C Foundation

Advanced Techniques

clean C

- code that compiles in both C and C++
  - C++ compiler is stricter than C
  - e.g. pre C99 did not require function declarations
  - e.g. C++ requires more conversions to be explicit
  - avoid C++ keywords

```
bool
catch
class
const_cast
delete
dynamic_cast
explicit
export
false
friend
mutable
namespace
new
operator
private
protected
public
reinterpret_cast
static_cast
template
this
throw
true
try
typeid
typename
using
virtual
wchar_t
```

C++ keywords that are not also C keywords comments

- **Comments can indicate missing code**

BEFORE

```
void test_is_leap_year(void)
{
    // years not divisible by 4 are leap years
    assert(is_leap_year(1906));
    assert(!is_leap_year(2009));

    // years divisible by 4 but not 100 are leap years
    assert(is_leap_year(1984));
    assert(is_leap_year(2008));

    // years divisible by 100 but not 400 are not leap years
    assert(!is_leap_year(1900));
    assert(!is_leap_year(2100));

    // years divisible by 400 are leap years
    assert(is_leap_year(2000));
    assert(is_leap_year(2400));
}
```

- **Imagine if C had no comments**

AFTER

```
void years_not_divisible_by_4_are_leap_years(void)
{
    assert(is_leap_year(1906));
    assert(!is_leap_year(2009));
}
void years_divisible_by_4_but_not_100_are_leap_years(void)
{
    assert(is_leap_year(1984));
    assert(is_leap_year(2008));
}
void years_divisible_by_100_but_not_400_are_not_leap_years(void)
{
    assert(!is_leap_year(1900));
    assert(!is_leap_year(2100));
}
void years_divisible_by _400_are_leap_years(void)
{
    assert(is_leap_year(2000));
    assert(is_leap_year(2400));
}
```

clarity ~ brevity

- prefer initialization to assignment

refactor

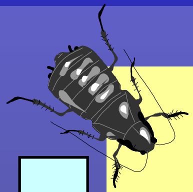
```
int count;
count = 0;
```

? ☹

```
int count = 0;
```

✓ ☺

- don't explicitly compare against true/false



```
if (has_prefix("is") == true)
    ...
```

? ☹

refactor

```
if (has_prefix("is"))
    ...
```

✓ ☺

implicit vs explict

- **avoid redundant use of true/false**

this version is very "solution focused"

```
bool is_even(int value)
{
    if (value % 2 == 0)
        return true;
    else
        return false;
}
```

?☹

↓ refactor

this version is less solution focused;
it is more problem focused;
it is more "declarative"

```
bool is_even(int value)
{
    return value % 2 == 0;
}
```

✓☺

implicit vs explict

- **make inter-statement dependencies explicit**

consider if you accidentally refactor the if without
the last return - oops

```
bool some_func(int value)
{
    if (value % 2 == 0)
        return alpha();
    return beta();
}
```

?☹

↓ refactor

the return statements are now at the
same indentation. logical == physical

```
bool some_func(int value)
{
    if (value % 2 == 0)
        return alpha();
    else
        return beta();
}
```

✓☺

- in general, beware of boolean literals

again, wordy, verbose

```
if (oldest)
    if (last_access < cut_off)
        return true;
    else
        return false;
else
    return false;
```

?☹

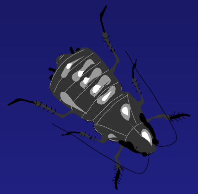
↓ refactor

much simpler, reads well

```
return oldest && last_access < cut_off;
```

✓☺

how to iterate



- iteration is a common bug hotspot
  - looping is easy, knowing when to stop is tricky!
- follow the fundamental rule of design
  - always design a thing by considering it in its next largest context
  - what do you want to be true *after* the iteration?
  - this forms the termination condition

```
... search(size_t end, int values[], int find)
{
    size_t at = 0;
    // values[at==0 → at==end] iteration
    at == end || values[at] == find
    ...
}
```

we didn't find it........... or ....we found it

(short-circuiting)

how to iterate

- **the negation of the termination condition is the iteration's continuation condition**
  - **!(at == end || values[at] == find)**
  - **at != end && values[at] != find**

equivalent
(DeMorgan's Law)

```
... search(size_t end, int values[], int find)
{
    size_t at = 0;
    while (at != end && values[at] != find)
    {
        ...
    }
    ...
}
```

```
at++;
```

short-circuiting protects values[at]

