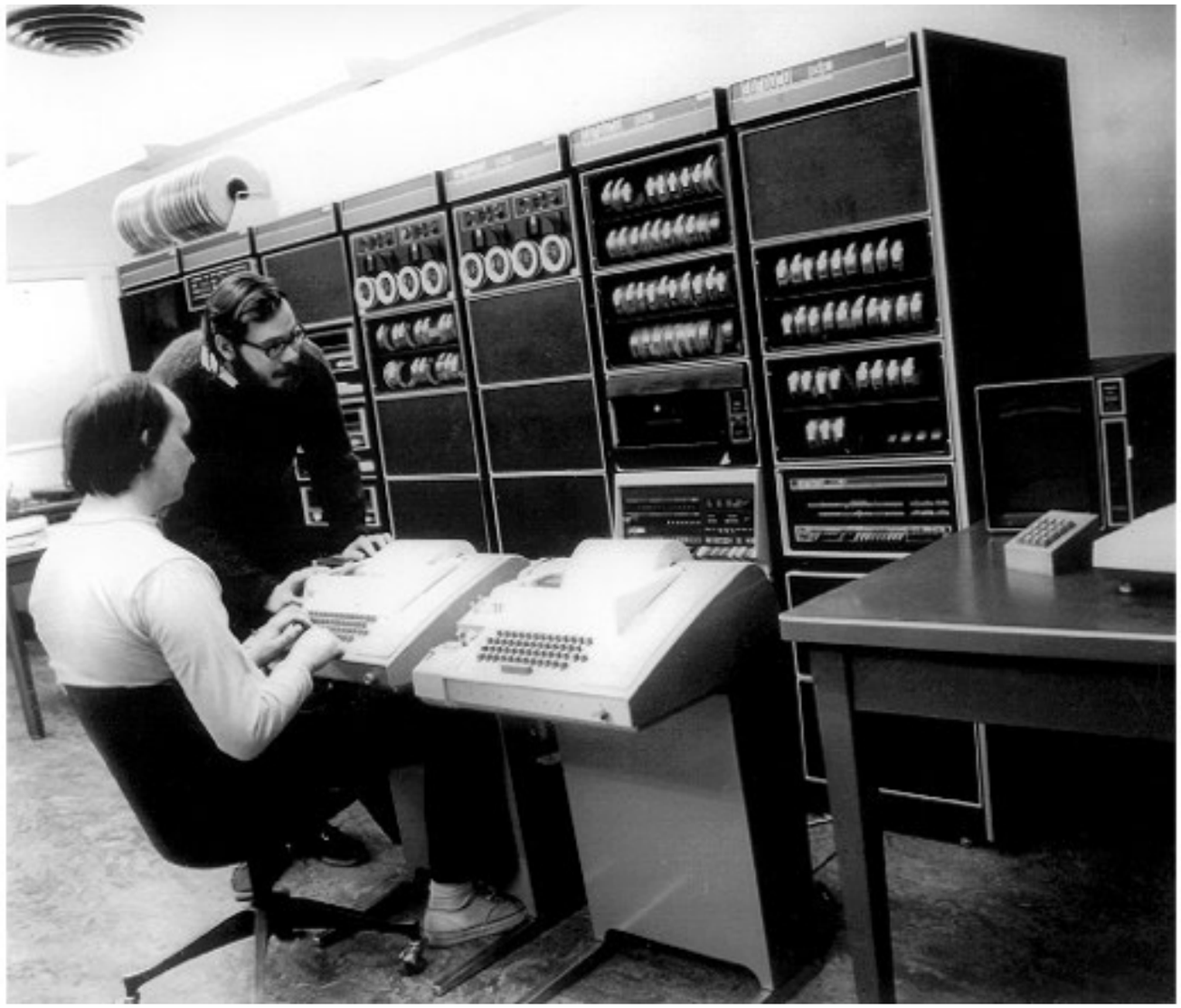
Pointers

"to get a deeper understanding of the language"



