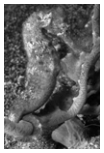
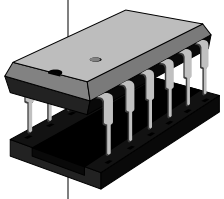
CS-034
Continuing with C

Thomas Doeppner
Pascal Van Hentenryck

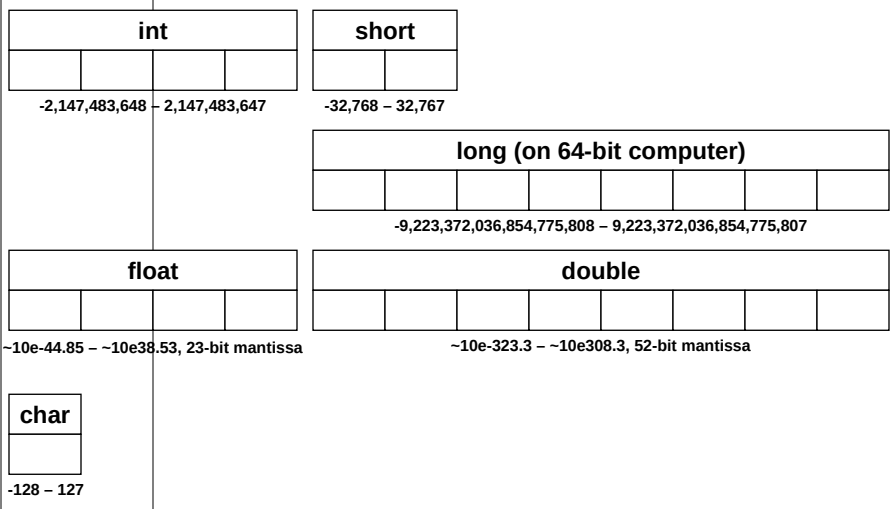


Memory



0
1
2
. . .
1,073,741,823

Basic Data Types



Characters

- **ASCII**
  - **American Standard Code for Information Interchange**
  - **works for:**
    - **English**
    - **Swahili**
    - **not much else**
  - **doesn't work for:**
    - **French**
    - **Dutch**
    - **Spanish**
    - **German**
    - **Arabic**
    - **Sanskrit**
    - **Chinese**
    - **pretty much everyone else**


Who cares!!
2/9/2005
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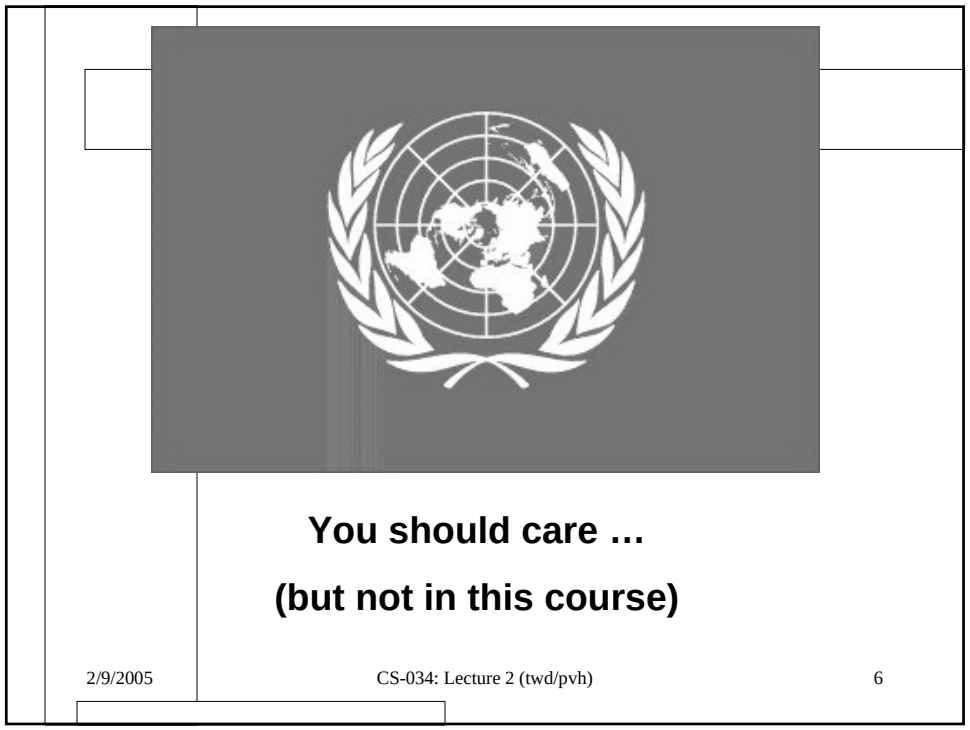
You should care …
(but not in this course)
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ASCII Character Set

