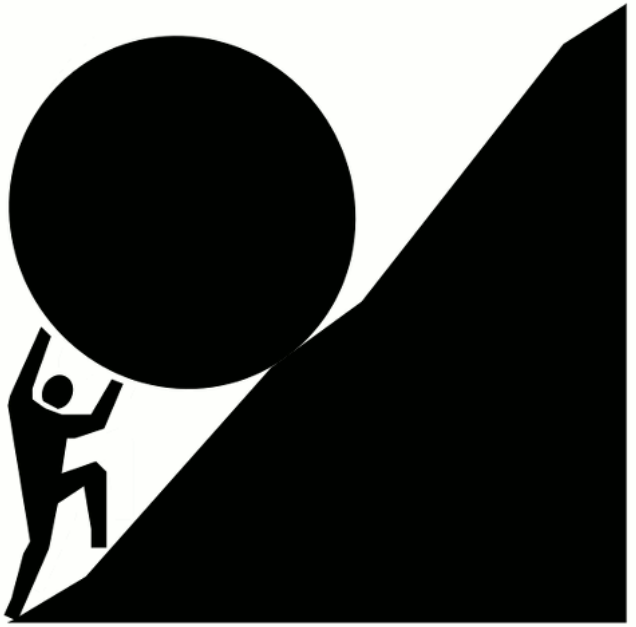
Admin

- Over halfway on our journey!
- Share/celebrate/commiserate



https://thefreethinkingmindblog.files.wordpress.com/2016/10/sisyphusgif.gif

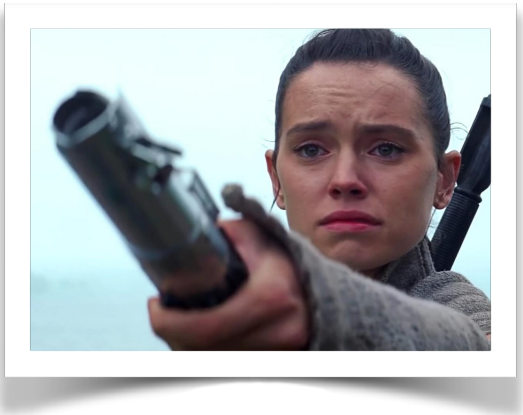
Today: Steps toward C mastery

C Language, advanced edition, loose ends

Hallmarks of good software

Tuning your development process:

Pro-tips and best practices



Typecasts

C type system

Each variable/expression has type

Warns/disallows operations that don't respect type

But... allows typecast to suppress/subvert

What does typecast actually do? Why is it allowed? Is it essential?

Is is sensible/necessary to:

- Cast to different bitwidth within same type family?
- Cast to add/remove qualifier (const, volatile)?
- Cast a pointer to different type of pointee?

Powerful but no safety!

Rule: work within type system, use only when you absolutely must

Pointers, arrays, structures

Will we ever know enough???

Pointers, address arithmetic exposed in C,
but not the only/best way to access memory

Array/structures provide abstraction
Improvement over raw address

Access to related data by index/offset/name
(underlying mechanism is still base address + delta)

A most unfortunate page break

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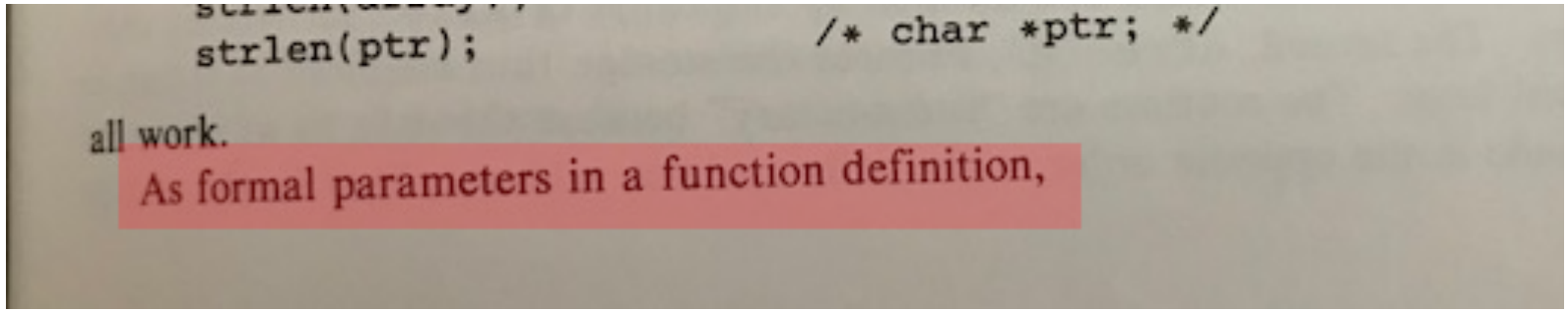

```
    strlen(ptr);                /* char *ptr; */
```