Deep C - a 3 day course
Jon Jagger & Olve Maudal

pointers

- a * in a declaration declares a pointer
- read declarations from right to left
- beware: the * binds to the identifier and not the type

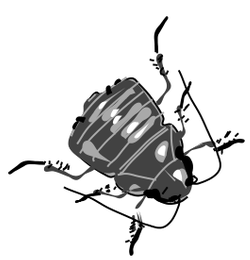
```
int * stream;

int * stream;

int * stream;
```

stream
is-a
pointer
to-an
int

```
int * pointer, value;
```

equivalent to

```
int * pointer;
int value;
```



the null pointer (NULL or 0)

- null never equals an objects' address
- the default for pointers with `static` storage class
- no default for pointers with `auto` storage class

```
int * pointer = NULL;
```

Equivalent

```
int * pointer = 0;
```

NULL is in <stddef.h>
(and others)

```
int * top_level;

void eg(void)
{
    int * local;
    static int * one;
    ...
}
```

implicit static storage class, defaults to null

implicit auto storage class, no default

explicit static storage class, defaults to 0

pointer true/false

- a pointer expression can implicitly be interpreted as true or false
- a null pointer is considered false
- a non-null pointer is considered true

```
int * pos; ...
```

```
if (pos)
if (pos != 0)
if (pos != NULL)
```

} equivalent

```
if (!pos)
if (pos == 0)
if (pos == NULL)
```

} equivalent

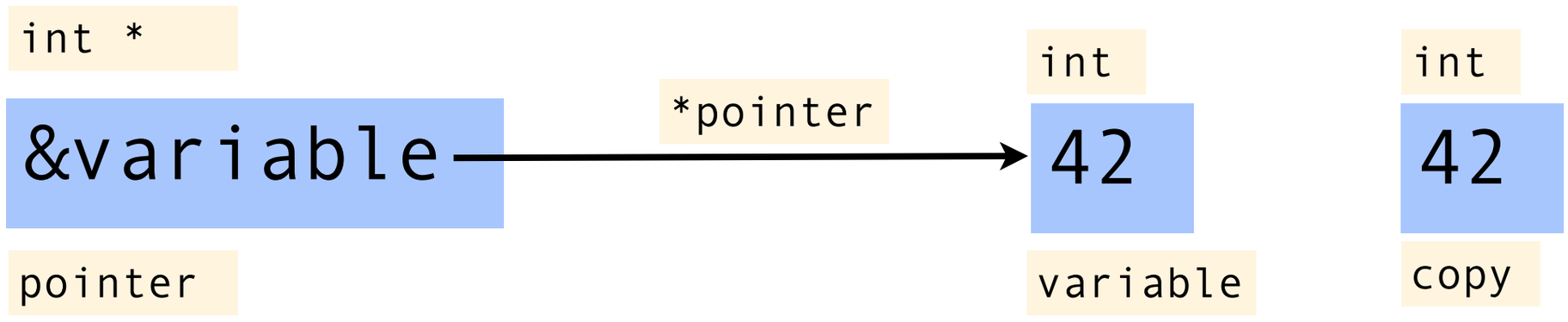
address-of / dereference

- unary & operator returns a pointer to its operand
- unary * operator dereferences a pointer
- & and * are inverses of each other: *&x == x
- *p is *undefined* if p is invalid or null

```
int variable = 42;
...
int * pointer = &variable;
int copy = *pointer;
```

* used in a declarator

* used in an expression



pointer function arguments

```
#include <stdio.h>

void swap(int * lhs, int * rhs)
{
    int temp = *lhs;
    *lhs = *rhs;
    *rhs = temp;
}

int main(void)
{
    int a = 4;
    int b = 2;
    printf("%d,%d\n", a, b);
    swap(&a, &b);
    printf("%d,%d\n", a, b);
}
```

array decay

- in an expression the name of an array "decays" into a pointer to element zero†
- array arguments are *not* passed by copy

these two declarations are equivalent

```
void display(size_t size, wibble * first);
void display(size_t size, wibble first[]);
```

```
wibble table[42] = { ... };
```

these two statements are equivalent

```
display(42, table);
display(42, &table[0]);
```

```
const size_t size =
    sizeof array / sizeof array[0];
```

