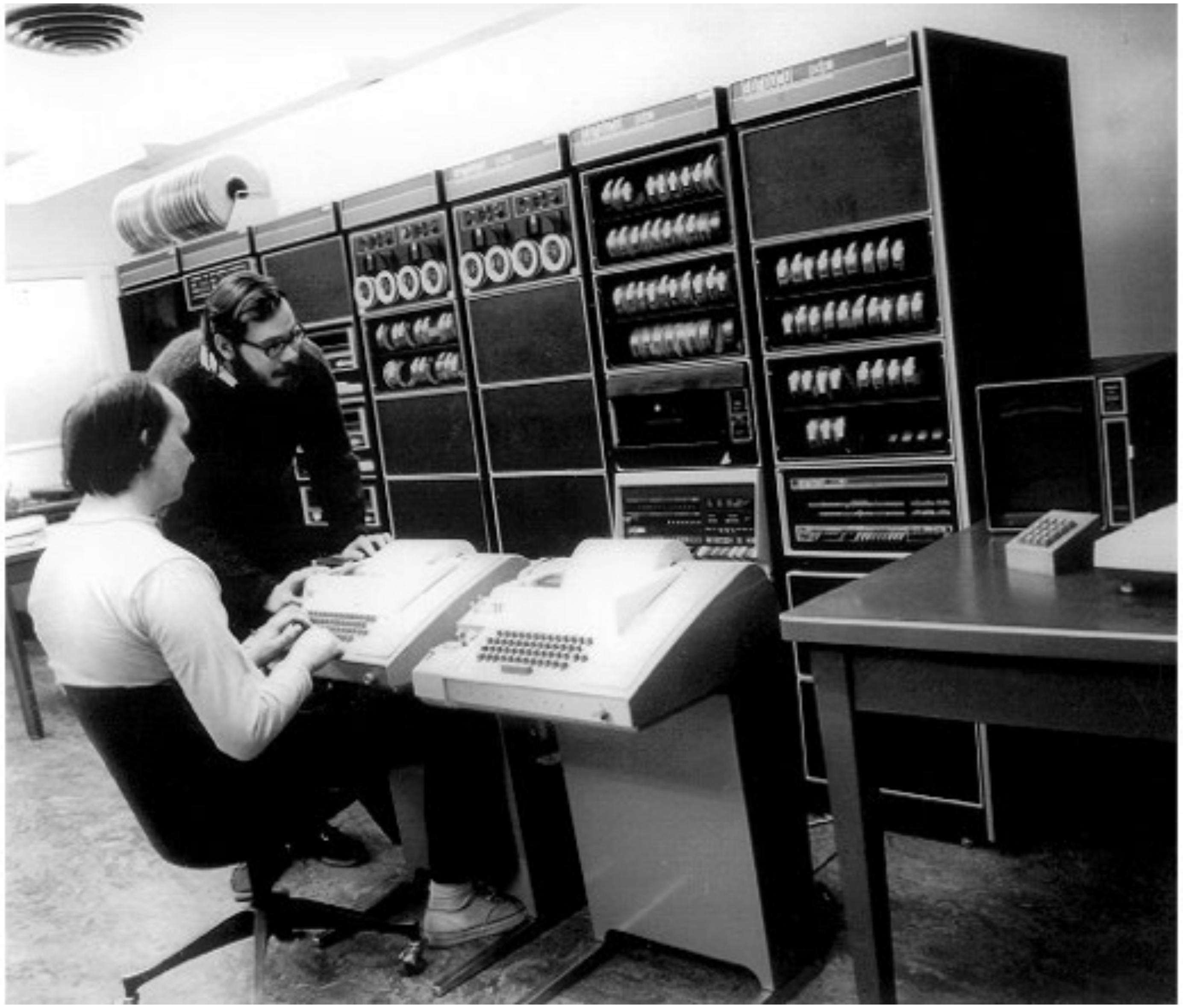
Pointers

"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;
```

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

preferred

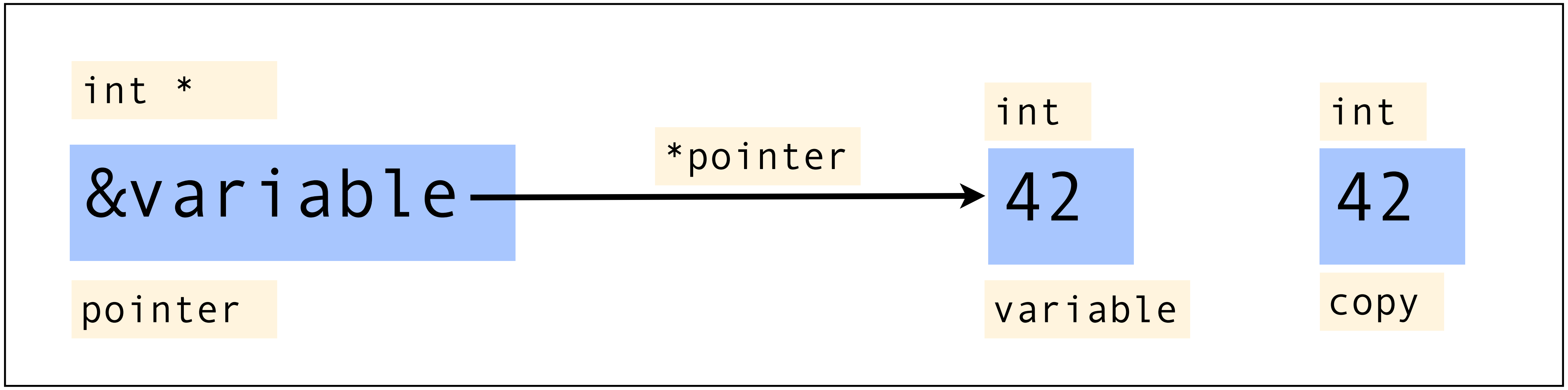
address-of / dereference

- 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



level diagram

pointer function arguments

```c
#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

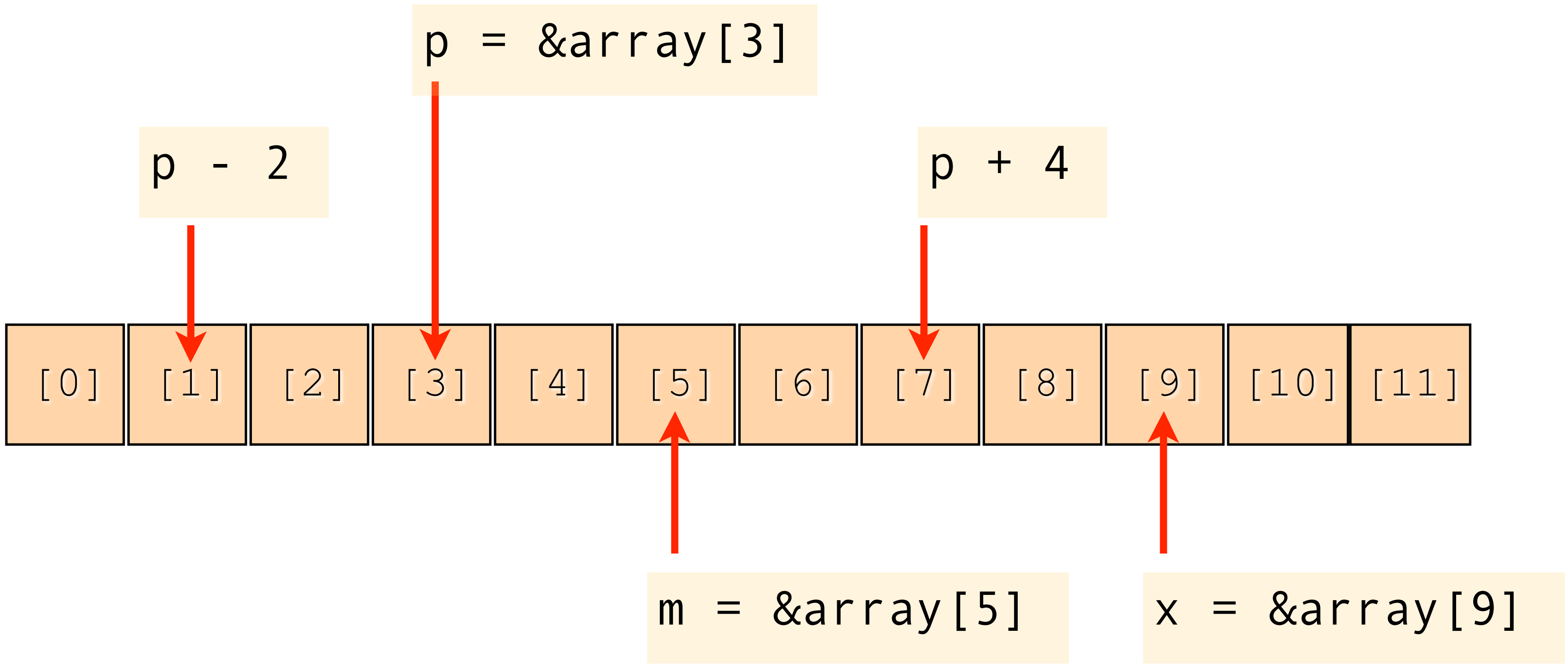
- what does the following program print?
- why?

```
#include <stdio.h>

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

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>



`p = &array[3]`

`p - 2`

`p + 4`

`[0] [1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11]`

`m = &array[5]`

`x = &array[9]`

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

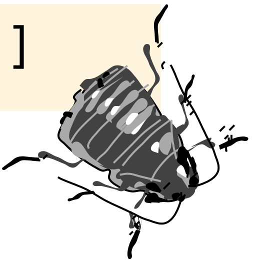
one beyond the end

- 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]
```