- **then simply fill in the loop body** ☺

bad typedef

- don't attempt to hide a pointer in a typedef
  - if it's a pointer make it look like a pointer
  - abstraction is about hiding ***unimportant*** details

?

date.h

```
typedef struct date * date;

bool date_equal(const date lhs, const date rhs);
```

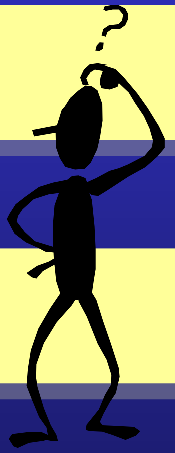
what is const?

```
bool date_equal(const struct date * lhs,
                const struct date * rhs);
```

is it the date object pointed to?

```
bool date_equal(struct date * const lhs,
                struct date * const rhs);
```

or is it the pointer?



good typedef

no * here

date.h

```
typedef struct date date;

bool date_equal(const date * lhs,
                const date * rhs);
```

alternatives

date.h

```
struct date;

bool date_equal(const struct date * lhs,
                const struct date * rhs);
```

strong typedef

- a typedef does *not* create a new type

```
typedef int mile;
typedef int kilometer;
```

```
void weak(mile lhs, kilometer rhs)
{
    lhs = rhs;
    ...
}
```

✓ ☹

- consider using a wrapper type instead...

```
typedef struct { int value; } mile;
typedef struct { int value; } kilometer;
```

```
void strong(mile lhs, kilometer rhs)
{
    lhs = rhs;
}
```

✗ ☺

weak enum

- enums are very weakly typed
  - an enum's enumerators are of type integer, not of the enum type itself!

```
typedef enum
{
    clubs, diamonds, hearts, spades
} suit;
```

```
typedef enum
{
    spring, summer, autumn, winter
} season;
```

```
void weak(void)
{
    suit trumps = winter;
}
```

✓ ☹

stronger enums

suit.h

```
typedef struct { int value; } suit;
extern const suit clubs, diamonds, hearts, spades;
```

season.h

```
typedef struct { int value; } season;
extern const season spring, summer, autumn, winter;
```

```
void strong(void)
{
    suit trumps = winter;
}
```

✗ ☺

season.c

```
const season spring = { 0 },
             summer = { 1 },
             autumn = { 2 },
             winter = { 3 };
```

```
const suit clubs    = { 0 },
           diamonds = { 1 },
           hearts   = { 2 },
           spades   = { 3 };
```

suit.c

side effects

- 5.1.2.3 Program semantics
  - At certain specified points in the execution sequence called sequence points,
    - all *side effects* of previous evaluations shall be complete and
    - no *side effects* of subsequent evaluations shall have taken place
- what constitutes a side effect?
  - accessing a volatile object
  - modifying an object
  - modifying a file
  - calling a function that does any of these

volatile

- 6.7.3 Type qualifiers
  - An object that has volatile-qualified type may be modified in ways unknown to the implementation or have other unknown side effects. Therefore any expression referring to such an object shall be evaluated strictly according to the rules… described in 5.1.2.3

```
int global;
volatile int reg;
...
    reg *= 1;

    reg = global;
    reg = global;

    int v1 = reg;
    int v2 = reg;
...
```

reg looks unchanged but reg is volatile so an access to the object is required. This access may cause its value to change.

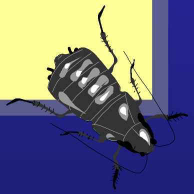
these cannot be optimized to a single assignment.

v1 might not equal v2.

