&*%&@#*!

```
int f (void) {
  int s = 1;
  int t = 1;
  int *ps = &s;
  int **pps = &ps;
  int *pt = &t;
  **pps = 2;
  pt = ps;
  *pt = 3;
  t = s;
}
```

s == 1, t == 1

s == 2, t == 1

s == 3, t == 1

s == 3, t == 3

Rvalues and Lvalues

What does **=** really mean?

```
int f (void) {
  int s = 1;
  int t = 1;
  t = s;
  t = 2;
}
```

left side of = is an “lvalue”
  it evaluates to a location (address)!
right side of = is an “rvalue”
  it evaluates to a value

There is an implicit * when a variable is used as an rvalue!

Parameter Passing in C

- Actual parameters are rvalues

```
void swap (int a, int b) {
   int tmp = b; b = a; a = tmp;
}

int main (void) {
   int i = 3;
   int j = 4;
   swap (i, j);
   ...
}
```

The value of i (3) is passed, not its location!
swap does nothing

Parameter Passing in C

```
void swap (int *a, int *b) {
   int tmp = *b; *b = *a; *a = tmp;
}

int main (void) {
   int i = 3;
   int j = 4;
   swap (&i, &j);
   ...
}
```

The value of &i is passed, which is the address of i

Is it possible to define swap in Python?

Beware!

```
int *value (void)
{
  int i = 3;
  return &i;
}

void callme (void)
{
  int x = 35;
}

int main (void) {
  int *ip;
  ip = value ();
  printf ("*ip == %d\n", *ip);
  callme ();
  printf ("*ip == %d\n", *ip);
}
```

*ip == 3

*ip == 35

But it could really be anything!

Manipulating Addresses

```
char s[6];
s[0] = 'h';
s[1] = 'e';
s[2]= 'l';
s[3] = 'l';
s[4] = 'o';
s[5] = '\0';
printf ("s: %s\n", s);
```

s: hello

expr1[expr2] in C is just syntactic sugar for *(expr1 + expr2)

Obfuscating C

```
char s[6];
*s = ‘h’;
*(s + 1) = ‘e’;
2[s] = ‘l’;
3[s] = ‘l’;
*(s + 4) = ‘o’;
5[s] = ‘\0’;
printf (“s: %s\n”, s);
```

s: hello

Fun with Pointer Arithmetic

```
int match (char *s, char *t) {
  int count = 0;
  while (*s == *t) { count++; s++; t++; }
  return count;
}

int main (void)
{
  char s1[6] = "hello";
  char s2[6] = "hohoh";

  printf ("match: %d\n", match (s1, s2));
  printf ("match: %d\n", match (s2, s2 + 2));
  printf ("match: %d\n", match (&s2[1], &s2[3]));
}
```

The **\0** is invisible!

&s2[1]
➔&(*(s2 + 1))
➔ s2 + 1

match: 1
match: 3
match: 2

Condensing match

```
int match (char *s, char *t) {
  int count = 0;
  while (*s == *t) { count++; s++; t++; }
  return count;
}
```

```
int match (char *s, char *t) {
  char *os = s;
  while (*s++ == *t++);
  return s – os - 1;
}
```

s++ evaluates to s_{pre}, but changes the value of s
Hence, C++ has the same value as C, but has unpleasant side effects.

Quiz

- What does `s = s++;` do?

  It is undefined!

  If your C programming contains it, a correct interpretation of your program could make $s = s_{pre} + 1$, $s = 37$, or blow up the computer.

Type Checking in C

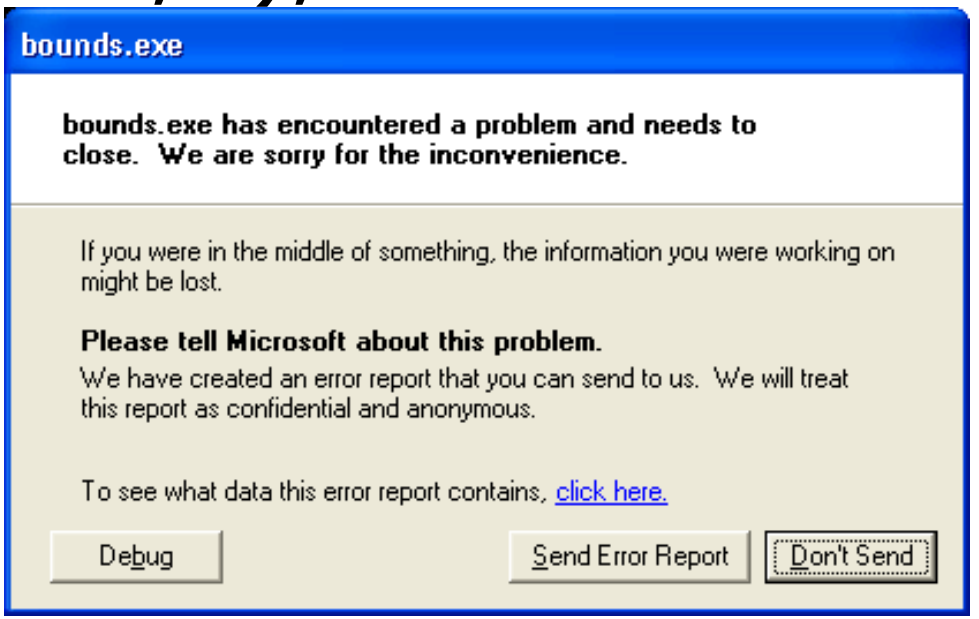
- Java: only allow programs the compiler can prove are type safe

