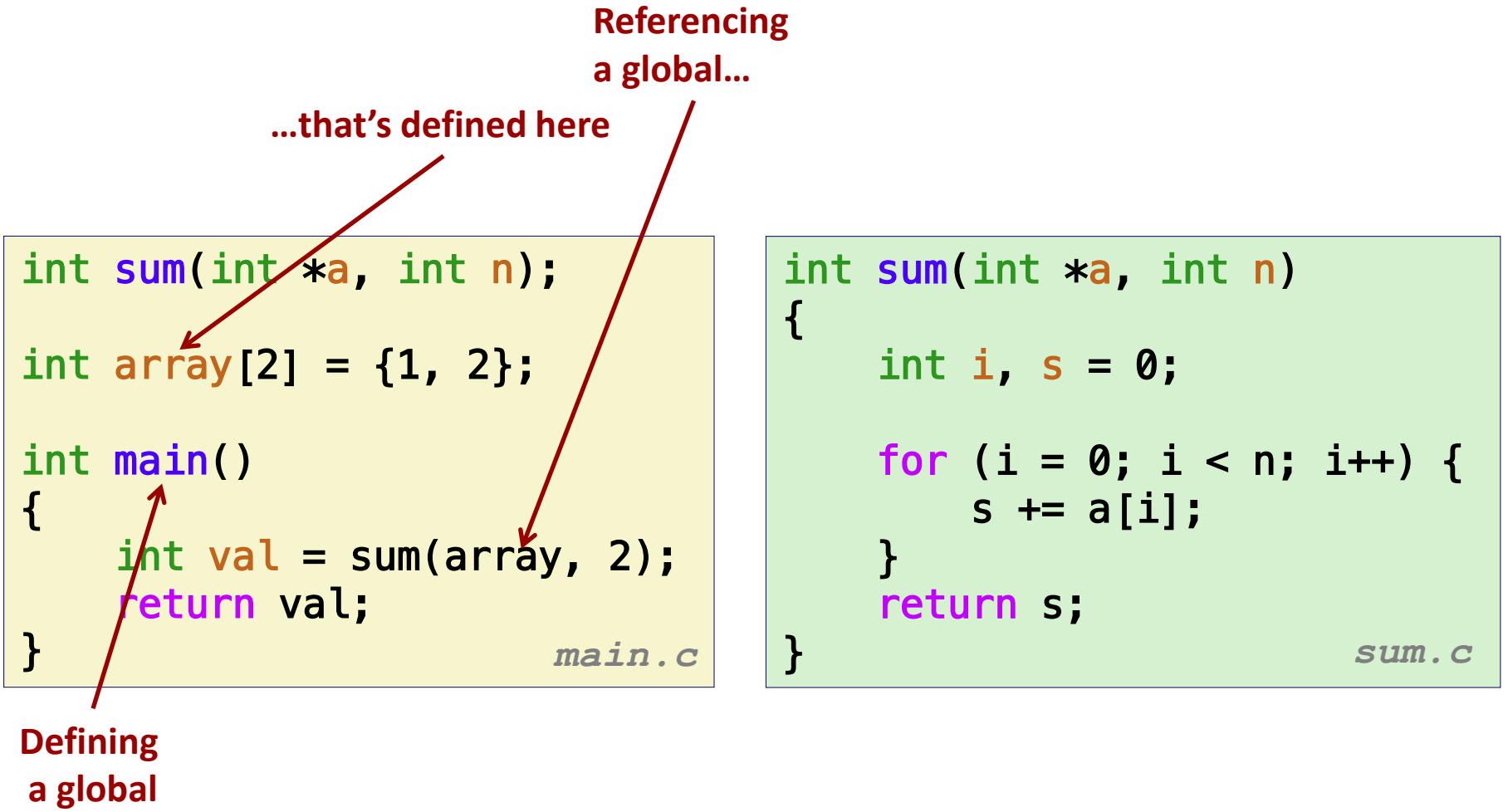