exercise

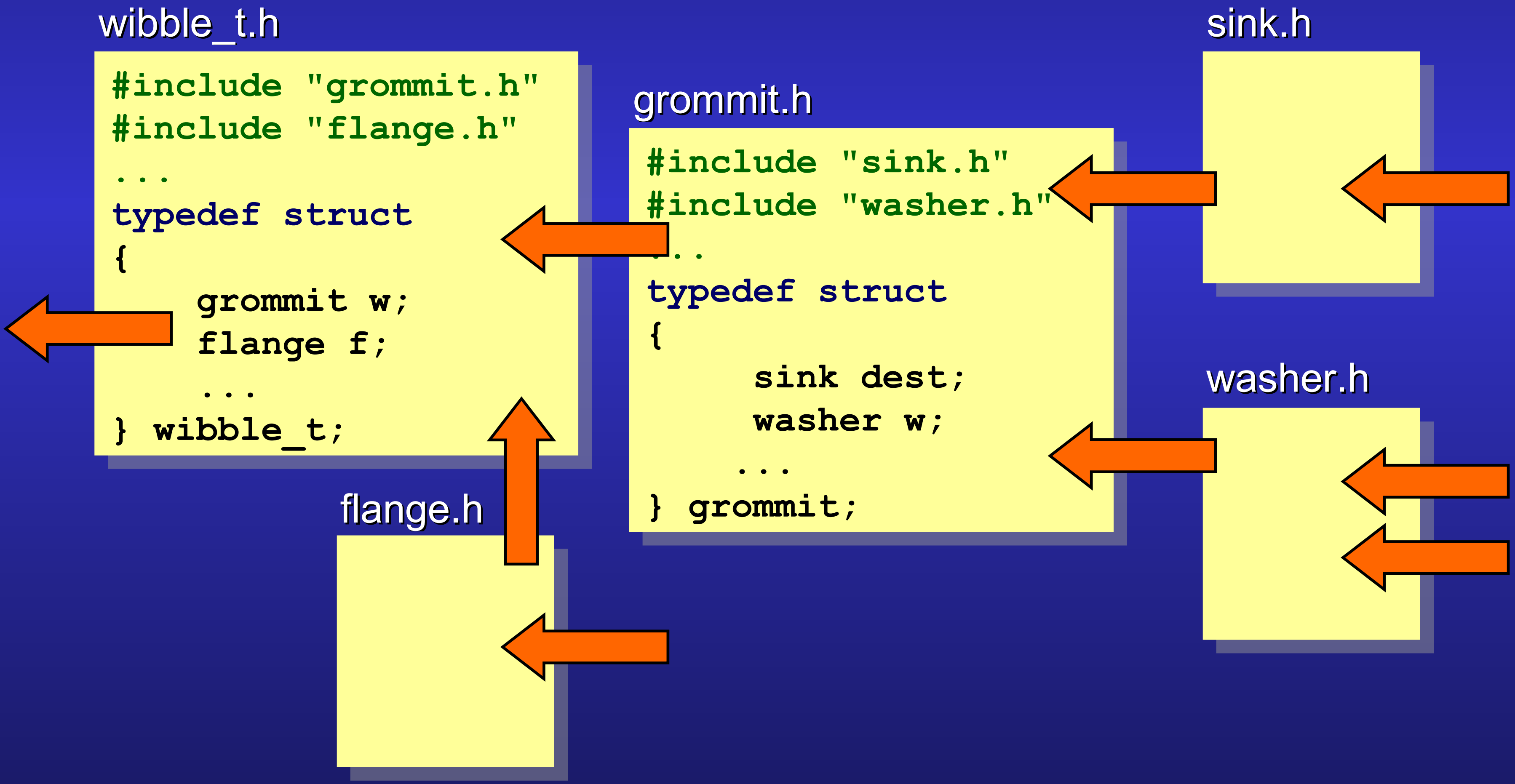
- in this statement…
  - where are the sequence points?
  - where are the side-effects?
  - is it undefined?

```
volatile int m;

void eg(void)
{
    int value = m + m;
    ...
}
```



dependencies

- #include dependencies are ***transitive***
  - if you change a .h file you have to recompile all files that #include it at any depth
  - a visible reflection of the physical coupling



wibble_t.h

```
#include "grommit.h"
#include "flange.h"
...
typedef struct
{
    grommit w;
    flange f;
    ...
} wibble_t;
```