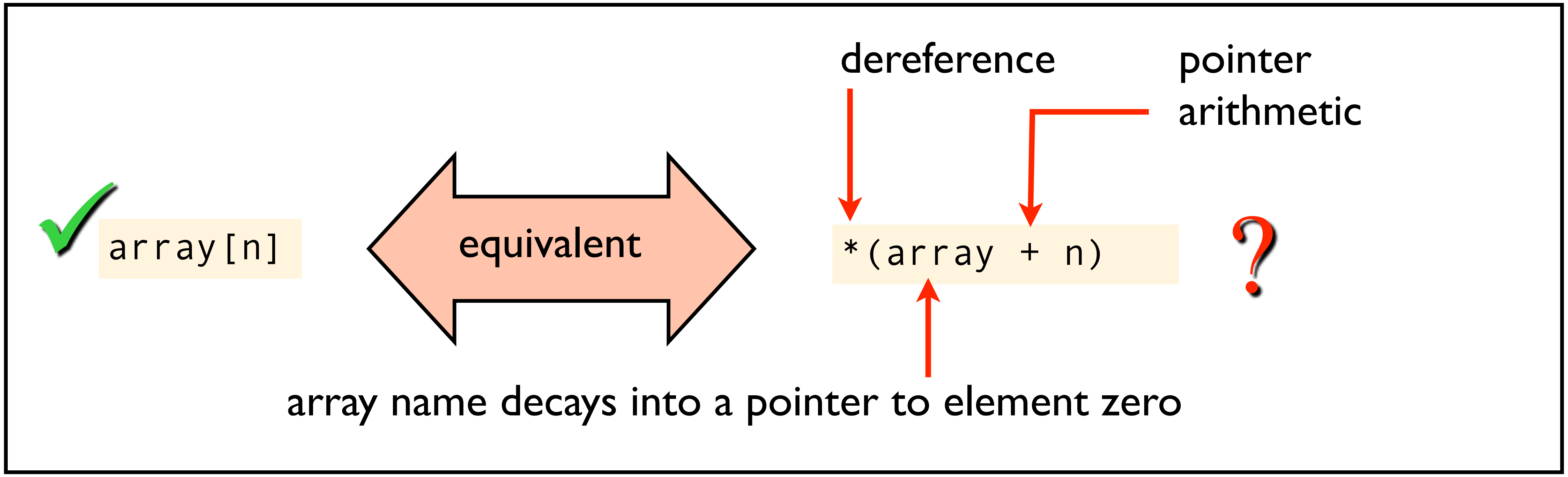
✓

```
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)`



dereference

pointer arithmetic

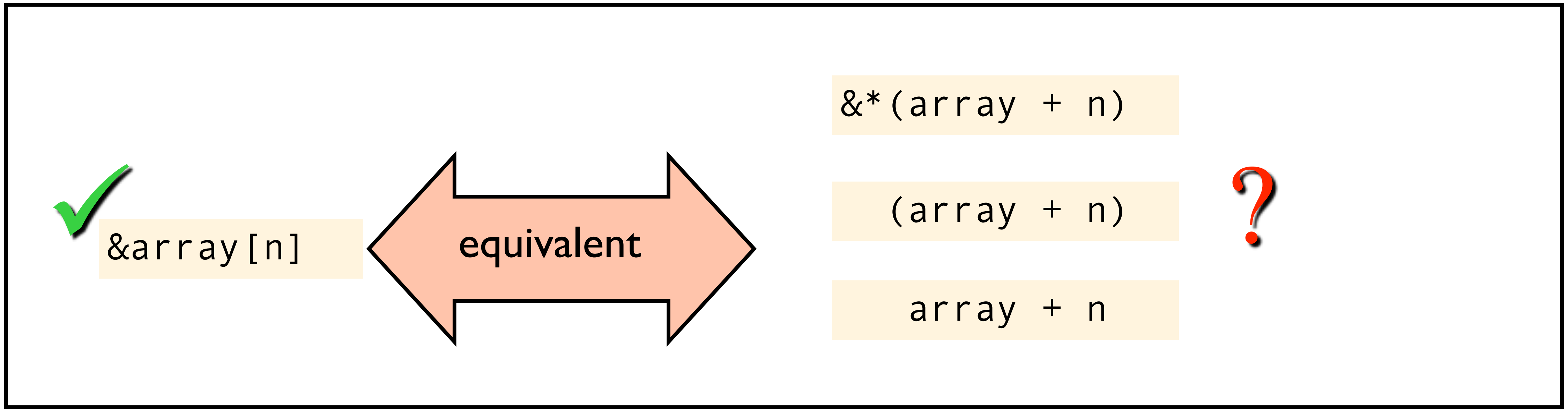
✓ `array[n]`

equivalent

`*(array + n)`

?

array name decays into a pointer to element zero



✓ `&array[n]`

equivalent