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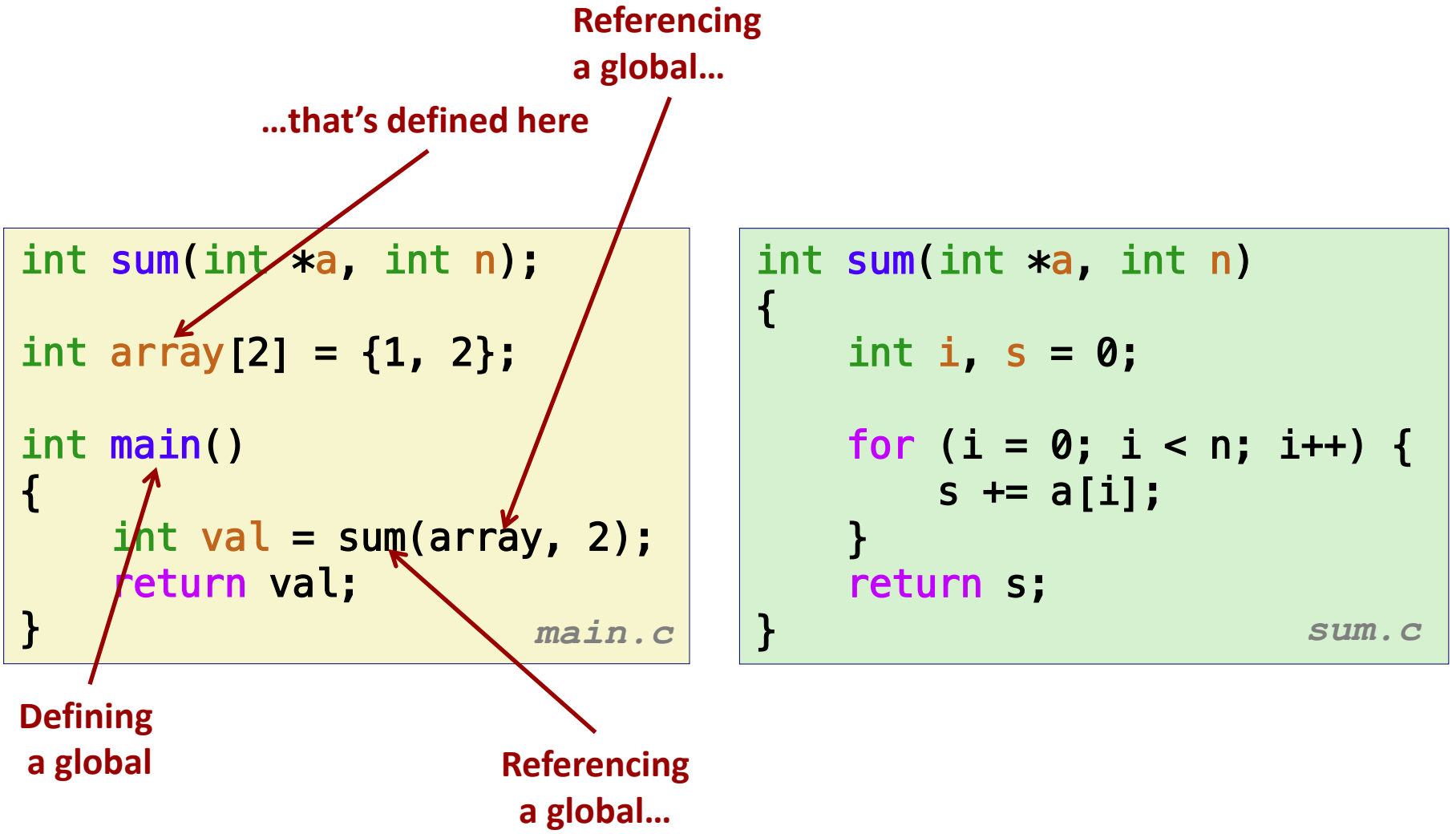