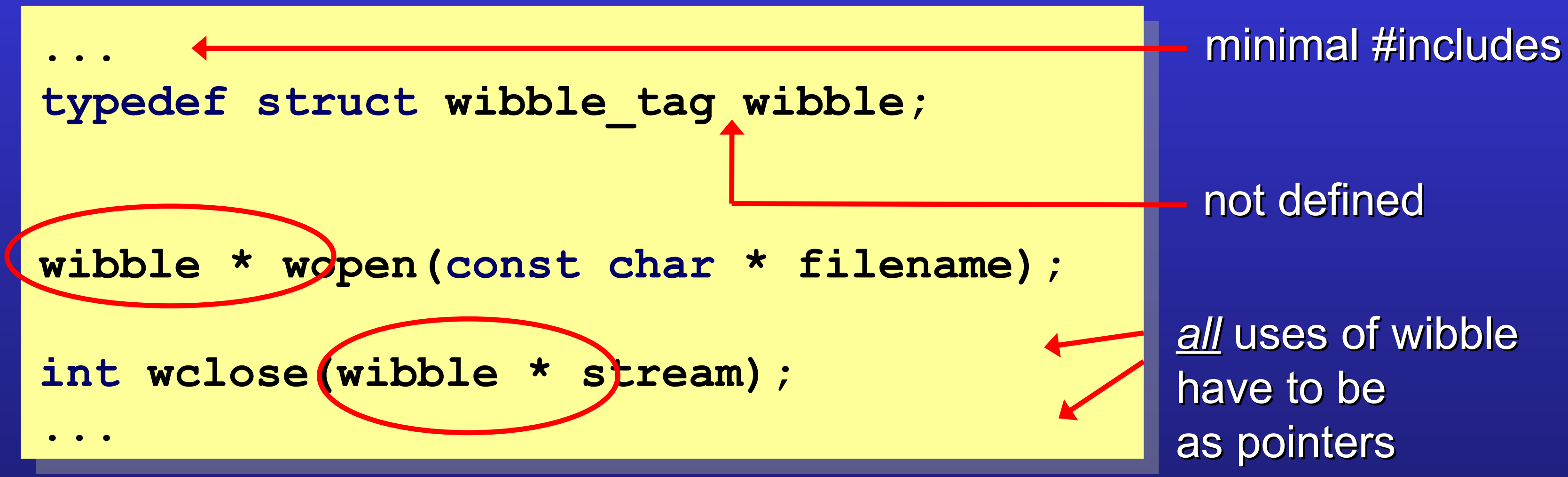
grommit.h

```
#include "sink.h"
#include "washer.h"
...
typedef struct
{
     sink dest;
     washer w;
    ...
} grommit;
```

opaque types

- an ADT implementation technique
  - a forward declaration gives the name of a type
  - the definition of the type – and it's accompanying #includes – are ***not*** specified in the header
  - all use of the type has to be as a pointer and all use of the pointer variable has to be via a function

wibble.h



```
...
typedef struct wibble_tag wibble;


wibble * wopen(const char * filename);

int wclose(wibble * stream);
...
```

minimal #includes

not defined

all uses of wibble have to be as pointers

module : use

- in most APIs the idea that a set of functions are closely related is quite weakly expressed

```
int main(int argc, char * argv[])
{
    wibble * w = wopen(argv[1]);
    ...
    wclose(w);
}
```

- a struct containing function pointers can express the idea more strongly

```
int main(int argc, char * argv[])
{
    wibble * w = wibbles.open(argv[1]);
    ...
    wibbles.close(w);
}
```

module : header

wibble.h

```
#ifndef WIBBLE_INCLUDED
#define WIBBLE_INCLUDED
...
...
typedef struct wibble_tag wibble;

struct wibble_api
{
    wibble * (*open )(const char *);
    ...
    int (*close)(wibble *);
};
extern const struct wibble_api wibbles;

#endif
```

module : source

wibble.c

```
#include "wibble.h"
...
...
static
wibble * open(const char * name)
{     ...
}
...
static
int close(wibble * stream)
{     ...
};
const struct wibble_api wibbles =
{
    open, ..., close
};
```

static linkage

no need to write
&open, &close

- opaque type memory management…
  - clients cannot create objects since they don't know how many bytes they occupy

wibble.h

```
...
typedef struct wibble wibble;
...
```

```
#include "wibble.h"

void client(void)
{
    wibble * pointer;
    ...
    wibble value;
    ...
    ptr = malloc(sizeof(*ptr));
}
```

✓ ✗

☹ ☺

ADT

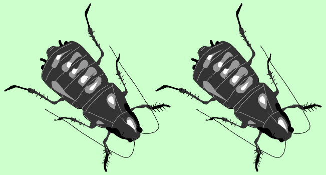
shadow data type

- an ADT can declare its size!
  - clients can now allocate the memory
  - true representation remains abstract ☺

wibble.h

```
typedef struct wibble
{
    unsigned char size[16];
} wibble;

bool wopen(wibble *, const char *);
void wclose(wibble *);
```

```
#include "wibble.h"
void client(const char * name)
{
    wibble w;
    if (wopen(&w, name))
        ...
    wclose(&w);
}
```