all work.

As formal parameters in a function definition,

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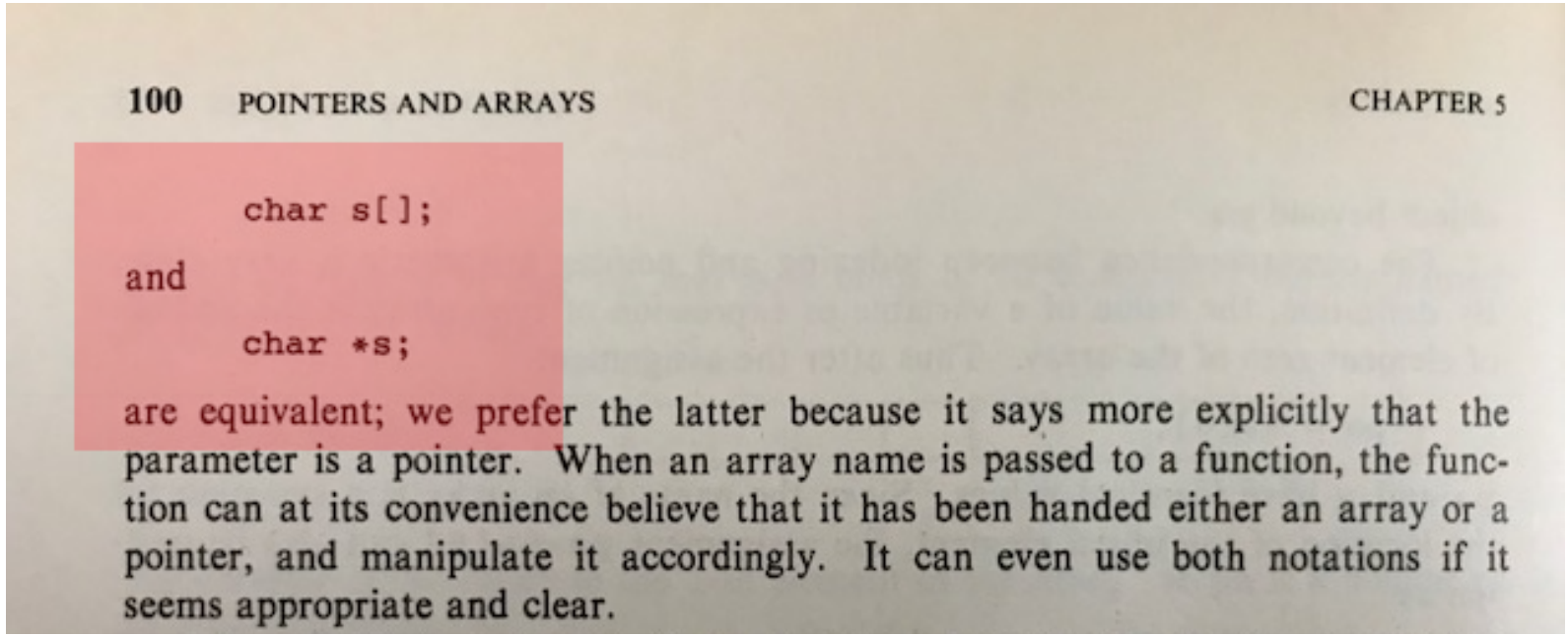



```
    char s[];
```

and

```
    char *s;
```

are equivalent; we prefer the latter because it says more explicitly that the parameter is a pointer. When an array name is passed to a function, the function can at its convenience believe that it has been handed either an array or a pointer, and manipulate it accordingly. It can even use both notations if it seems appropriate and clear.

