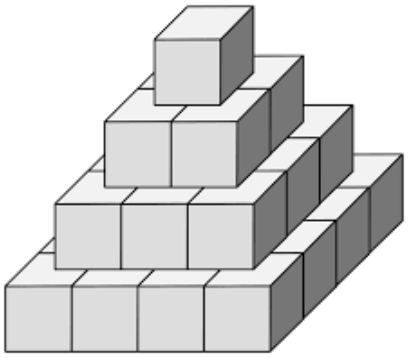
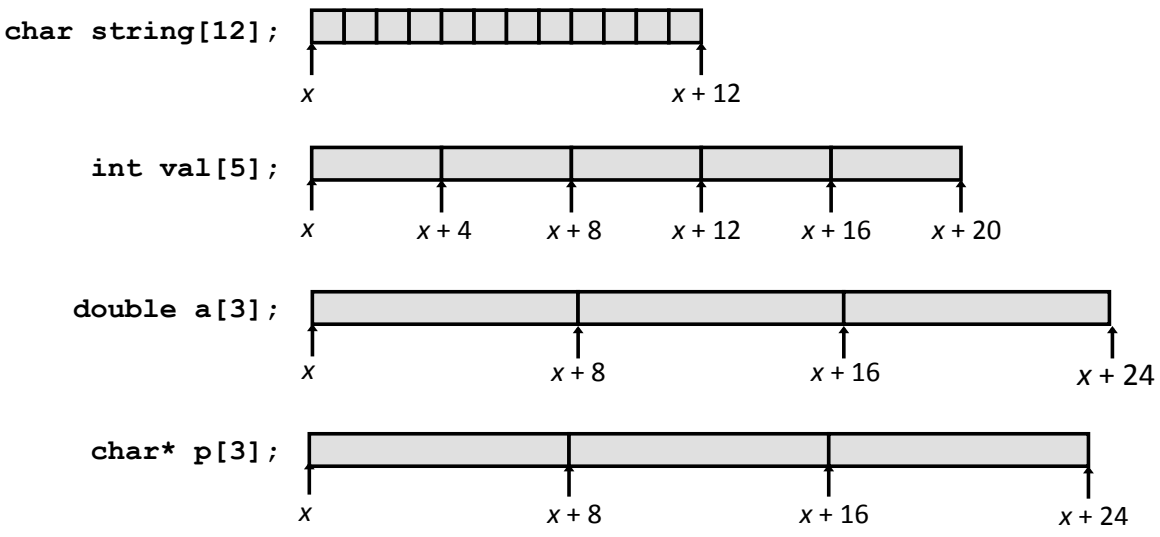
Machine Code: Structures



Arrays



Array Access

```
int get_val(int a[], int i) {
  return a[i];
}
```

```
  # %rdi = a
  # %rsi = i
movl (%rdi,%rsi,4), %eax  # a[i]
```

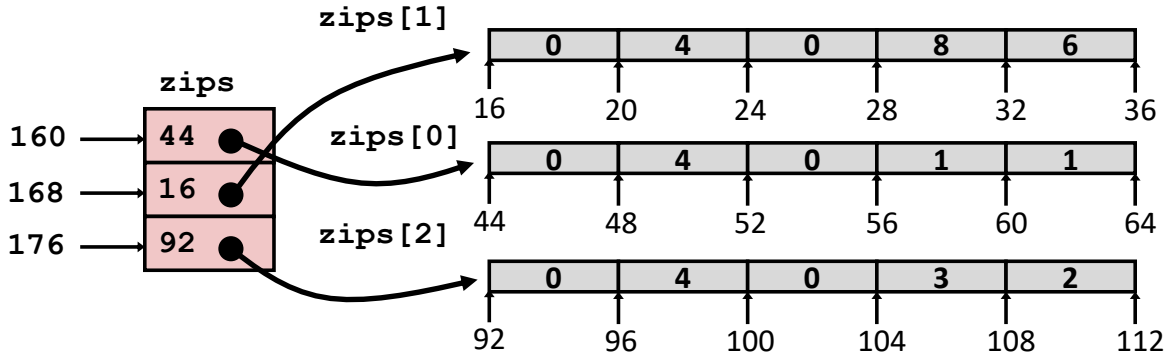

Array Loop

```
void inc5(int a[]) {
  int i;
  for (i = 0; i < 5; i++) {
    a[i]++;
  }
}
```

```
  # %rdi = a
  movl    $0, %eax          #   i = 0
  jmp     .L3               #   goto middle
.L4:                        # loop:
  addl    $1, (%rdi,%rax,4) #   a[i]++
  addq    $1, %rax          #   i++
.L3:                        # middle:
  cmpq    $4, %rax          #   i:4
  jbe     .L4               #   if <=, goto loop
  ret
```

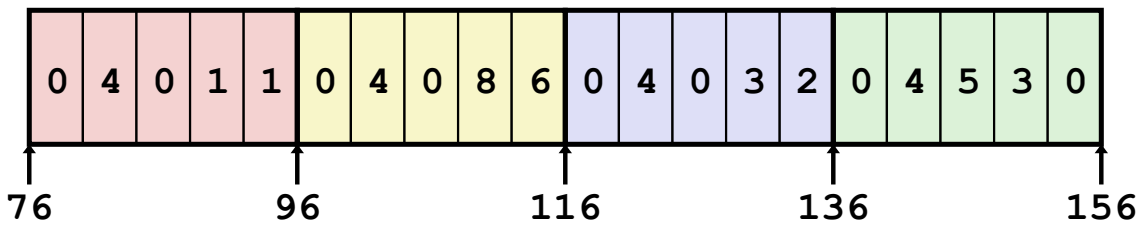
Multi-Level Array

```
int* zips[3];  // stored at address 160
zips[0] = (int*) malloc(sizeof(int) * 5);
zips[0][1] = 4;
...
```