☹ ✓

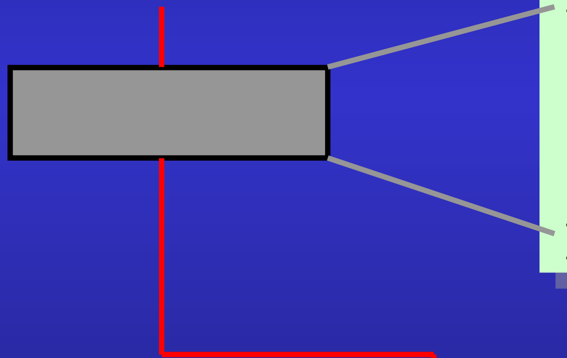
shadowed type

- **implementation needs to…**
  - **define the true representation type**

wibble.c

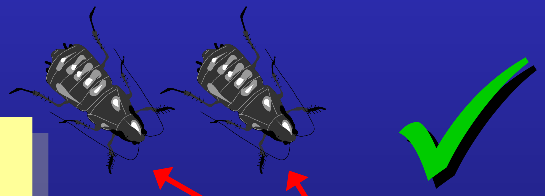
```
#include "grommit.h"
#include "flange.h"

typedef struct
{
    grommit g;
    flange f;
    ...
} wibble_rep;
```

the analogy is that the true type casts a shadow which reveals only its size



wibble.h

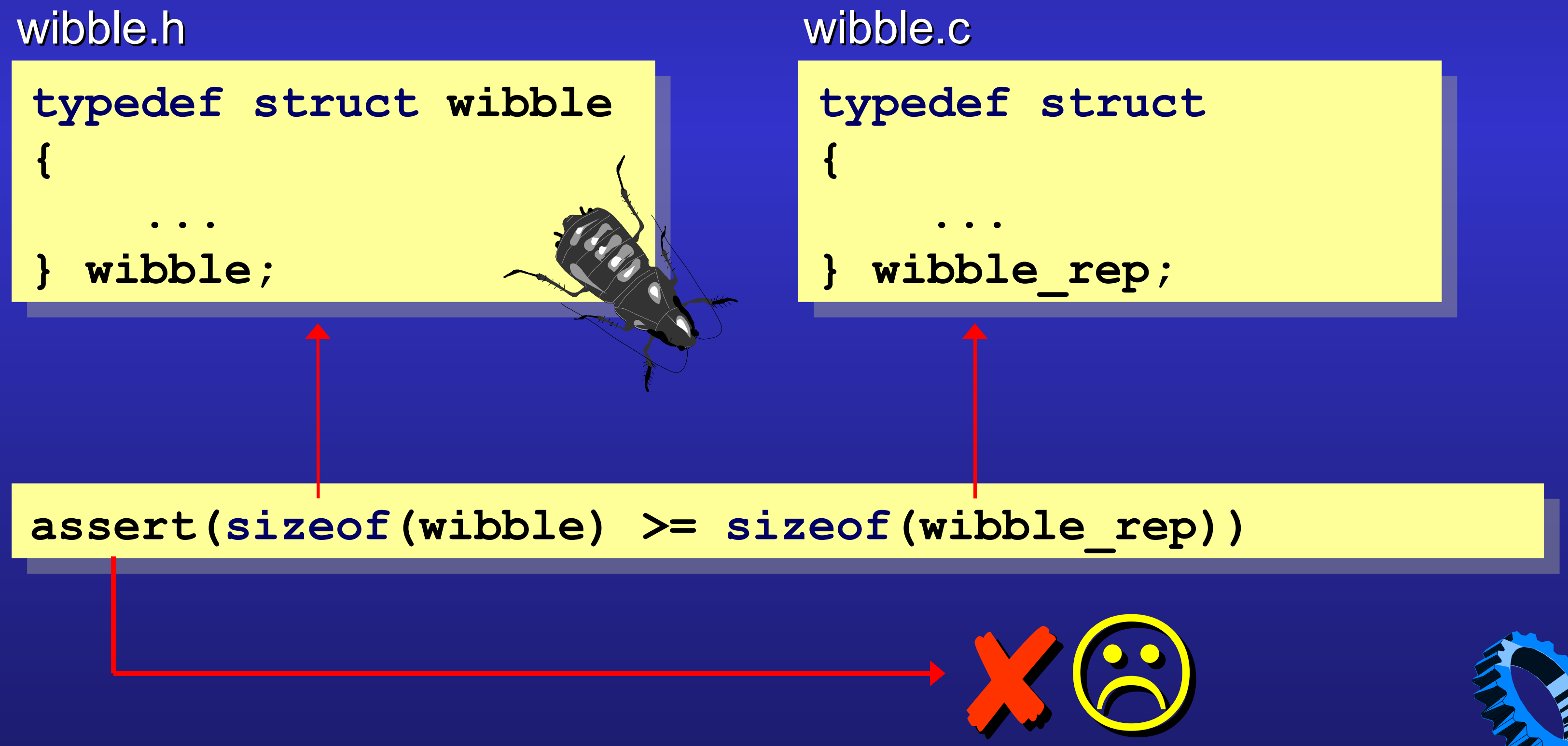
```
typedef struct wibble
{
    unsigned char size[16];
} wibble;
```