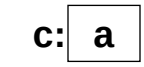
```
    00 10 20 30 40 50 60 70 80 90 100 110 120
   ----------------------------------------
 0: \0 \n       (  2  <  F  P  Z  d   n   x
 1:    \v       )  3  =  G  Q  [  e   o   y
 2:    \f    sp *  4  >  H  R  \  f   p   z
 3:    \r    !  +  5  ?  I  S  ]  g   q   {
 4:          "  ,  6  @  J  T  ^  h   r   |
 5:          #  -  7  A  K  U  _  i   s   }
 6:          $  .  8  B  L  V  `  j   t   ~
 7: \a       %  /  9  C  M  W  a  k   u  DEL
 8: \b       &  0  :  D  N  X  b  l   v
 9: \t       '  1  ;  E  O  Y  c  m   w
```


*char*s as Integers

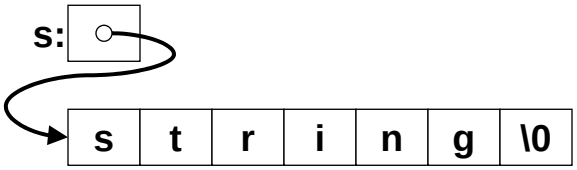
```
char tolower(char c) {
  if (c >= 'A' && c <= 'Z')
     return c + 'a' – 'A';
  else
     return c;
}
```

Character Strings

```
char c = 'a';
```




```
char *s = "string";
```



Quiz (1)

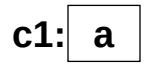
Is there any difference between *c1* and *c2* in the following?

```
char c1 = 'a';
char *c2 = "a";
```

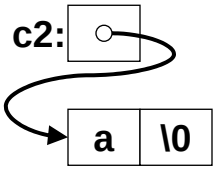
Answer (1)

Yes!!

```
char c1 = 'a';
```




```
char *c2 = "a";
```

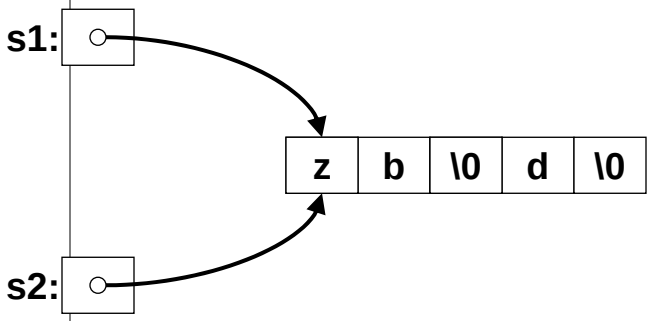


Quiz (2)

What do *s1* and *s2* refer to after the following is executed?

```
char *s1 = "abcd";
char *s2 = s1;
s1[0] = 'z';
s1[2] = '\0';
```

Answer (2)



Structures

```
struct ComplexNumber {
    float real;
    float imag;
};

struct complex x;
x.real = 1.4;
x.imag = 3.65e-10;
```

