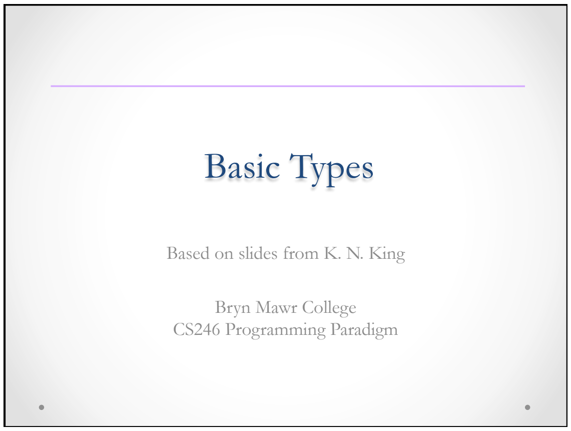
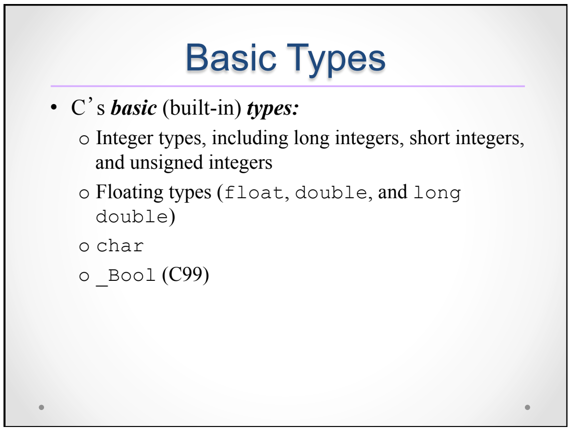


# Basic Types

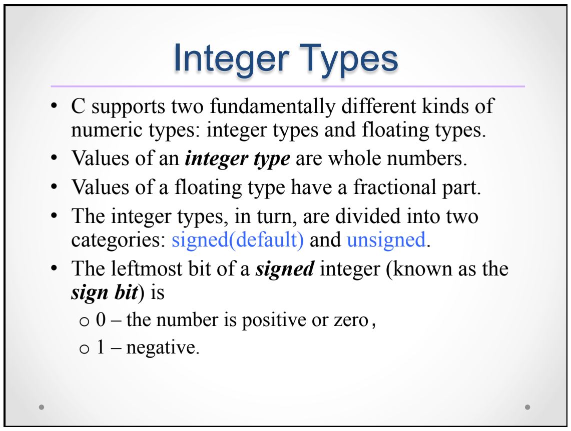
Based on slides from K. N. King

Bryn Mawr College
CS246 Programming Paradigm



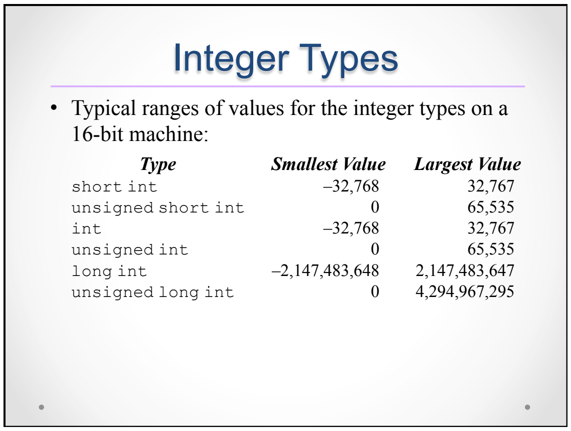
## Basic Types

- C’s ***basic*** (built-in) ***types:***
  - Integer types, including long integers, short integers, and unsigned integers
  - Floating types (`float`, `double`, and `long double`)
  - `char`
  - `_Bool` (C99)