Still some problems though…

problem 1

- the size of the type must not be smaller than the size of the type it shadows
  - assert only works at runtime
  - it would be safer to check at compile time



wibble.h

```
typedef struct wibble
{
    ...
} wibble;
```

wibble.c

```
typedef struct
{
    ...
} wibble_rep;
```

```
assert(sizeof(wibble) >= sizeof(wibble_rep))
```

✗ ☹

deep magic

- use a compile time assertion
  - you cannot declare an array with negative size

compile_time_assert.h

```
#define COMPILE_TIME_ASSERT(desc,exp) \¬
              extern char desc [ (exp) ? 1 : -1 ]
```

```
#include "compile_time_assert.h"
COMPILE_TIME_ASSERT(ok, 1 == 1);
```

✓

```
#include "compile_time_assert.h"
COMPILE_TIME_ASSERT(
    your_message,
    1 == 0);
```

✗

```
gcc→
  error: size of array 'your_message' is negative
```

compatible size

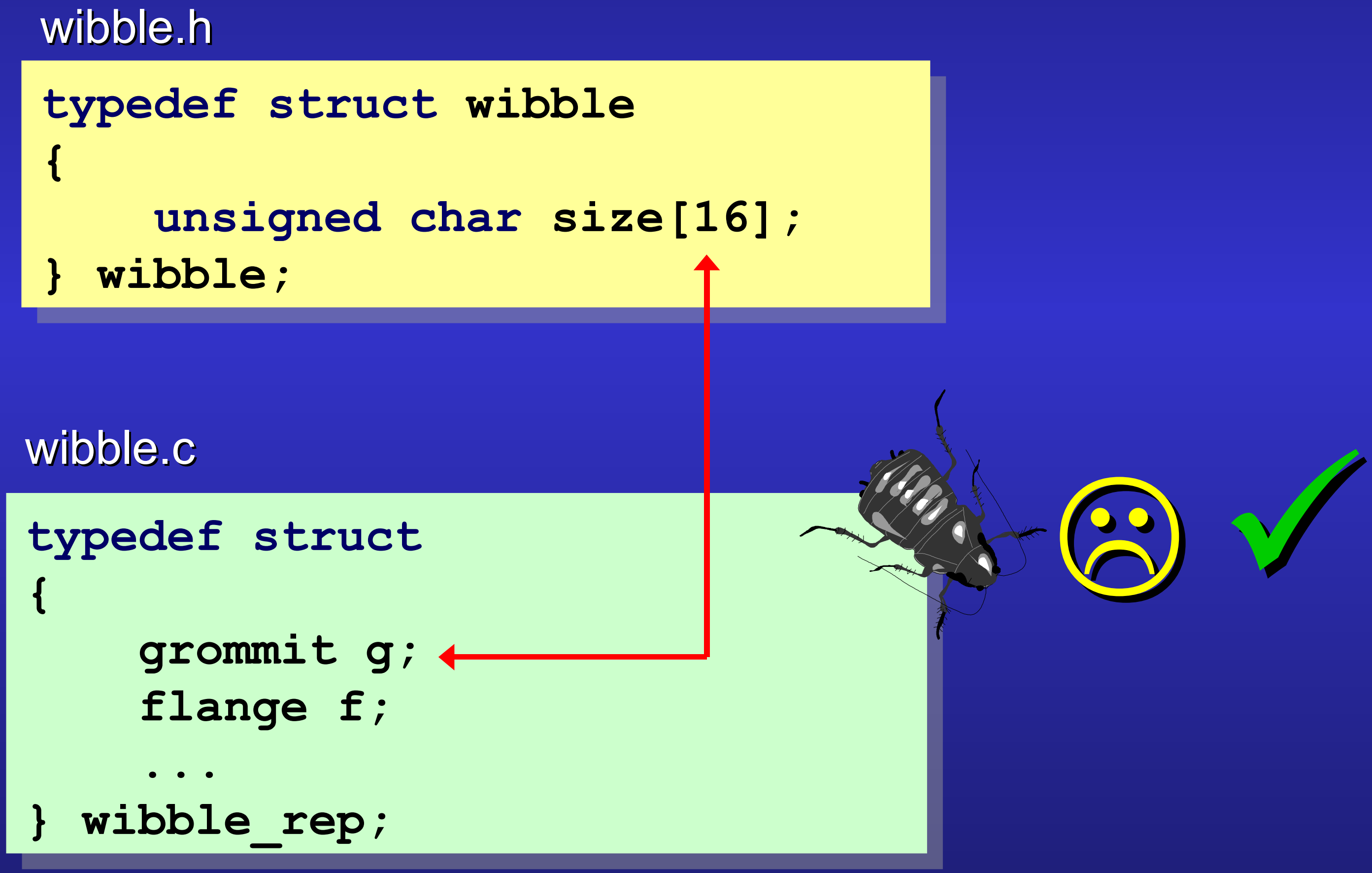
wibble.c

```
#include "wibble.h"
#include "flange.h"
#include "grommet.h"
#include "compile_time_assert.h"

typedef struct
{
    grommet g;
    flange f;
} wibble_rep;

COMPILE_TIME_ASSERT(
    sizeof_wibble_not_less_than_sizeof_wibble_rep,
    sizeof(wibble) >= sizeof(wibble_rep));
...
```

