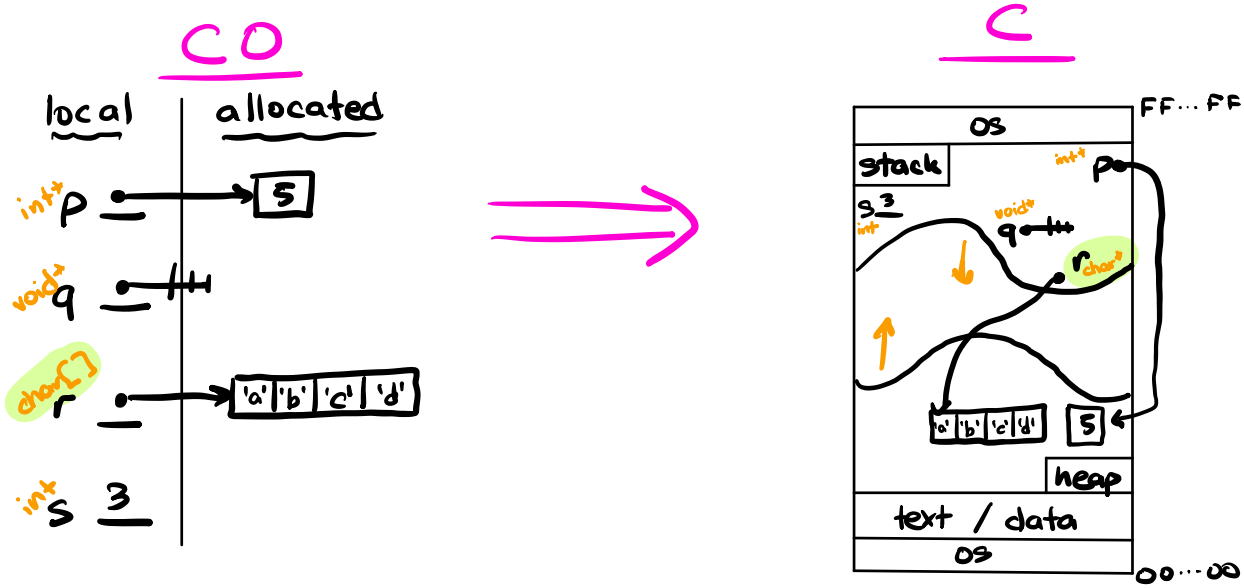
C Memory Model



allocating memory

allocating a pointer ...

... in CO: `type* p = alloc(type);` (initializes to default value)

... in C: `type* p = malloc( );` (not initialized!)

or `type* p = calloc( );` (initialized to 0)

allocating an array ...

... in CO: `type[] a = alloc_array(type, n);` (initialized)

... in C: `type* a = malloc( );` (not initialized!)

or `type* a = calloc( );` (initialized)

keep in mind:

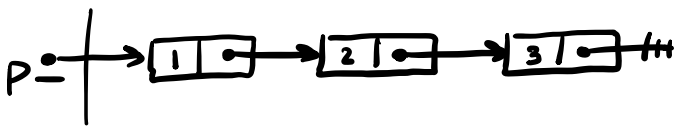
- sizeof(type) gives the number of bytes needed to store type
- malloc/calloc can return NULL; use xmalloc/xcalloc or do NULL checks
- malloc is faster than calloc since it doesn't initialize the bytes
- values in a malloced block are undefined; overwrite it before use
- freeing!

freeing memory

if you allocate it, you free it (mostly*)

- no garbage collection in C!
- don't double free the same memory location
- good practice to not free NULL
- if there is some kind of nested structure, free the inside first!

ex)



what happens when we call free(p)?

- use data structure free functions if available

now why the (mostly*) up there?

- sometimes, we handoff ownership of memory to the client (like in task 5 of COVM!)
- or we may want to keep using the memory

Stack stuffs

structs

- can have structs on the stack in C
  - heap: `struct smth* s = malloc(sizeof(struct smth));`
  - stack: `struct smth s;` (not initialized!) → same as `(*s).x`
  - on heap, access fields with `->` (like `s->x`)
  - on stack, access fields with `.` (like `s.x`)

arrays

- can have stack arrays in C
  - stack: `int a[4] = {1,2,3,4}`
    - or `int a[] = {1,2,3,4,5}` (length is inferred)
    - `int a[6];` (not initialized!)

strings ...

String stuffs

strings are just null-terminated char arrays!

stack

```
char str[] = "honk";   (auto null-terminated)
```
or
```
char str[] = {'c', 'h', 'o', 'n', 'k', '\0'}   (not auto null-term)
```

heap

```
char* str = xcalloc(sizeof(char), n);
    ... char assignments ...
```

ex) what is the max length string we can safely put in str?

data

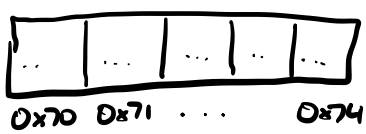
```
char* str = "122";   (auto null-term)
```
↑ this is read-only!

Casting + pointer arithmetic

tip: casting to char* is good for stepping through bytes

- different from integer casting:
  does not actually change any data ever!
- just looks at memory differently

ex) `char *A = 0x70;`
how many bytes does *A read?



(short)A ? *(int*)A ? *(void*)A?

- type also affects pointer arithmetic

ex) `char* A = 0x70;`
what is A+1? A-3? A+2? (int*)A)+2? ((long*)A)+2?

- A[i] = *(A+i)

address-of

- for any variable x, &x is the memory address x is located at
  even for pointers! this is the location of the pointer, NOT the location it points to!!
- if x has type t, &x has type t*
- useful to allow functions to change stack/local memory

ex)
```
void fun(int *x) {
    *x = 122;
}
...
int x = 150;
fun(&x);
```

what is the value of x after this?

be careful of scope!!

do NOT do this:

```
int *terrible() {
    int horrible = 92;
    return &horrible;
}
```

horrible goes out of scope at the end of the function, so the return value is basically useless