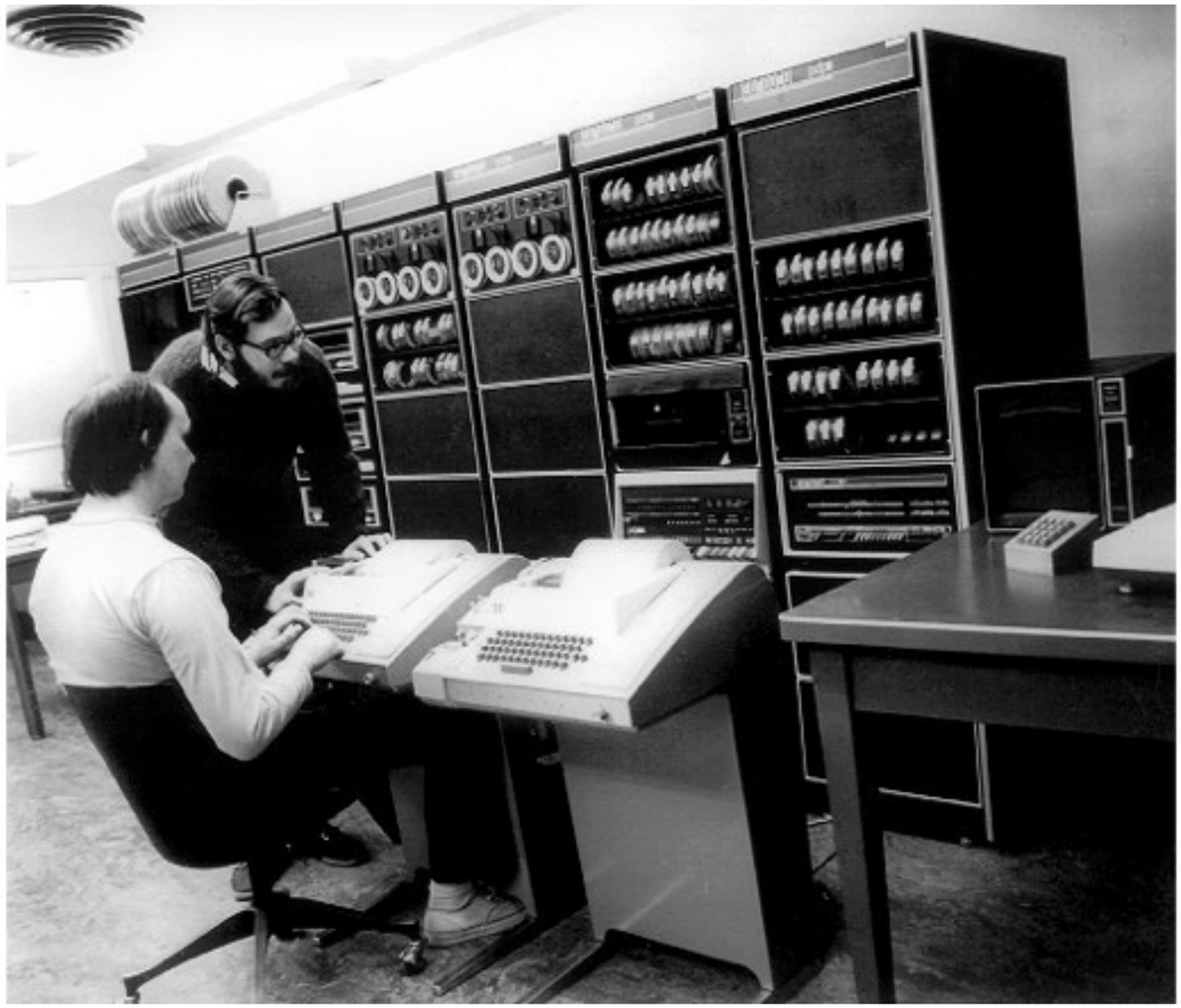
Structures

"to get a deeper understanding of the language"



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

typedef

- aids portability and expresses intention

```
void eg(void)
{
    struct wibble buffer[4096];
    unsigned int count = sizeof(buffer);
    ...
}
```

```
#include <stddef.h>

void f(void)
{
    struct wibble buffer[4096];
    size_t byte_count = sizeof(buffer);
    ...
}
```

typedef

c11

- c99 does *not* allow duplicate typedefs
- c11 does

```
typedef struct date date;
typedef struct date date;
```

```
typedef struct date date;
typedef struct date date;
```

c11

gcc: -std=c11

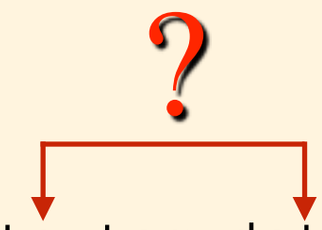
clang: -x c -std=c11

struct typedef

- a struct's tagname and its typedef name are the *same* type
- giving them different names is misleading

date.h

```
struct date_tag
{
    ...
};
typedef struct date_tag date;
```



```
#include "date.h"

void delay(struct date_tag deadline);
```