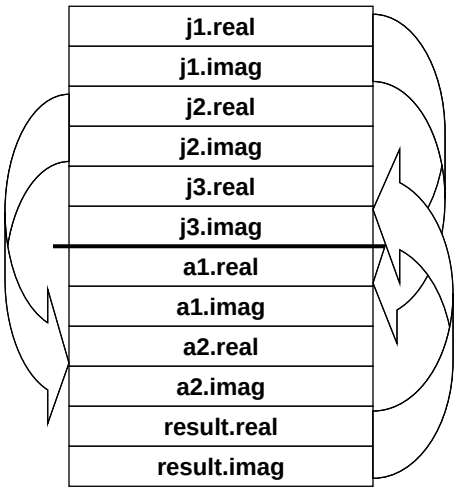
*struct*s and Functions

```
struct ComplexNumber ComplexAdd(
        struct ComplexNumber a1,
        struct ComplexNumber a2) {
    struct ComplexNumber result;
    result.real = a1.real + a2.real;
    result.imag = a1.imag + a2.imag;
    return result;
}
```


*struct*s as Arguments

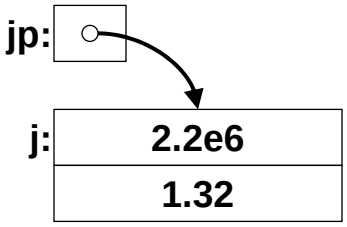
```
struct ComplexNumber j1 = {3.6, 2.125};
struct ComplexNumber j2 = {4.32, 3.1416};
struct ComplexNumber j3;

j3 = ComplexAdd(j1, j2);
```

The Stack …



Pointers to *structs*

```
struct ComplexNumber j;
struct ComplexNumber *jp = &j;
jp->real = 2.2e6;
jp->imag = 1.32;
```



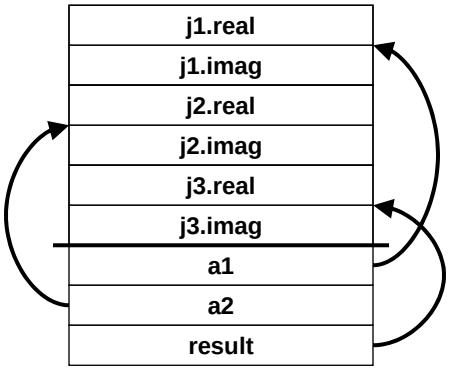
Passing *struct*s More Cheaply …

```
void ComplexAdd(
    struct ComplexNumber *a1,
    struct ComplexNumber *a2,
    struct ComplexNumber *result) {
  result->real = a1->real + a2->real;
  result->imag = a1->imag + a2->imag;
  return;
}
```


Using It …

```
struct ComplexNumber j1 = {3.6, 2.125};
struct ComplexNumber j2 = {4.32, 3.1416};
struct ComplexNumber j3;

ComplexAdd(&j1, &j2, &j3);
```

The Stack …



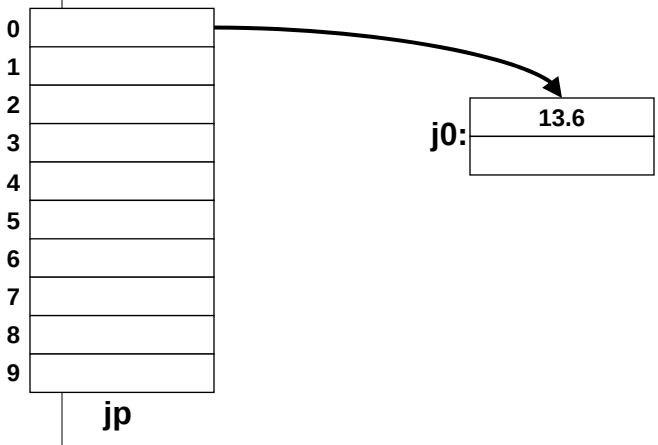
Arrays of *structs*

```
struct ComplexNumber j[10];
j[0].real = 8.127649;
j[0].imag = 1.76e18;
```

Arrays, Pointers, and *structs*

```
/* What's this? */
struct ComplexNumber *jp[10];


struct ComplexNumber j0;
jp[0] = &j0;
jp[0]->real = 13.6;
```


Memory View



What's Your Sign?

- **Default: signed integers**
- **Unsigned integers: no negatives**
  - **`unsigned int`**
    - **0 – 2^{32}-1 (4,294,967,295)**
  - **`unsigned short`**
    - **0 – 2^{16}-1 (65,535)**
  - **`unsigned char`**
    - **0 – 2^{8}-1 (255)**

Why Care?