## Integer Types

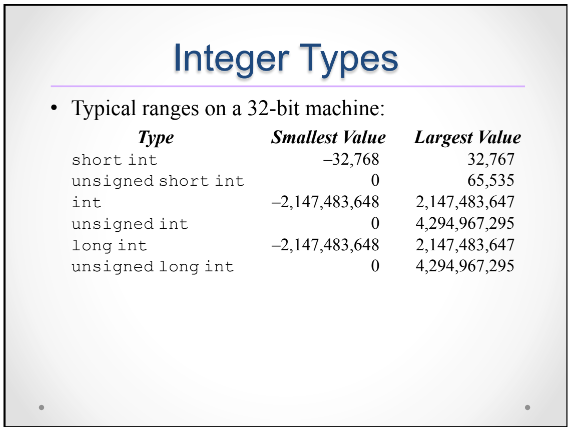
- C supports two fundamentally different kinds of numeric types: integer types and floating types.
- Values of an ***integer type*** are whole numbers.
- Values of a floating type have a fractional part.
- The integer types, in turn, are divided into two categories: signed(default) and unsigned.
- The leftmost bit of a ***signed*** integer (known as the ***sign bit***) is
  - 0 – the number is positive or zero,
  - 1 – negative.



## Integer Types

- Typical ranges of values for the integer types on a 16-bit machine:

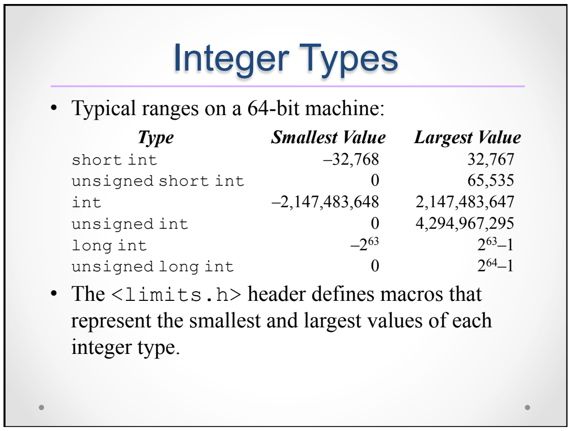
| *Type* | *Smallest Value* | *Largest Value* |
|---|---:|---:|
| `short int` | –32,768 | 32,767 |
| `unsigned short int` | 0 | 65,535 |
| `int` | –32,768 | 32,767 |
| `unsigned int` | 0 | 65,535 |
| `long int` | –2,147,483,648 | 2,147,483,647 |
| `unsigned long int` | 0 | 4,294,967,295 |



## Integer Types

- Typical ranges on a 32-bit machine:

| *Type* | *Smallest Value* | *Largest Value* |
|---|---:|---:|
| `short int` | –32,768 | 32,767 |
| `unsigned short int` | 0 | 65,535 |
| `int` | –2,147,483,648 | 2,147,483,647 |
| `unsigned int` | 0 | 4,294,967,295 |
| `long int` | –2,147,483,648 | 2,147,483,647 |
| `unsigned long int` | 0 | 4,294,967,295 |



## Integer Types

- Typical ranges on a 64-bit machine:

| *Type* | *Smallest Value* | *Largest Value* |
|---|---:|---:|
| `short int` | –32,768 | 32,767 |
| `unsigned short int` | 0 | 65,535 |
| `int` | –2,147,483,648 | 2,147,483,647 |
| `unsigned int` | 0 | 4,294,967,295 |
| `long int` | $-2^{63}$ | $2^{63}-1$ |
| `unsigned long int` | 0 | $2^{64}-1$ |

- The `<limits.h>` header defines macros that represent the smallest and largest values of each integer type.

# Integers Constants

- ***Constants*** are numbers that appear in the text of a program.
- C allows integer constants to be written in decimal (base 10), octal (base 8), or hexadecimal (base 16).