Pointers and arrays, the same thing?

Arrays and pointers, arrays of pointers, arrays of arrays, ...

```
void strings(void)
{
        // where/how much space is allocated for each? How initialized?
    char a[10];
    char b[] = "dopey";
    const char *c = "happy";
    char *d = malloc(10);
    memcpy(d, "grumpy", 7);

    char *all[] = {a, b, c, d};
    char matrix[2][4];

    // which of these memory locations are valid to write?
    *a = 'A';
    *b = 'B';
    *c = 'C';
    *d = 'D';
    all[1][1] = 'E';
    matrix[1][1] = 'F';

    // What is output if print a, b, c, d, all[1], matrix[1] ?
```

Data alignment

"Natural" or "self" alignment

4-byte store/load at address that is multiple of 4

8-byte at multiple of 8

System optimized for natural alignment

Unaligned access may be allowed (possible performance penalty) or disallowed (exception). Worst option would allow, but behave wrong. Which case do we get on Pi?

Our stack and heap align to 8 (sizeof largest primitive) to avoid alignment woes

Function pointers

One of the more mind-bending features of C

Treat functions as data, execute code at address

Runtime dispatch (instead of compile-time)

Command table, invoke by name (lab5, assign5)

Polymorphism, object = data + operations

```
typedef struct {
   int x, y, w, h;
   void (*draw)(shape_t *s);
} shape_t;
```

```
shape_t s1 = {0, 0, 3, 9, draw_rect};
shape_t s2 = {0, 0, 8, 8, draw_oval};

s1.draw(&s1);
s2.draw(&s2);
```

What you need to write good software

- Productive development process
- Effective testing
- Proficient debugging strategy
- Priority on good design/readability/maintainability

What is different about **systems software**?

Terse and unforgiving, details matter

All depend on it, bugs have consequences

Not enough to know what code does, but also how/why

```
void uart_init() {
    unsigned int ra;

    // Configure the UART
    PUT32(AUX_ENABLES, 1);
    PUT32(AUX_MU_IER_REG, 0);
    PUT32(AUX_MU_CNTL_REG, 0);
    PUT32(AUX_MU_LCR_REG, 3);
    PUT32(AUX_MU_MCR_REG, 0);
    PUT32(AUX_MU_IER_REG, 0);
    PUT32(AUX_MU_IIR_REG, 0xC6);
    PUT32(AUX_MU_BAUD_REG, 270);
    ra = GET32(GPFSEL1);
    ra &= ~(7 << 12);
    ra |= 2 << 12;
    ra &= ~(7 << 15);
    ra |= 2 << 15;
    PUT32(GPFSEL1,ra);
    PUT32(GPPUD,0);
    for (ra = 0; ra < 150; ra++) dummy(ra);
    PUT32(GPPUDCLK0, (1 << 14) | (1 << 15));
    for (ra = 0; ra < 150; ra++) dummy(ra);
    PUT32(GPPUDCLK0, 0);
    PUT32(AUX_MU_CNTL_REG, 3);
}
```