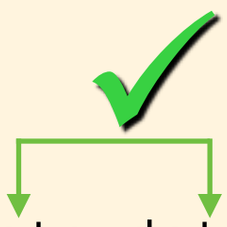
```
#include "date.h"

void delay(date deadline);
```

struct typedef

- a struct/enum/union's tagname and its typedef name* should be the *same*

date.h

```
struct date
{
    ...
};
typedef struct date date;
```



```
#include "date.h"

void delay(struct date deadline);
```

```
#include "date.h"

void delay(date deadline);
```

**if it has a typedef*

initialization

- structs support a convenient { aggregate } initialisation
- allows const struct variables
- missing fields are default initialised
- not permitted for assignment
- list cannot be empty

```
struct date deadline = { 2015, may, 1 };
```

```
const struct project fubar =
    { "fubar", { 2015, may, 1 } };
```

```
struct date deadline;
deadline = { 2015, may, 1 };
```

```
struct date deadline = { };
```

representation dependency

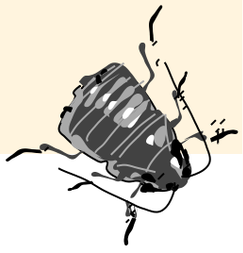
- initialization in member order is a representation dependency :-(
- makes the representation harder to change

```
struct date
{
    int year;
    int month;
    int day;
};
```

refactor?

```
struct date
{
    int day;
    int month;
    int year;
};
```

```
struct date deadline =
{
    2015,
    may,
    1
};
```



dot designators c99

- structs support designator identifiers
- allows struct data members to be changed
- missing members are still default initialised

```
struct date
{
    int year;
    int month;
    int day;
};
```

refactor

```
struct date
{
    int day;
    int month;
    int year;
};
```

```
struct date deadline =
{
    .year = 2015,
    .month = may,
    .day = 1
};
```

refactor

compound literals c99

- aggregate initialization list can be "cast"
- "cast" type becomes type of expression
- assignment works with the "cast" :-)

works for plain initialiser lists

```
deadline = (struct date){ 2015, may, 1 };
```

works for dot designators

```
deadline =
    (struct date){ .year = 2015, .month = may, .day = 1 };
```

allows creation of anonymous objects

```
void f(struct date when);

f((struct date){ .year = 2015, .month = may, .day = 1 });
f((const struct date){ 2015, may, 1 });
```

compound literals c99

- you can even take the address of an anonymous object.
- the anonymous object pointed to...
  - has automatic storage class
  - is scoped to the enclosing block

```
int delay(const struct date * deadline);
```



```
delay(&(struct date){ .year = 2015, .month = may, .day = 1 });
```


```
delay(&(const struct date){ 2015, may, 1 });
```

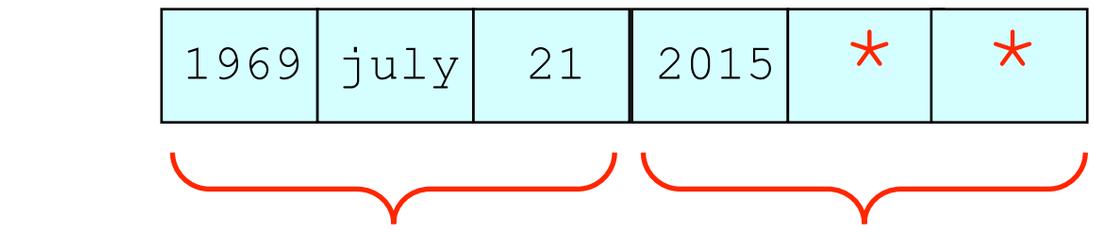

arrays and structs

- [*int*] and *.identifier* designators can be combined

array of structs

```
struct date milestones[] =
{
    [0] = { 1969, july, 21 },
    [1].year = 2015
};
```