  Exception: **run-time** type errors for downcasts and array element stores.

- C: trust the programmer. If she really wants to compare apples and oranges, let her.
- Python: don't trust the programmer or compiler – check everything at runtime.

Type Checking

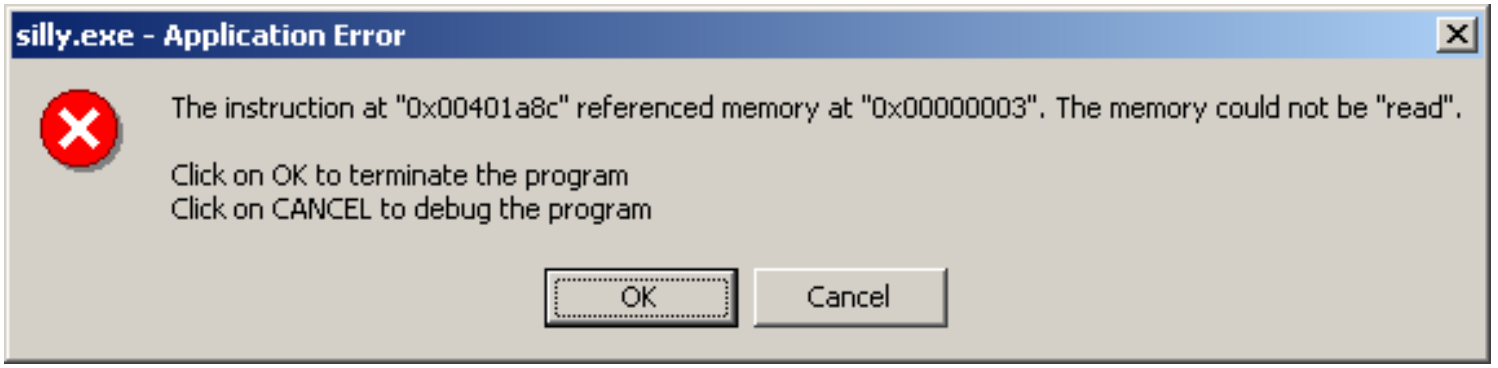
```
int main (void) {
  char *s = (char *) 3;
  printf ("s: %s", s);
}
```



Windows XP (SP 2)

Type Checking

```
int main (void) {
  char *s = (char *) 3;
  printf ("s: %s", s);
}
```



Windows 2000

(earlier versions of Windows would just crash the whole machine)

Exercise

- Study Section 6.3 from the textbook

Skip

- Study section 6.5 from the textbook
- We studied section 6.6 Strings under one dimensional char arrays in ch 5

6.7 Dynamic Memory Allocation

- Dynamically allocated memory is determined at *runtime*
- A program may create as many or as few variables as required, offering greater flexibility
- Dynamic allocation is often used to support data structures such as stacks, queues, linked lists and binary trees.
- Dynamic memory is finite
- Dynamically allocated memory may be freed during execution

Dynamic Memory Allocation

- Memory is allocated using the:
  - malloc function (memory allocation)
  - calloc function (cleared memory allocation)
- Memory is released using the:
  - free function
- The size of memory requested by malloc or calloc can be changed using the:
  - realloc function

malloc and calloc

- Both functions return a pointer to the newly allocated memory
- If memory can not be allocated, the value returned will be a **NULL** value
- The pointer returned by these functions is declared to be a **void pointer**
- A cast operator should be used with the returned pointer value to coerce it to the proper pointer type

Example of malloc and calloc

```
int n = 6, m = 4;
double *x;
int *p;
```

x

```
/*  Allocate memory for 6 doubles.  */
x = (double *)malloc(n*sizeof(double));
```

p

```
/*  Allocate memory for 4 integers.  */
p = (int *)calloc(m,sizeof(int));
```