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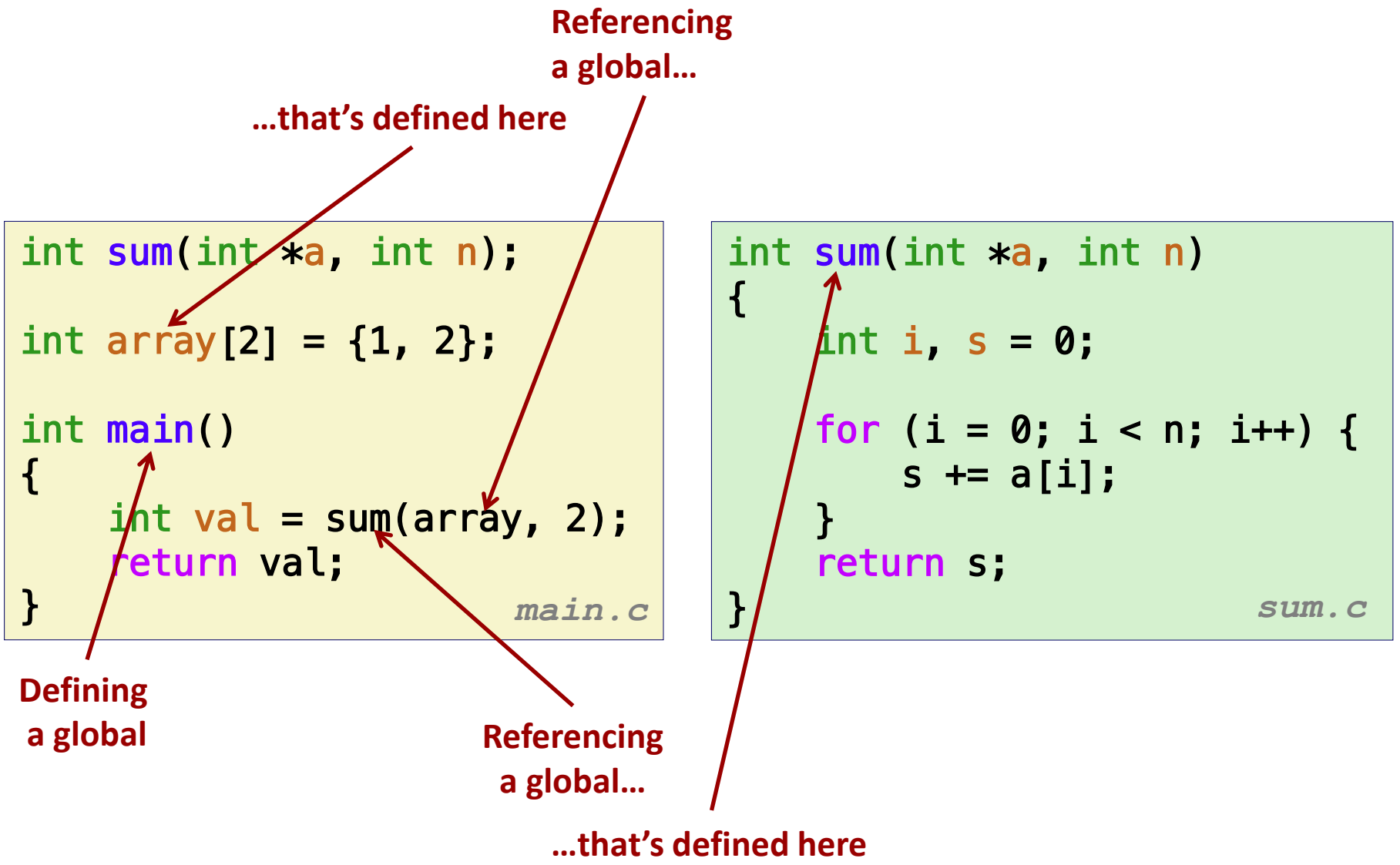