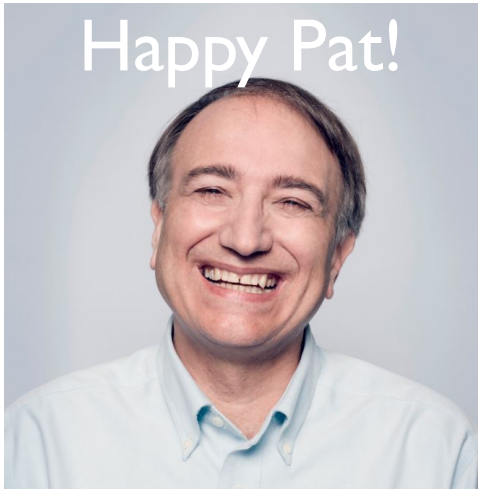
Sad Pat

```
void uart_init(void)
{
    gpio_set_function(GPIO_TX, GPIO_FUNC_ALT5);
    gpio_set_function(GPIO_RX, GPIO_FUNC_ALT5);

    int *aux = (int*)AUX_ENABLES;
    *aux |= AUX_ENABLE;

    uart->ier  = 0;
    uart->cntl = 0;
    uart->lcr  = MINI_UART_LCR_8BIT;
    uart->mcr  = 0;
    uart->iir  = MINI_UART_IIR_RX_FIFO_CLEAR |
                 MINI_UART_IIR_RX_FIFO_ENABLE |
                 MINI_UART_IIR_TX_FIFO_CLEAR |
                 MINI_UART_IIR_TX_FIFO_ENABLE;

    // baud rate ((250,000,000/115200)/8)-1 = 270
    uart->baud = 270;
    uart->cntl = MINI_UART_CNTL_TX_ENABLE |
                 MINI_UART_CNTL_RX_ENABLE;
 }
```



A tale of two bootloaders

https://github.com/dwelch67/raspberrypi/blob/master/bootloader03/bootloader03.c

https://github.com/cs107e/cs107e.github.io/blob/master/labs/lab4/code/bootloader/bootloader.c

Thank you, David Welch, we owe you!

If I have seen further than others, it is by standing upon the shoulders of giants.
— Isaac Newton

If I have not seen as far as others, it is because there were giants standing on my shoulders.
— Hal Abelson

The value of code reading

Consider:

Is is clear what the code intends to do?

Are you confident of the author's understanding?

Would you want to maintain this code?

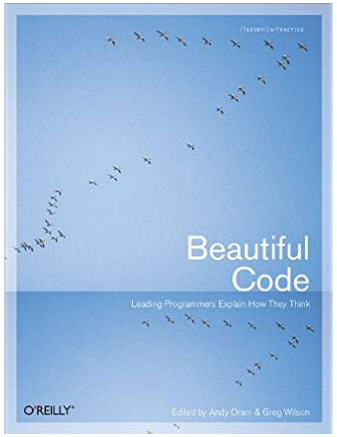
Open source era is fantastic!

https://github.com/dwelch67/raspberrypi

https://musl.libc.org

https://git.busybox.net/busybox/

https://sourceware.org/git/?p=glibc.git



***Section lead CS106**: will read a lot of code and learn much!*

What makes for good style?

- Adopts the conventions of the existing code base
- Common, idiomatic choices where possible
- Logical decomposition, easy to follow control flow
- Re-factored for code unification/re-use
- Easy to understand and **maintain**

Consider: If someone else had to fix a bug in my code, what could I do to make their job easier?

> "There are two ways of constructing a software design. One way is to make it so simple that there are obviously no deficiencies. And the other way is to make it so complicated that there are no obvious deficiencies."- C.A.R. Hoare

Development process

— Write the high-quality version first (and only!)

— Decompose problems, not programs

— Implement from bottom up, each step should be testable

— Unifying common code means less code to write, test, debug, and maintain!

— Don't depend on comments to make up for lack of readability in the code itself

— One-step build

Tests are your friend!

Think of the tests as a specification of what your code should do. Assertions will clarify your understanding how it should work.

Implement the simplest possible thing first, then test it. A simple thing is more much likely to work than a complex thing. Go forward in epsilon-steps.

Never delete a test. Keep re-running all of them at each step. You may break something that used to work and you want to hear about it.

Debugging for the win

Rule #1: be systematic

Focus on what is testable/observable.

Hunches can be good, but if fact and hunch collide, fact wins.

Everything is happening for a reason, even if it doesn't seem so at first.

Engineering best practices

Test, test, test, and test some more

Start from a known working state, take small steps

Make things visible (printf, logic analyzer, gdb)

Methodical, systematic. Form hypotheses and perform experiments to confirm.

Fast prototyping, embrace automation, one-click build, source control, clean compile

Don't let bugs get you down, natural part of the work, relish the challenge -- you will learn something new!

Wellness important! ergonomics, healthy sleep/fuel, maintain perspective

Share your stories and pro-tips

Design, write, test, debug, …

Which parts of your approach/process are working well for you?

Which parts are not?