†except in a `sizeof` expression

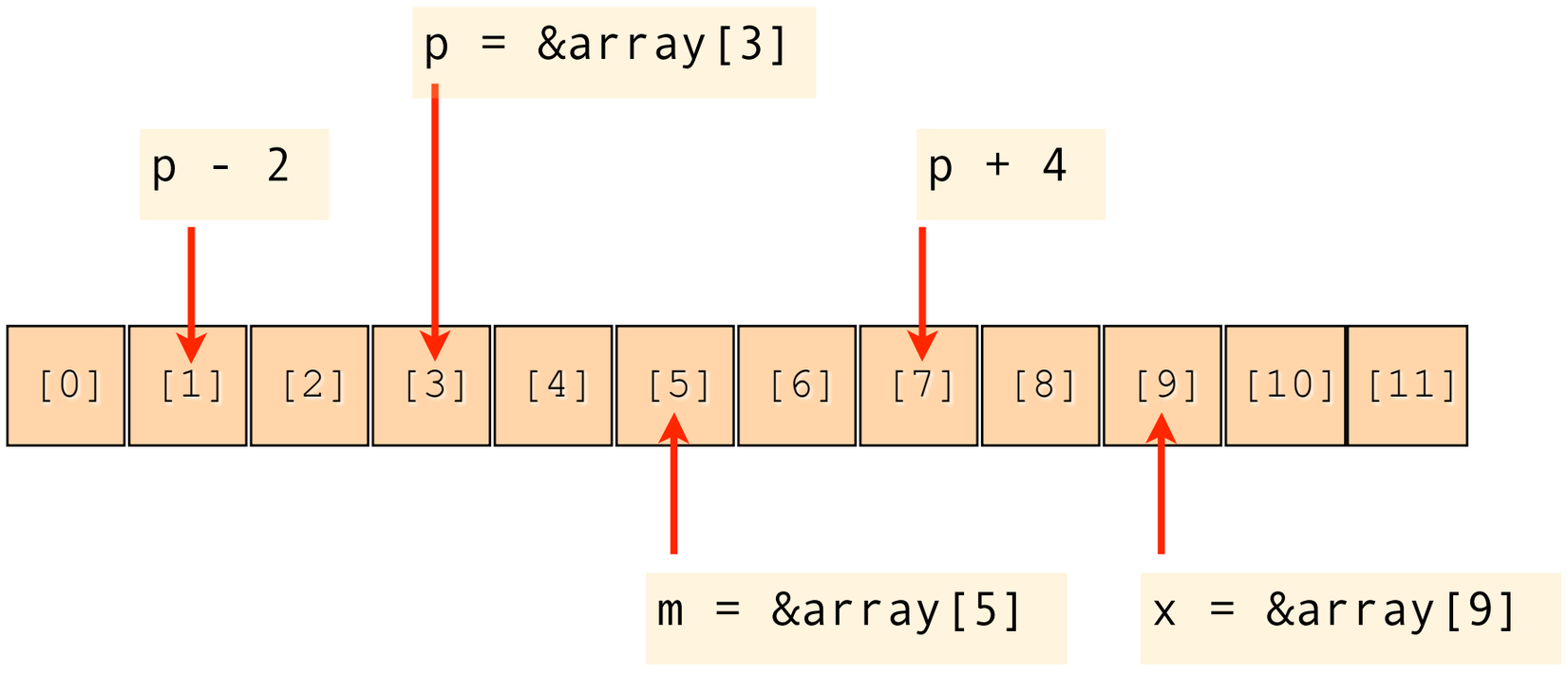
exercise

- what does the following program print?
- why?

```
#include <stdio.h>

int main(void)
{
    int array[] = { 0,1,2,3 };
    int clone[] = { 0,1,2,3 };
    puts(array == clone
        ? "same" : "different");
    return 0;
}
```

pointer arithmetic

- is in terms of the target type, not bytes
- p++ moves p so it points to the next element
- p-- moves p so it points to the previous element
- (pointer – pointer) is of type `ptrdiff_t` <stddef.h>




```
assert(x - m == +4);
assert(m - x == -4);
```