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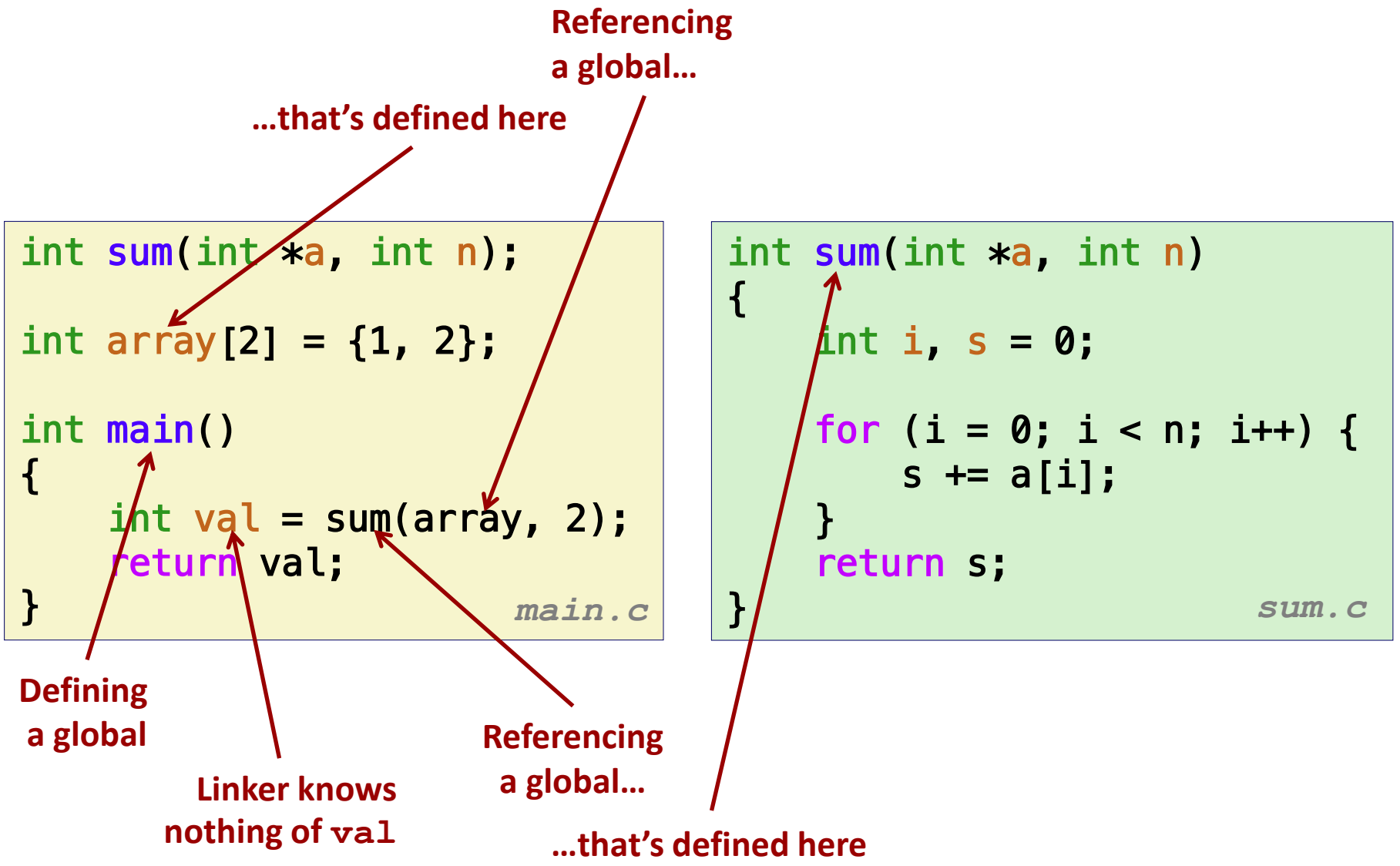