Nested Array

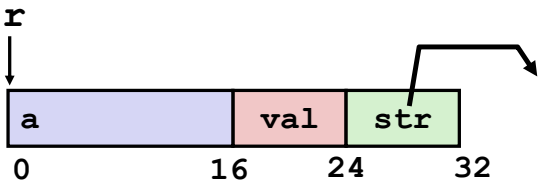
```
int zips[4][5];  // stored at address 76
zips[0][1] = 4;
...
```



Structs

New 32-byte type!

```
struct thing {
    int a[4];
    long val;
    char* str;
};
```

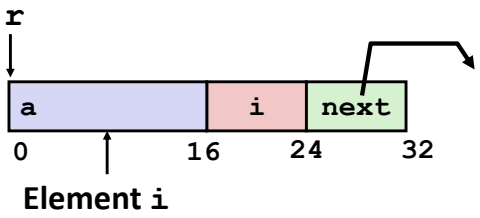



```
struct thing x; // 32 bytes
struct thing y; // 32 bytes

x.val = 5;
x.a[1] = 2;
x.str = "hello";

y = x; // copy full struct
```

```
struct thing* p; // 8 bytes
p = malloc(sizeof(struct thing));

// form 1
(*p).val = 7; // NOT p.val = 7

// form 2 (preferred)
p->val = 7; // same as form 1

struct thing* p2;
p2 = p; // just a pointer copy
```


Linked List Example

```
struct list_el {
    int a[4];
    long i;
    struct list_el* next;
};
```




```
void set_val
   (struct list_el* n, int val) {
  while (n) {
    long i = n->i;
    n->a[i] = val;
    n = n->next;
  }
}
```

Register	Value
%rdi	n
%rsi	val

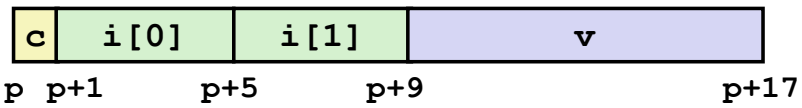
```
.L1:                                # loop:
  movq    16(%rdi), %rax            #   i = M[n+16]
  movl    %esi, (%rdi,%rax,4)       #   M[n+4*i] = val
  movq    24(%rdi), %rdi            #   n = M[n+24]
  testq   %rdi, %rdi                #   Test n
  jne     .L1                       #   if !=0 goto loop
```

Struct Naming: typedef

```
// give type T another name: U
typedef T U;


// idiomatic struct usage:
// defines a type "struct thing" with alias "thing"
// T is "struct thing { ... }", U is "thing"
typedef struct thing {
  ...
} thing;


thing x; // now can omit "struct" from type name
x.i = 5;


thing* p = malloc(sizeof(thing)); // easier!
p->i = 3;
```


Data Alignment

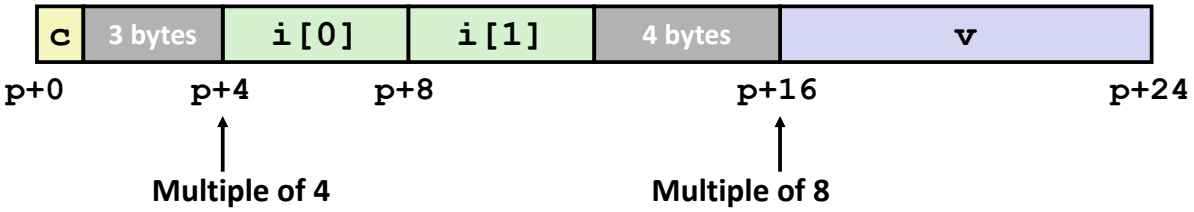
Unaligned Data




```
struct S {
  char c;
  int i[2];
  double v;
};
```

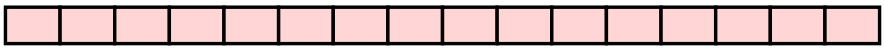
Alignment Rule: address of each field must be a multiple of the field size

Aligned Data

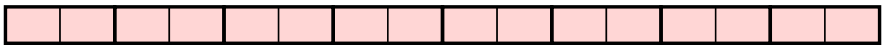


Floating Point: YMM/XMM Registers

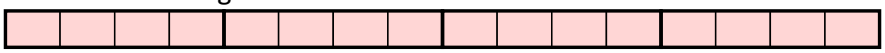
- 16 single-byte integers



- 8 16-bit integers



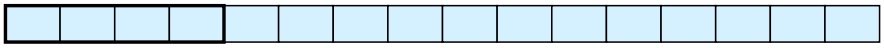
- 4 32-bit integers



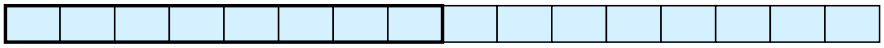
- 4 single-precision floats

- 2 double-precision floats

- 1 single-precision float



- 1 double-precision float



Different FP instruction sets! (SSE, AVX, …) `vcvttsd2siq`