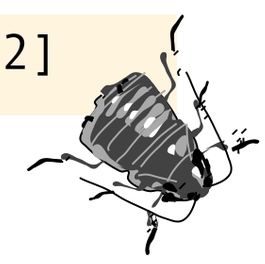
one beyond the end

- a pointer can point just beyond an array
- can't be dereferenced
- can be compared with
- can be used in pointer arithmetic

```
int array[42];
```

undefined

```
array[42]
```



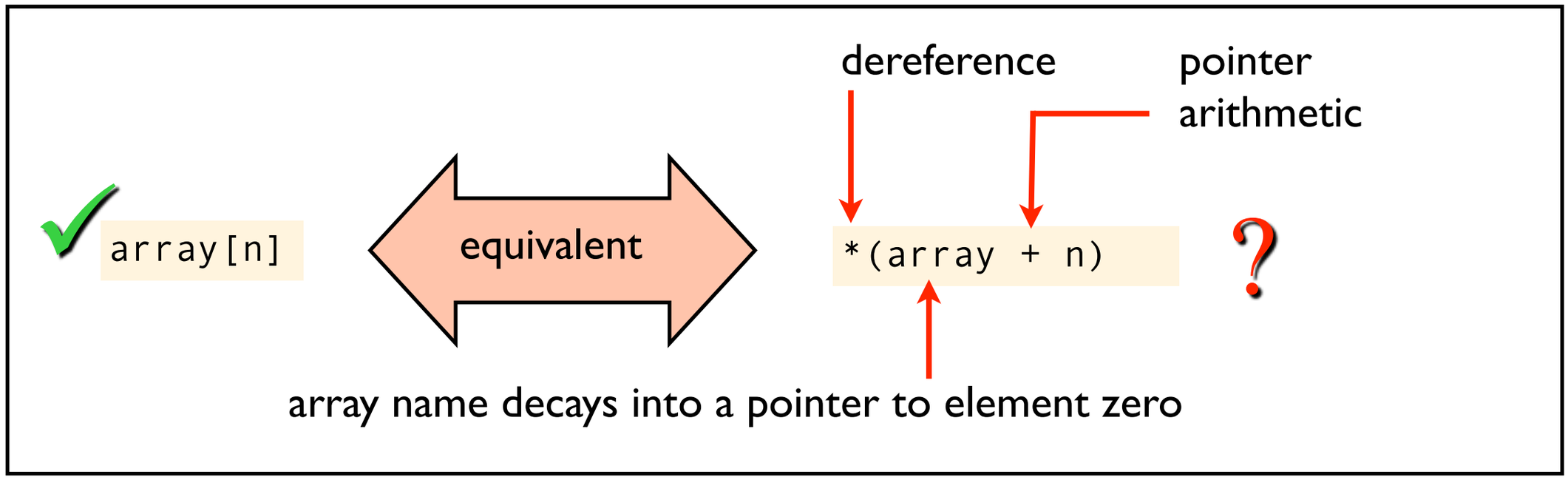
not undefined

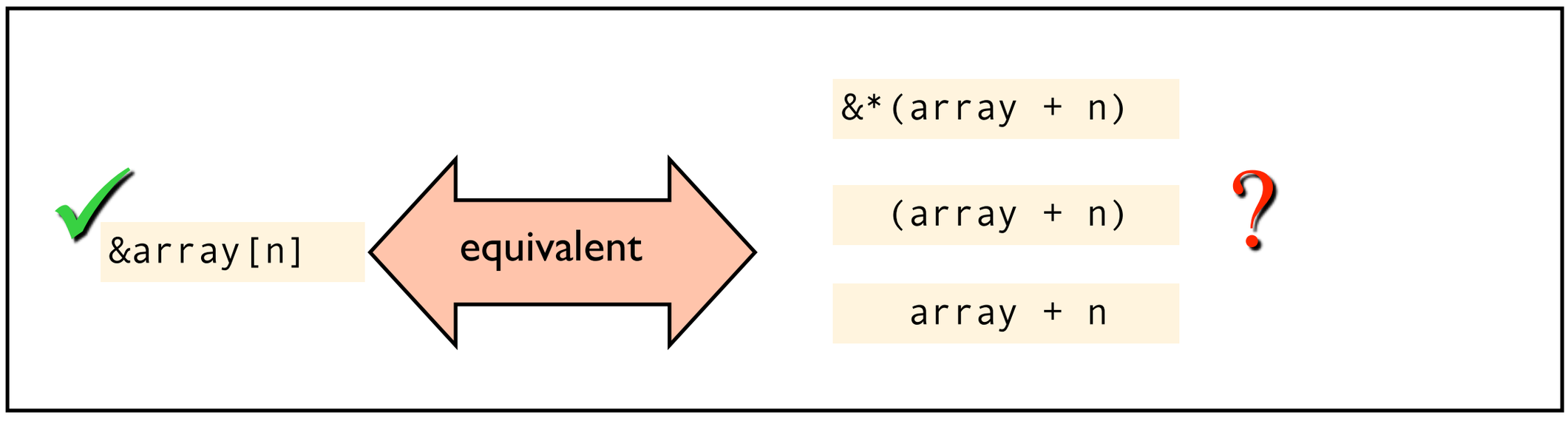
```
&array[42]
```

```
int * p = &array[0];
int * q = &array[42];
assert(q - p == 42);
```

pointers ←→ arrays

- array indexing is syntactic sugar