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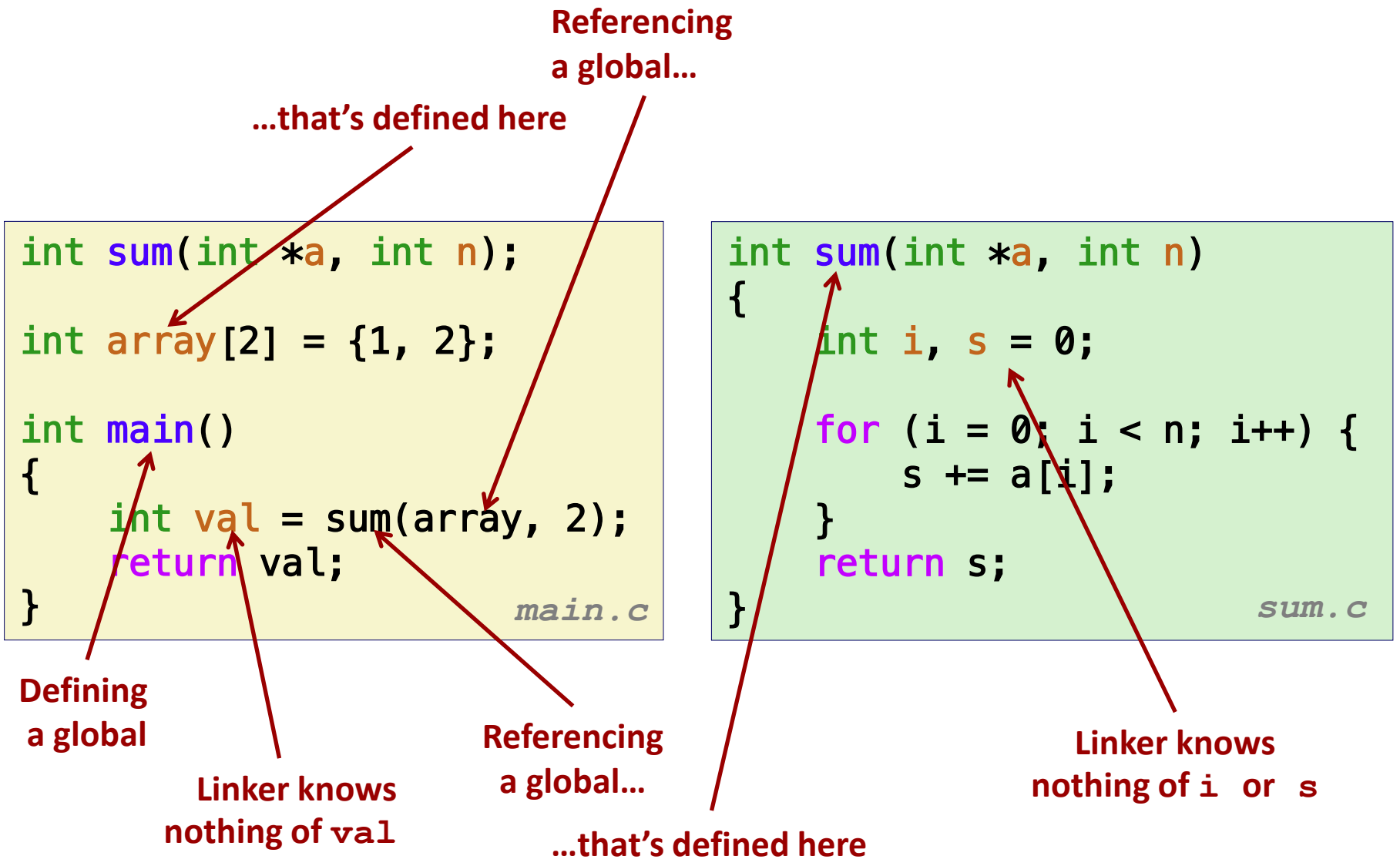