`&*(array + n)`

`(array + n)`

`array + n`

?

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]`

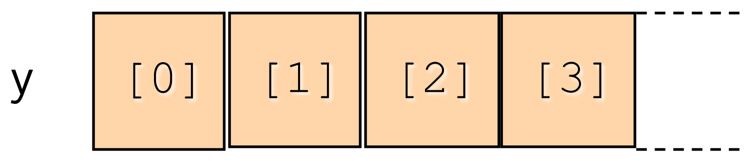
So....
`a[n] == n[a]`

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

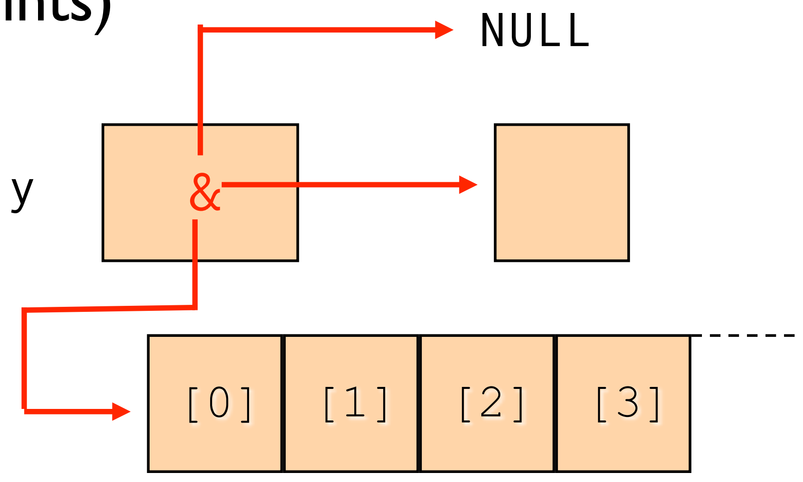
y is an array of int (of unspecified size)