c99

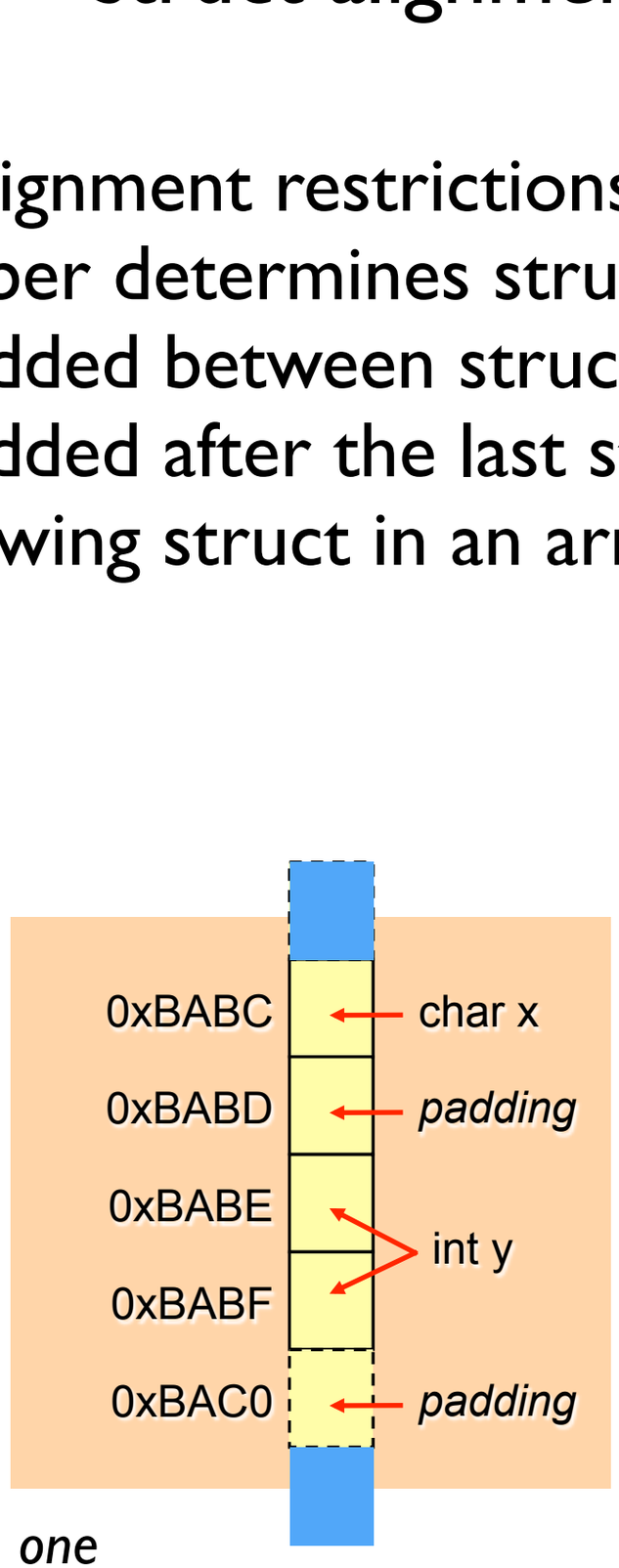


* default value = 0

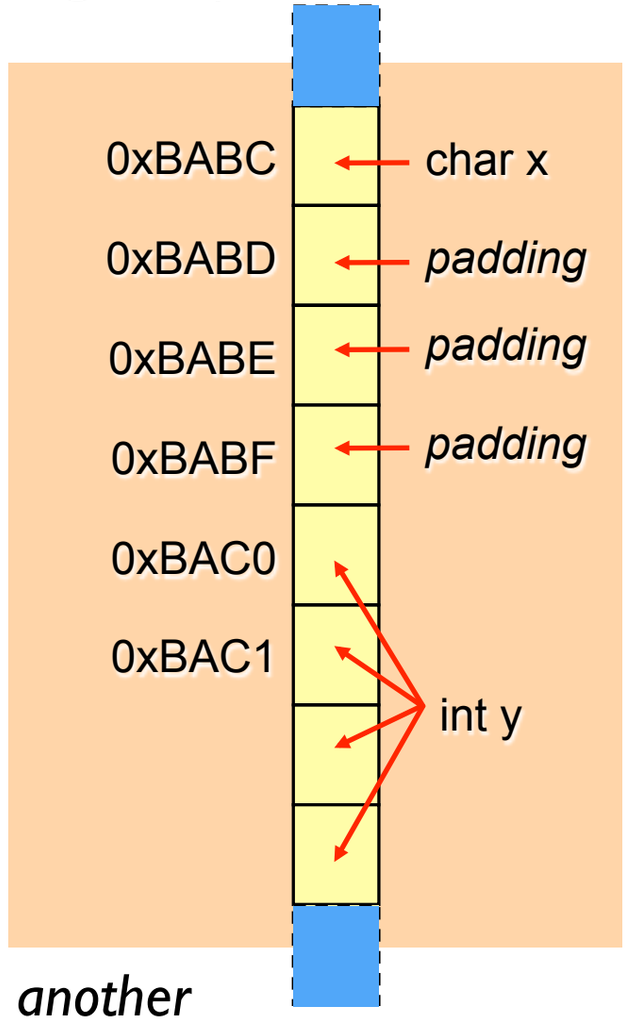
struct alignment-padding

- types can have alignment restrictions
- first struct member determines struct's alignment
- padding can be added between struct members
- padding can be added after the last struct member
  (to ensure following struct in an array is aligned)

```
struct point
{
    char x;
    int y;
};
```



one alternative



another alternative

struct =

- struct assignment *might* perform a simple bitwise copy
- struct assignment *might not* copy padding bytes

```
void some_func(const struct date * deadline)
{
    struct date delayed;
    memcpy(&delayed, deadline, sizeof delayed);
    ...
}
```

```
void some_func(const struct date * deadline)
{
    struct date delayed = *deadline;
    ...
}
```

struct ==

- structs do *not* support == or != operators
- using memcmp is *flawed* because of padding!
- only safe approach is to compare each member

```
struct date now = { ... };
struct date due = { ... };
```

```
if (now == due)   ✗   compile time error
```

```
if (memcmp(&now, &due, sizeof now) == 0)
```

```
bool date_equal(const struct date * lhs,
                const struct date * rhs)
{
  return lhs->year == rhs->year &&
         lhs->month == rhs->month &&
         lhs->day == rhs->day;
}
```

✓

struct hack c99

- last member may be an incomplete array type
- can't be the only member of the struct
- as if size of array is zero?!

```
struct small_message
{
    char size;
    char letters[];
};
```

incomplete array type

```
struct small_message var;
assert(sizeof var == 1);
assert(sizeof(struct small_message) == 1);

struct small_message array[42];
assert(sizeof array == 42);
assert(sizeof(struct small_message[42]) == 42);
```

struct hack

- allows struct type to overlay memory
- as if variable-length array was last member

```
...
int main(void)
{