- **You need twice as many positive values**
- **Negative values don't make sense**
  - **a negative size?!**
- **It's not really supposed to be a number**
  - **a bit string**

Numeric Conversions

```
short a;
int b;
float c;
b = a; /* always works */
a = b; /* sometimes works */
c = b; /* sort of works */
b = c; /* sometimes works */
```


Explicit Conversions: Casts (1)

```
float x, y=2.0;
int i=1, j=2;

x = i/j + y;
  /* what's the value of x? */
```

Explicit Conversions: Casts (2)

```
float x, y=2.0;
int i=1, j=2;
float a, b;

a = i;
b = j;
x = a/b + y;
  /* now what's the value of x? */
```


Explicit Conversions: Casts (3)

```
float x, y=2.0;
int i=1, j=2;

x = (float)i/(float)j + y;
  /* and now what's the value of x? */
```

Bitwise Operations

```
int x;
int y;
x = y & 0xff000;
  /* extract the middle bits */
x = x | 0731;
  /* turn on certain bits */
x = x ^ y;
  /* compute the bitwise exclusive or */
```


More Bitwise Operations

```
int x;
int y;

x = x << 3;
  /* left shift 3 bits (multiply by 8?) */
y = x >> 4;
  /* right shift 4 bits (divide by 16) */
x = ~017;
  /* x is set to the one's complement of
     octal 17 (0xfffffff0) */
```

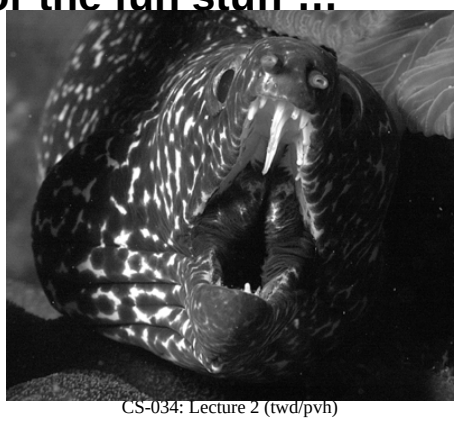
Bit Strings

- **Use bits to represent status**

```
char device = 0;
const char PowerOn = 0x1;
const char Ready = 0x2;
const char Go = 0x4;
const char Line1 = 0x8;
const char Line2 = 0x10;
const char Line3 = 0x20;
const char Line4 = 0x40;
const char Line5 = 0x80;
device = PowerOn|Ready;
device = device | Go | Line5;
```


Transition

- **Things have been straightforward**
- **Now for the fun stuff ...**



Fun with Functions (1)

```
void ArrayDouble(int A[], int len) {
  int i;
  for (i=0; i<len; i++)
     A[i] = 2*A[i];
}
```


Fun with Functions (2)

```
void ArrayBop(int A[],
     unsigned int len,
     int (*func)(int)) {
  int i;
  for (i=0; i<len; i++)
     A[i] = (*func)(A[i]);
}
```

Fun with Functions (3)

```
int triple(int arg) {
  return 3*arg;
}

int main() {
  int A[20];
  … /* initialize A */
  ArrayBop(A, 20, triple);
  return 0;
}
```


Swap, Revisited

```
void swap (int *i, int *j) {
  int *tmp;
  tmp = j; j = i; i = tmp;
}
/* can we make this generic? */
```

Casts, Revisited

- **Two purposes**
  - **coercion**

```
int i, j;
float a;
a = (float i)/(float j);
```

  - **intimidation**

```
float x, y;
swap((int *)&x, (int *)&y);
```


Nothing, and More …

- ***void* means, literally, nothing:**

```
void NotMuch(void) {
  printf("I do nothing\n");
}
```

- **What does *void* * mean?**
  - **it's a pointer to anything you feel like**
    - **a generic pointer**

Rules

- **Use with other pointers**

```
int *x;
void *y;
x = y; /* legal */
y = x; /* legal */
```

- **Dereferencing**

```
void *z;
*z /* illegal!*/
```


An Application: Generic Swap

```
void gswap (void *p1, void *p2,
     unsigned int size) {
  int i;
  for (i=0; i <= size; i++) {
     char tmp;
     tmp = ((char *)p1)[i];
     ((char *)p1)[i] = ((char *)p2)[i];
     ((char *)p2)[i] = tmp;
  }
}
```