```
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++;
```

C was designed so that the syntax of use mirrors the syntax of declaration

```
        int identifier;
         ↕      ↕
typedef int identifier;
```

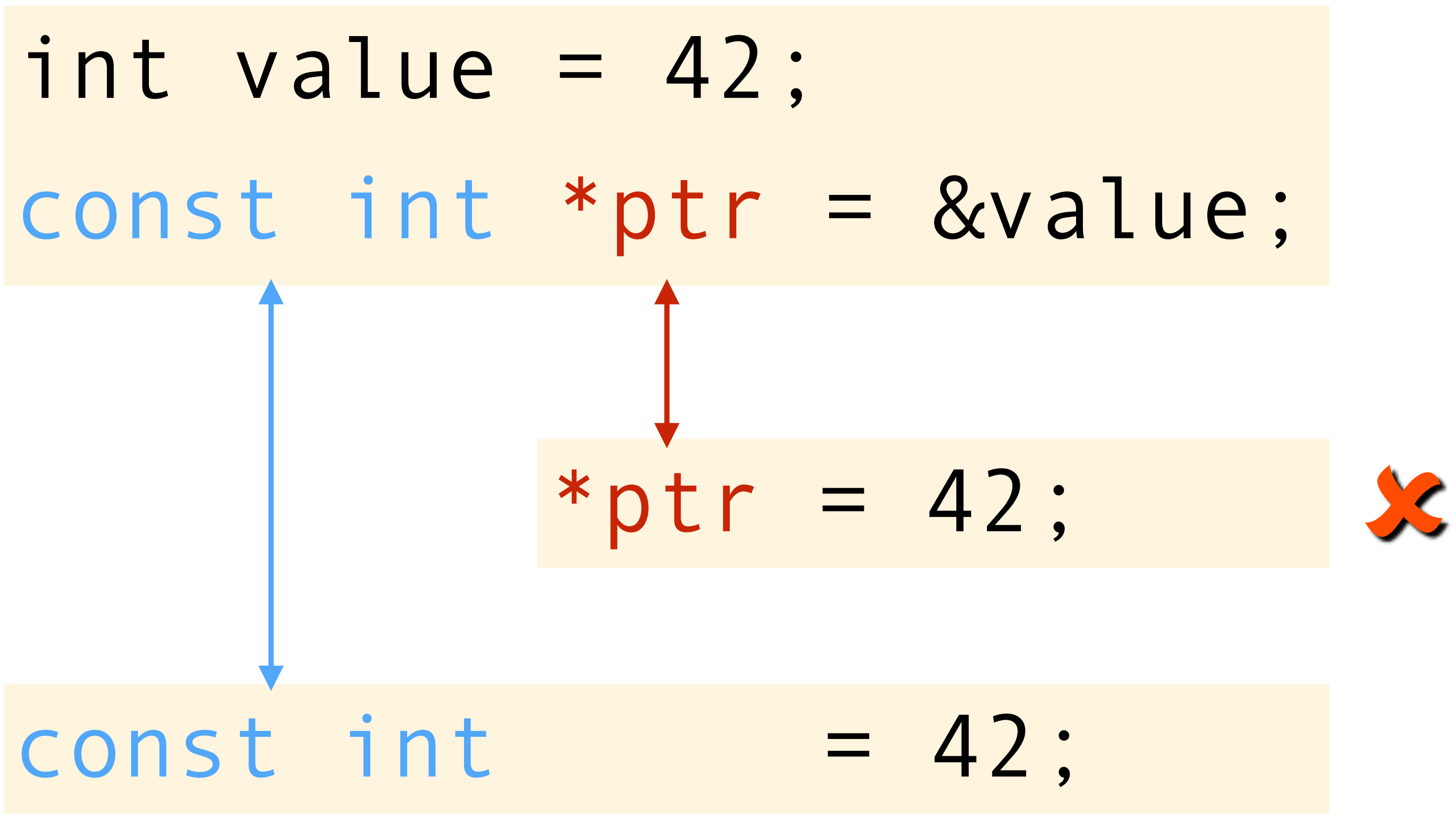
```
       int *pointer = &variable;
           ↕  ↕
int copy = *pointer;
           ↕  ↕
           *pointer = 42;
```