    char buffer[] =
    {
        5, 'h','e','l','l','o',
        2, ',',' ',
        5, 'w','o','r','l','d',
        1, '\n',
    };
    const struct small_message * msg;
    int n = 0;
    do {
        msg = (const struct small_message *)&buffer[n++];
        n += printf("%.*s", msg->size, msg->letters);
    } while (msg->size != 0);
}
```

```
hello, world
```

summary

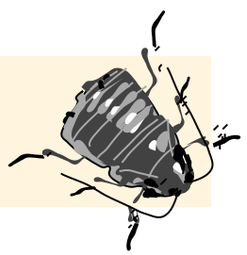
- make struct's tagname and typedef name the same
- structs are the most common user defined type
- structs support = assignment
- structs do not support == equality (beware padding)
- struct typically pad between members
- structs have a rich compound literal syntax (c99)
- struct hack allows variable length struct (c99)

_Alignas

c11

- a new declaration alignment-specifier
- _Alignas(type-name)
- _Alignas(constant-expression)
- #include <stdalign.h> provides alignas macro
- #include <stddef.h> provides max_align_t
- #include <stdlib.h> provides aligned_alloc()

```
char buffer[sizeof(date)];
date * ptr = (date*)buffer;
```



```
#include <stdalign.h>

alignas(date) char buffer[sizeof(date)];
date * ptr = (date*)buffer;
```

```
#include <stdalign.h>
#include <stddef.h>

alignas(max_align_t) char buffer[sizeof(date)];
date * ptr = (date*)buffer;
```

_Alignof

c11

- _Alignof(type-name) is the size_t alignment of type-name
- valid alignment values are always integral powers of 2
- char has the weakest alignment requirement
- #include <stdalign.h> provides alignof macro

```c
#include <stdalign.h>
#include <stddef.h>
#include <stdio.h>

int main(void)
{
    printf("%zu\n", alignof(char));
    printf("%zu\n", alignof(short));
    printf("%zu\n", alignof(int));
    printf("%zu\n", alignof(long));
    printf("%zu\n", alignof(void*));
    printf("%zu\n", alignof(float));
    printf("%zu\n", alignof(double));
    printf("%zu\n", alignof(max_align_t));
}
```

```
1
2
4
8
8
4
8
16
```

eg