✗ ☺ ✓ ☺

problem 2

- the two types must be alignment compatible
  - this means the first member of both types must be alignment compatible



wibble.h

```
typedef struct wibble
{
    unsigned char size[16];
} wibble;
```

wibble.c

```
typedef struct
{
    grommit g;
    flange f;
    ...
} wibble_rep;
```

☹ ✓

alignment solution

- **use a union to force alignment**

alignment.h

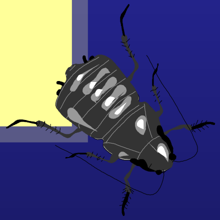
```
typedef union
{
    char c,*cp; int i,*ip; long l,*lp; long long ll,*llp;
    float f,*fp; double d,*dp; long double ld,*ldp;
    void *vp;
    void (*fv)(void); void (*fo)(); void (*fe)(int,...);
} alignment;
```

List all the primitive types in here.
One must have the strictest alignment

wibble.h

```
#include "alignment.h"
...
typedef union wibble
{
    alignment universal;
    unsigned char size[16];
} wibble;
...
```

☺ ✓



problem 3

- unions are much rarer than structs
  - design is as much about *use* as implementation

forward declaration

client.h

```
typedef struct wibble wibble;
...
```

Oooops: it's a union not a struct ☹

- 6.7.2.3 Tags
  Paragraph 1, sentence 2
  Where two declarators that use the same tag declare the same type, they *shall* both use the same choice of struct, union, or enum.

wrapper struct

- put a union object inside a struct!
  - drop the union tag name

wibble.h

```
...
typedef struct wibble
{
    union
    {
        alignment universal;
        unsigned char size[16];
    } shadow;
} wibble;
...
```

☺ ✓

one object

- 6.7.2.3 Tags
  Paragraph 4, sentence 2
  Each declaration of a structure, union, or enumerated type which does not include a tag declares a distinct type

- conversion can be via memcpy
  - helper function allows assignment

☺ ✓

wibble.c

```
static inline wibble shadow(wibble_rep * src)
{
    wibble dst;
    memcpy(&dst, src, sizeof(*src));
    return dst;
}

bool wopen(wibble * w, const char * name)
{
    wibble_rep rep = {
        .g = ...,
        .f = ...,
    };
    *w = shadow(&rep);
    ...;
}
```

conversions 2

- conversion can be via pointer casts
  - helper function allows → operator

☺ ✓

wibble.c

```
static inline wibble_rep * rep(wibble * w)
{
    return (wibble_rep *)w;
}

void wclose(wibble * w);
{
    rep(w)->g = ...;
    rep(w)->f = ...;
    ...
}
```

Contact

- This course was written by

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