```
int days_in_month[12];
          ↕        ↕
 ...days_in_month[at]...
```

```
void func(int a, int b);
       ↕      ↕      ↕
     func(    4,     2);
```

syntax trick

- syntax of use mirrors syntax of declaration
- declaration tells you the type and any qualifiers



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

```
          *ptr = 42;
```

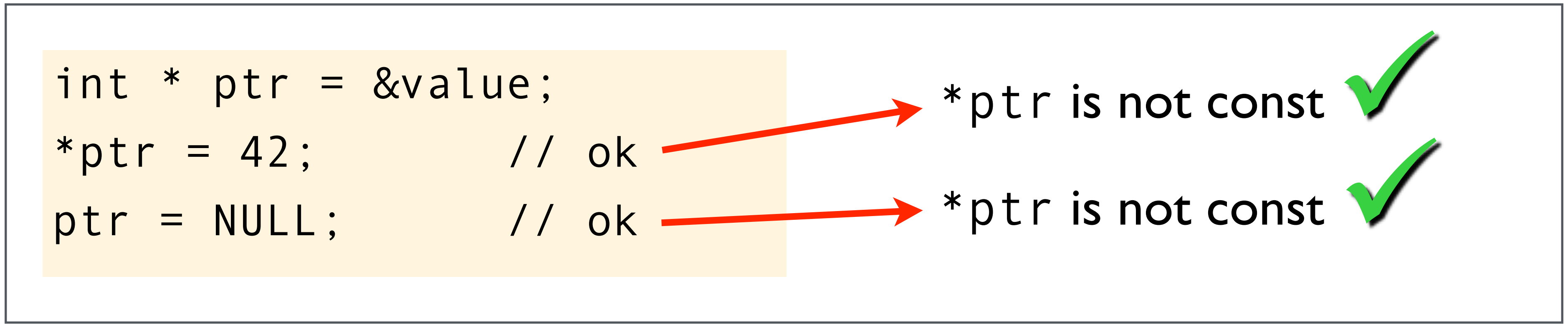
✗

```
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

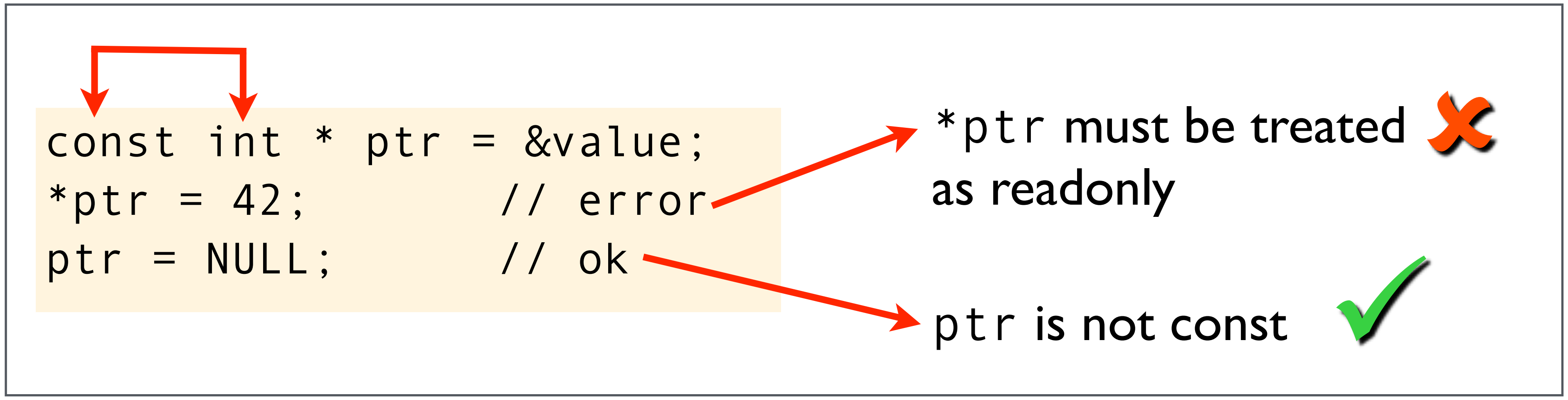
```
int value = 0;
```



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

*ptr is not const ✓

*ptr is not const ✓

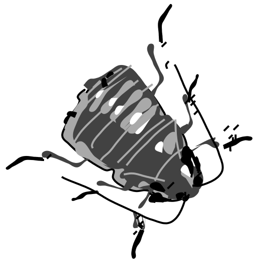


```
const int * ptr = &value;
*ptr = 42;         // error
ptr = NULL;        // ok
```