- the compiler converts `a[i]` into `*(a + i)`





We know `a[n]` is syntactic sugar for `*(a + n)`

We also know that
`a+n == n+a`

Therefore
`*(a + n) == *(n + a)`

But
`*(n + a) == n[a]`

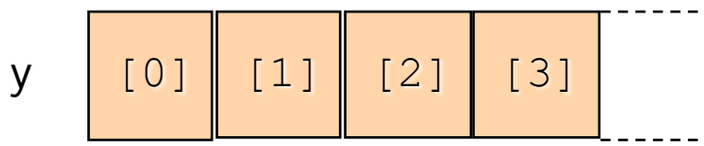
So....
`a[n] == n[a]`

pointers != arrays

- very closely related but *not* the same
- declare as a pointer → define as a pointer
- declare as an array → define as an array

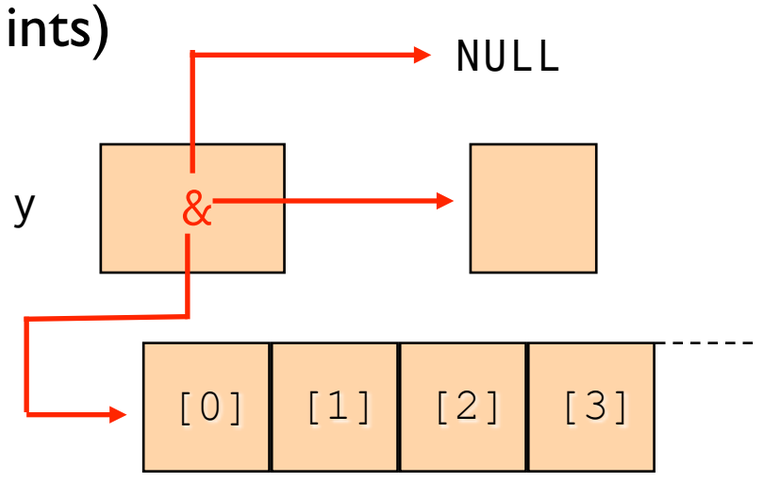
y is an array of int (of unspecified size)

```
extern int y[];
y[n]
```