Local Symbols

- **Local non-static C variables vs. local static C variables**
  - local non-static C variables: stored on the stack
  - local static C variables: stored in either `.bss`, or `.data`

```
int f()
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    static int x = 0;
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Creates local symbols in the symbol table with unique names, e.g., `x.1` and `x.2`.

How Linker Resolves Duplicate Symbol Definitions

- **Program symbols are either *strong* or *weak***
  - ***Strong***: procedures and initialized globals
  - ***Weak***: uninitialized globals

p1.c

```
int foo=5;

p1() {
}
```

p2.c

```
int foo;

p2() {
}
```

How Linker Resolves Duplicate Symbol Definitions

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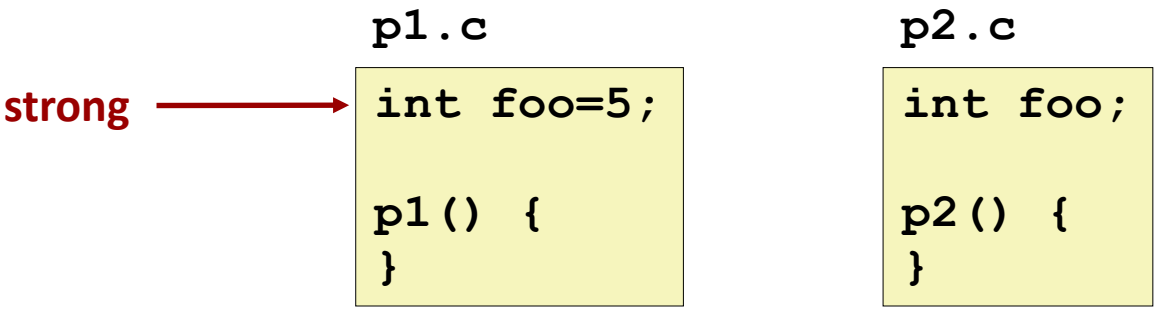

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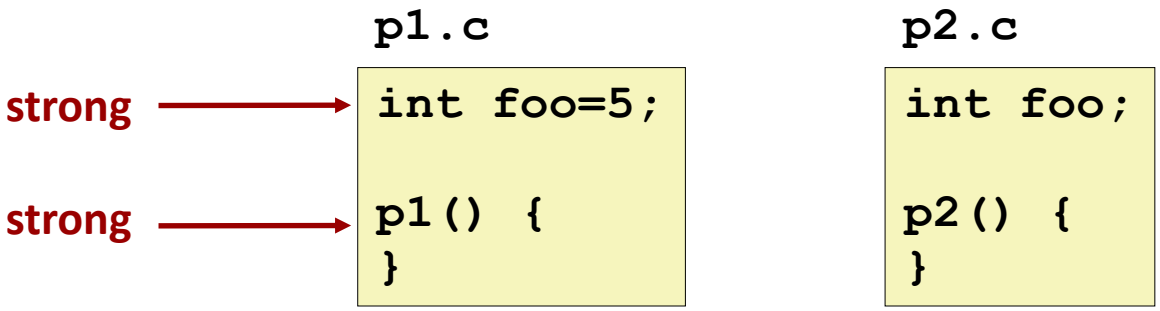

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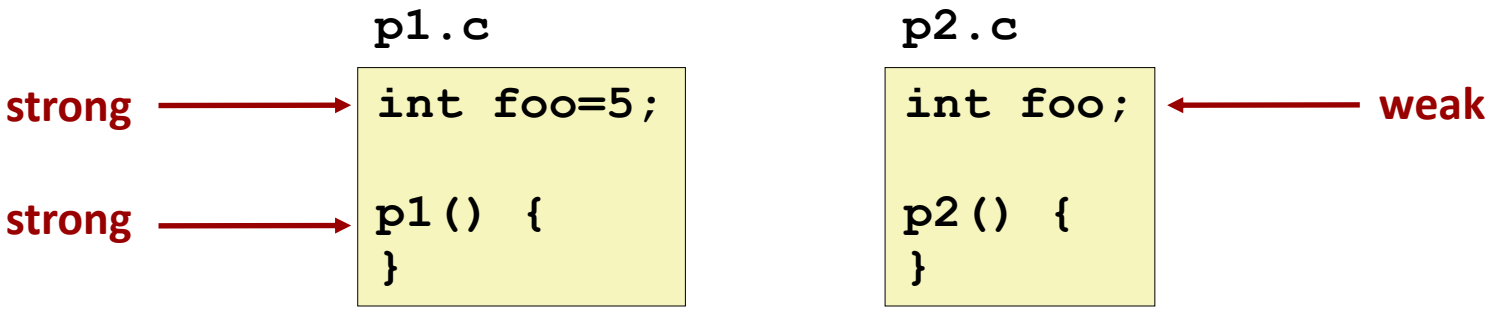

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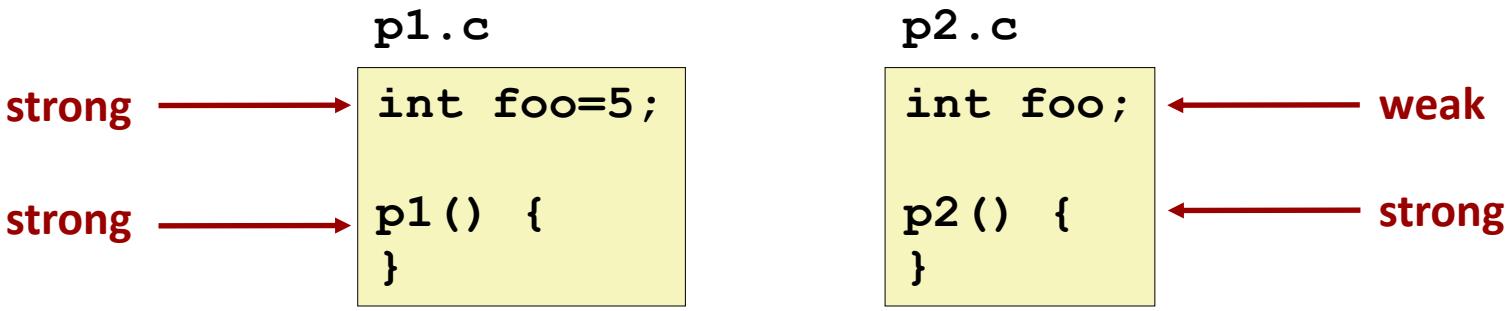

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  - Each item can be defined only once
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  - Otherwise: Linker error

- **Rule 2: Given a strong symbol and multiple weak symbols, choose the strong symbol**
  - References to the weak symbol resolve to the strong symbol

- **Rule 3: If there are multiple weak symbols, pick an arbitrary one**
  - Can override this with `gcc -fno-common`

Linker Puzzles

```
int x;
p1() {}
```

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Link time error: two strong symbols (**p1**)

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References to **x** will refer to the same uninitialized int. Is this what you really want?

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```
int x;
int y;
p1() {}
```

```
double x;
p2() {}
```

Linker Puzzles

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Writes to **x** in **p2** might overwrite **y**!
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Writes to **x** in **p2** might overwrite **y**! Evil!

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int x=7;
int y=5;
p1() {}
```

```
double x;
p2() {}
```

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References to **x** will refer to the same initialized variable.

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References to **x** will refer to the same initialized variable.

Nightmare scenario: two identical weak structs, compiled by different compilers with different alignment rules.

Global Variables

- **Avoid if you can**

- **Otherwise**
  - Use **`static`** if you can
  - Initialize if you define a global variable
  - Use **`extern`** if you reference an external global variable