*ptr must be treated as readonly ✗

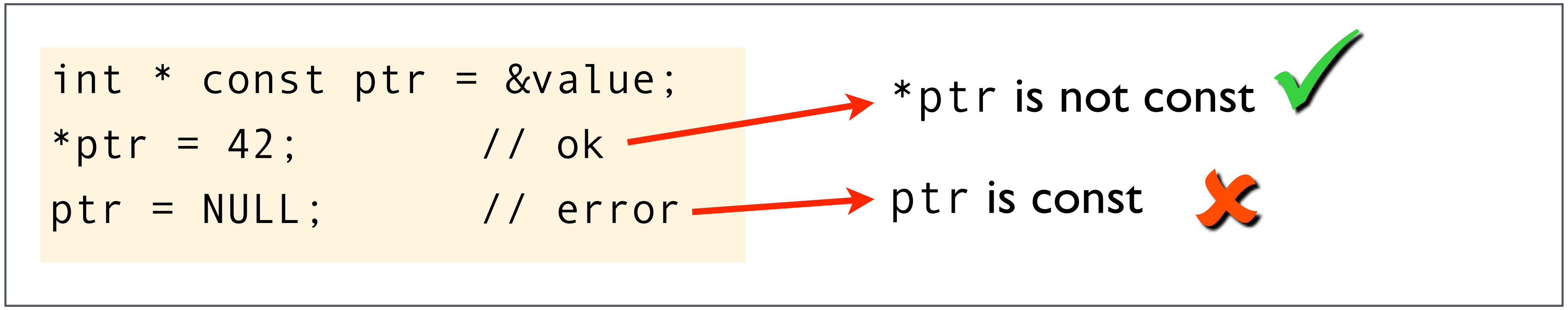
ptr is not const ✓

pointer + const



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

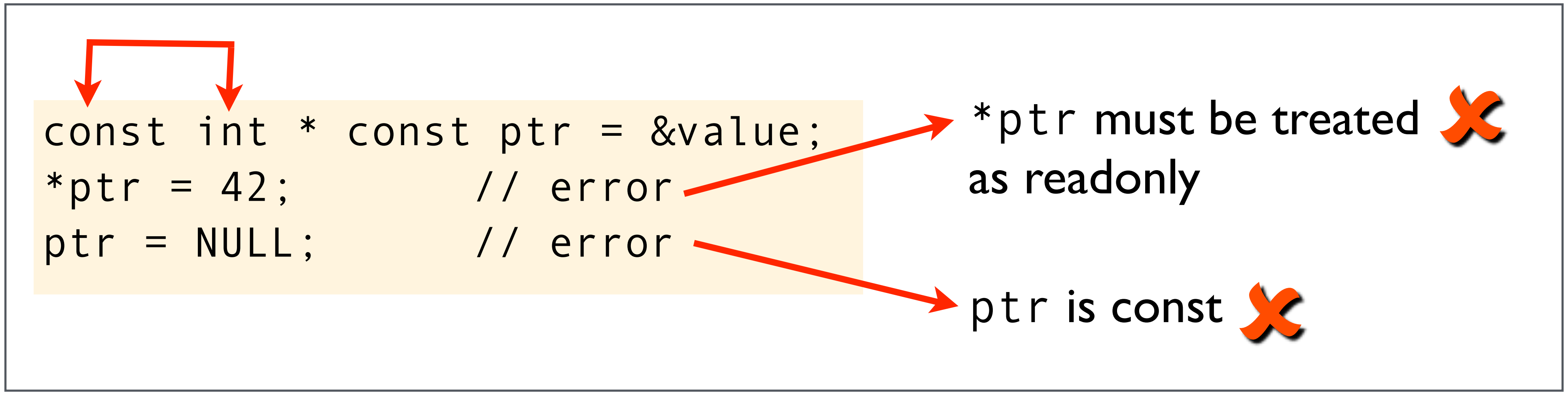
```
int value = 0;
```



```
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 ✗

restrict

- applies only to pointer declarations
- `type*restrict p` → `*p` is accessed *only* via `p` in the surrounding block
- enables pointer no-alias optimizations
- a compiler is free to ignore it

c99

```
void f(int n, int * restrict p, int * restrict q)
{
    while (n-- > 0) {
        *p++ = *q++;
    }
}
```

```
void g(void)
{
    int d[100];
    f(50, d + 50, d);   // ok