Using Generic Swap

```
short a, b;
gswap(&a, &b, sizeof(short));

int x, y;
gswap(&x, &y, 4);

int A[] = {1, 2, 3}, B[] = {7, 8, 9};
gswap(A, B, sizeof(A));
```


sizeof

```
int main( ) {
  int A[] = {1, 2, 3};
  char s1[] = "hello";
  char *s2 = "goodbye";

  printf(%d, %d, %d\n",
         sizeof(A),
         sizeof(s1),
         sizeof(s2));
}
```

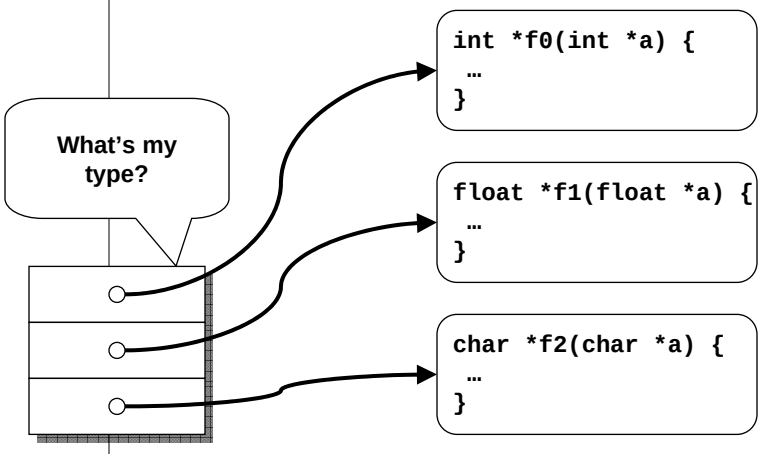
```
% gcc sizeof.c –o sizeof
% ./sizeof
12, 6, 4
```

More …

```
int main( ) {
  void func(int arg[]); /* declared before
                           defined */
  int A[10];
  func(A);
  return 0;
}

void func(int arg[]) {
  printf("%d\n", sizeof(arg));
}
```

```
% gcc sizeof2.c –o sizeof2
% ./sizeof2
4
```


For Our Next Trick …



Working Our Way There …

- **An array of 3 ints**
  - **int A[3];**
- **An array of 3 int *s**
  - **int *A[3];**
- **A func returning an int *, taking an int ***
  - **int *f(int *);**
- **A pointer to such a func**
  - **int *(*f)(int *);**

There …

- **An array of func pointers**
  - **int *(*f[3])(int *);**
- **An array of generic func pointers**
  - **void (*f[3])(void *);**

Using It

```
int *f0(int *a) { … }
float *f1(float *a) { … }
char *f2(char *a) { … }
int main() {
  int x = 1;
  int *p;
  void *(*f[3])(void *);
  f[0] = (void *(*)(void *))f0;
  f[1] = (void *(*)(void *))f1;
  f[2] = (void *(*)(void *))f2;
  p = f[0](&x);
}
```


Casts, Yet Again

- **They tell the C compiler: "shutup, I know what I'm doing"**
- **Sometimes true**

```
f[0] = (void *(*)(void *))f0;
```

- **Sometimes false**

```
int f = 7;
(void(*)(int))f(2);
```

Laziness …

- **Why type the declaration**

```
void *(*f)(void*, void *);
```

- **You could, instead, type**

```
MyType f;
```

- **(If, of course, you can somehow define *MyType* to mean the right thing)**

typedef

- **Allows one to create new names for existing types**

```
typedef int *IntP;

int *x;
```

– **means the same as**

```
IntP x;
```

More typedefs

```
typedef struct {
  float real;
  float imag;
} complex_t;

complex_t I, *IP;
```


And …

```
typedef void *(*MyFunc)(void *, void *);

MyFunc f;

/* you must do its definition the long
   way */

void *f(void *a1, void *a2) {
  …
}
```

And Finally …

- **What's a possible use of …**

```
void **
```

?