y is a pointer to an int (or to an array of ints)

```
extern int * y;
y[n]
```



pointer confusion

- be clear what your expression refers to
- the pointer, the thing the pointer points to, both?

```
int array[42];
int * pointer = &array[0];
```

```
pointer = &array[9];
```

the pointer

```
pointer++;
```

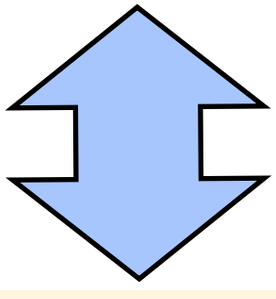
the pointer

```
*pointer = 0;
```

the int the pointer points to

```
int v = *pointer++;
```

both!


equivalent

```
int v = *pointer;
pointer++;
```

syntax trick

- syntax of use mirrors syntax of declaration

```
int value = 42;
const int *ptr = &value;
```

```
*ptr = 42;
```

```
const int       = 42;
```

pointer + const

- often causes confusion
- again, be clear what your expression refers to
- read `const` on the pointer's target as readonly

```
int value = 0;
```

```
int * ptr = &value;
*ptr = 42;          // ok
ptr = NULL;         // ok
```

*ptr is not const ✓

*ptr is not const ✓

```
const int * ptr = &value;
*ptr = 42;          // error
ptr = NULL;         // ok
```

*ptr must be treated as readonly ✗

ptr is not const ✓

pointer + const

- often causes confusion
- again, be clear what your expression refers to
- read `const` on the pointer's target as readonly

```
int value = 0;
```

```
int * const ptr = &value;
*ptr = 42;          // ok
ptr = NULL;         // error
```

`*ptr` is not const ✓

`ptr` is const ✗

```
const int * const ptr = &value;
*ptr = 42;          // error
ptr = NULL;         // error
```

`*ptr` must be treated as readonly ✗

`ptr` is const ✗

function pointers

- `( )` is a binary operator with very high precedence
- `f(a,b)` is like an infix version of `( )( f, a, b )`
- you can name a function without calling it!
- the result is a strongly typed function pointer

* is needed here

```
#include <stdio.h>

int add(int a, int b) { return a + b; }
int sub(int a, int b) { return a - b; }

int main(int argc, char * argv[])
{
    int (*f)(int,int) =
        argc % 2 == 0 ? add : sub;

    printf("%d\n", f(3, 1));
}
```

function pointer arguments

- function pointers can be function parameters!
- * is optional on the parameter

* is not needed here

```
int call(int (*f)(int,int))
{
    return (*f)(3, 1);
}
```

equivalent

```
int call(int f(int,int))
{
    return f(3, 1);
}
```

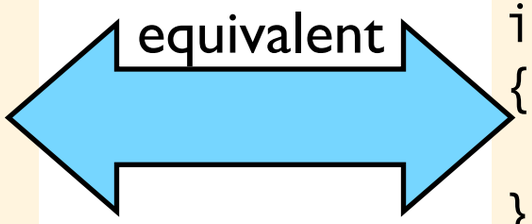
```
#include <stdio.h>

int add(int a, int b) { return a + b; }
int sub(int a, int b) { return a - b; }

int main(int argc, char * argv[])
{
    int (*f)(int,int) =
        argc % 2 == 0 ? add : sub;

    printf("%d\n", call(f));
}
```

function pointer arguments

- `typedef` can often help

```
typedef int func(int, int);
```

```
int call(func * f)
{
    return (*f)(3, 1);
}
```




```
int call(func f)
{
    return f(3, 1);
}
```

summary

- pointers can point to...
  - nothing, i.e., null (expressed as NULL or 0)
  - a variable whose address has been taken (&)
  - a dynamically allocated object in memory (from malloc, calloc or realloc – don't forget to free)
  - an element within or one past the end of an array

- pointer arithmetic is scaled

- pointers and arrays share many similarities
  - but they are not the same
  - the differences are as important as the similarities

- be clear about what you can do with a pointer
  - be clear about what's `const`
  - respect `restrict`

- function pointers