    f(50, d + 1,  d);   // undefined-behaviour
}
```

remember this?

```
int f(int * p, int * q)
{
    return (*p) - (*q)++;
}
```

*p (value computation)
is ***unsequenced***
relative to
(*q)++ (side effect)

undefined if p and q point to the same object

```
int f(int * restrict p, int * restrict q)
{
    return (*p) - (*q)++;
}
```

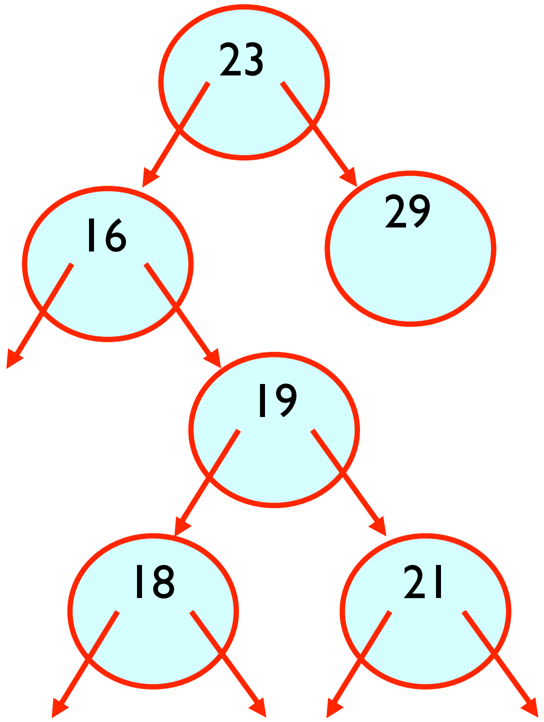
p and q do ***not*** point to the same object

restrict

c99

- restrict can be used on pointer data members
- enables the same no-alias optimizations

```
struct tree_node
{
    int count;
    struct tree_node * restrict left;
    struct tree_node * restrict right;
};
```



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`