# Octal and Hexadecimal Numbers

- Octal numbers use only the digits 0 through 7.
- Each position in an octal number represents a power of 8.
  - The octal number 237 represents the decimal number $2 \times 8^2 + 3 \times 8^1 + 7 \times 8^0 = 128 + 24 + 7 = 159$.
- A hexadecimal (or hex) number is written using the digits 0 through 9 plus the letters A through F, which stand for 10 through 15, respectively.
  - The hex number 1AF has the decimal value $1 \times 16^2 + 10 \times 16^1 + 15 \times 16^0 = 256 + 160 + 15 = 431$.

# Integer Constants

- ***Decimal*** constants contain digits between 0 and 9, but must not begin with a zero:

  `15   255   32767`
- ***Octal*** constants contain only digits between 0 and 7, and must begin with a zero:

  `017   0377   077777`
- ***Hexadecimal*** constants contain digits between 0 and 9 and letters between `a` and `f`, and always begin with `0x`:

  `0xf   0xff   0x7fff`
- The letters in a hexadecimal constant may be either upper or lower case:

  `0xff   0xfF   0xFf   0xFF   0Xff   0XfF   0XFf   0XFF`

# Integer Constants

- To force the compiler to treat a constant as a long integer, just follow it with the letter `L` (or `l`):

  `15L   0377L   0x7fffL`
- To indicate that a constant is unsigned, put the letter `U` (or `u`) after it:

  `15U   0377U   0x7fffU`
- `L` and `U` may be used in combination:

  `0xffffffffUL`

  The order of the `L` and `U` doesn't matter, nor does their case.

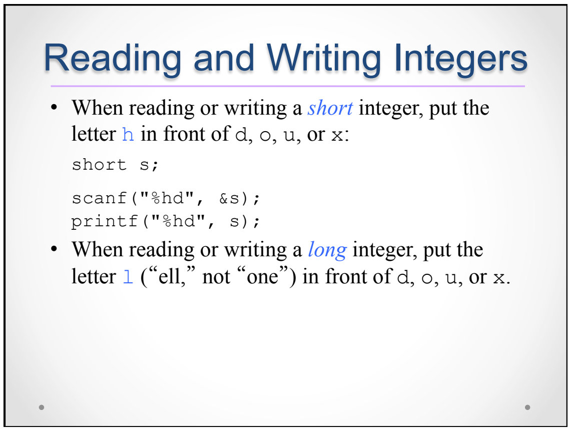
# Integer Overflow

- When arithmetic operations are performed on integers, it's possible that the result will be too large to represent.
- If the result can't be represented as an `int` (because it requires too many bits), we say that ***overflow*** has occurred.
  - When overflow occurs during an operation on *signed* integers, the program's behavior is undefined.
  - When overflow occurs during an operation on *unsigned* integers, the result *is* defined: we get the correct answer modulo $2^n$, where $n$ is the number of bits used to store the result.

# Reading and Writing Integers

- When reading or writing an *unsigned* integer, use the letter `u`, `o`, or `x` instead of `d` in the conversion specification.

```
unsigned int u;

scanf("%u", &u);  /* reads  u in base 10 */
printf("%u", u);  /* writes u in base 10 */
scanf("%o", &u);  /* reads  u in base  8 */
printf("%o", u);  /* writes u in base  8 */
scanf("%x", &u);  /* reads  u in base 16 */
printf("%x", u);  /* writes u in base 16 */
```

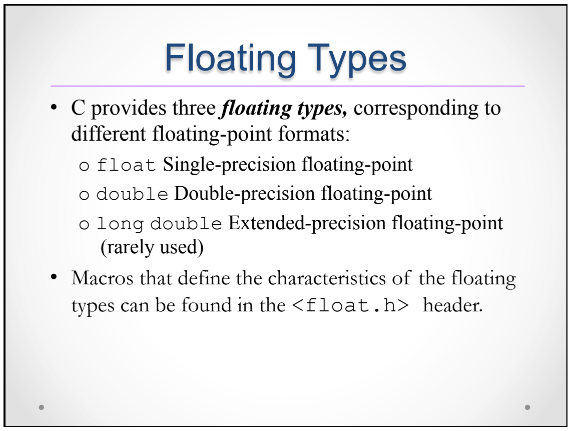


## Reading and Writing Integers

- When reading or writing a *short* integer, put the letter `h` in front of `d`, `o`, `u`, or `x`:

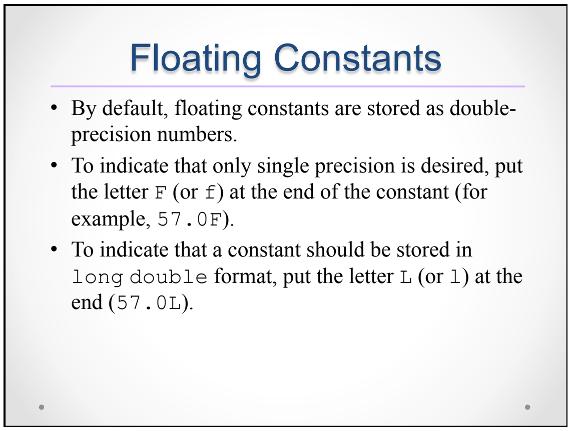
```
short s;

scanf("%hd", &s);
printf("%hd", s);
```

- When reading or writing a *long* integer, put the letter `l` (“ell,” not “one”) in front of `d`, `o`, `u`, or `x`.



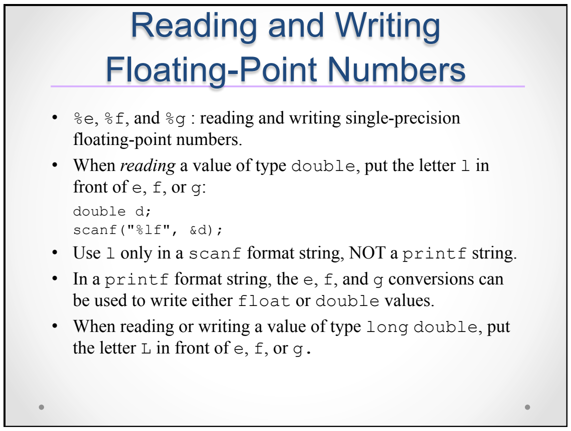
## Floating Types

- C provides three ***floating types,*** corresponding to different floating-point formats:
  - o `float` Single-precision floating-point
  - o `double` Double-precision floating-point
  - o `long double` Extended-precision floating-point (rarely used)
- Macros that define the characteristics of the floating types can be found in the `<float.h>` header.



## Floating Constants

- By default, floating constants are stored as double-precision numbers.
- To indicate that only single precision is desired, put the letter `F` (or `f`) at the end of the constant (for example, `57.0F`).
- To indicate that a constant should be stored in `long double` format, put the letter `L` (or `l`) at the end (`57.0L`).

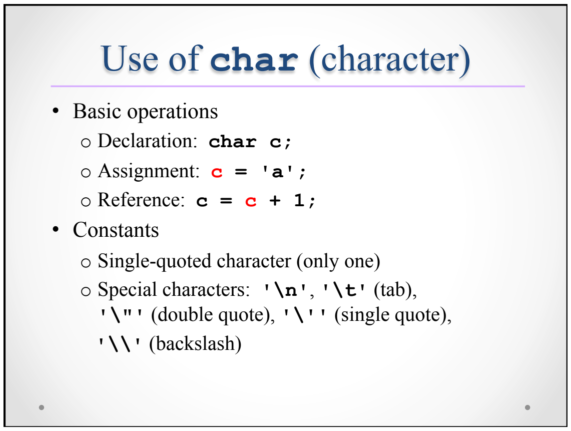


## Reading and Writing Floating-Point Numbers

- `%e`, `%f`, and `%g` : reading and writing single-precision floating-point numbers.
- When *reading* a value of type `double`, put the letter `l` in front of `e`, `f`, or `g`:

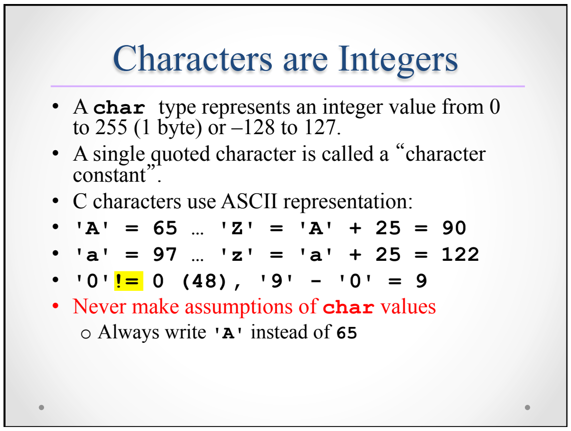
```
double d;
scanf("%lf", &d);
```

- Use `l` only in a `scanf` format string, NOT a `printf` string.
- In a `printf` format string, the `e`, `f`, and `g` conversions can be used to write either `float` or `double` values.
- When reading or writing a value of type `long double`, put the letter `L` in front of `e`, `f`, or `g.`



## Use of **`char`** (character)

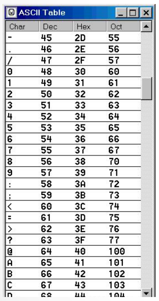
- Basic operations
  - o Declaration: **`char c;`**
  - o Assignment: **`c = 'a';`**
  - o Reference: **`c = c + 1;`**
- Constants
  - o Single-quoted character (only one)
  - o Special characters: **`'\n'`**, **`'\t'`** (tab), **`'\"'`** (double quote), **`'\''`** (single quote), **`'\\'`** (backslash)



## Characters are Integers

- A **`char`** type represents an integer value from 0 to 255 (1 byte) or –128 to 127.
- A single quoted character is called a “character constant”.
- C characters use ASCII representation:
- **`'A' = 65 … 'Z' = 'A' + 25 = 90`**
- **`'a' = 97 … 'z' = 'a' + 25 = 122`**
- **`'0' != 0 (48), '9' - '0' = 9`**
- Never make assumptions of **`char`** values
  - o Always write **`'A'`** instead of **`65`**

# ASCII Table



| Char | Dec | Hex | Oct |
|---|---|---|---|
| - | 45 | 2D | 55 |
| . | 46 | 2E | 56 |
| / | 47 | 2F | 57 |
| 0 | 48 | 30 | 60 |
| 1 | 49 | 31 | 61 |
| 2 | 50 | 32 | 62 |
| 3 | 51 | 33 | 63 |
| 4 | 52 | 34 | 64 |
| 5 | 53 | 35 | 65 |
| 6 | 54 | 36 | 66 |
| 7 | 55 | 37 | 67 |
| 8 | 56 | 38 | 70 |
| 9 | 57 | 39 | 71 |
| : | 58 | 3A | 72 |
| ; | 59 | 3B | 73 |
| < | 60 | 3C | 74 |
| = | 61 | 3D | 75 |
| > | 62 | 3E | 76 |
| ? | 63 | 3F | 77 |
| @ | 64 | 40 | 100 |
| A | 65 | 41 | 101 |
| B | 66 | 42 | 102 |
| C | 67 | 43 | 103 |
| D | 68 | 44 | 104 |

American Standard Code for Information Interchange

A standard way of representing the alphabet, numbers, and symbols (in computers)

wikipedia on ASCII

# Escape Sequences

- A character constant is usually one character enclosed in single quotes.
- ***Escape sequences*** provide a way to represent special characters that are invisible (nonprinting) or can't be entered from the keyboard.
- There are two kinds of escape sequences: ***character escapes*** and ***numeric escapes.***

# Character Escapes

- A complete list of character escapes:

| *Name* | *Escape Sequence* |
|---|---|
| Alert (bell) | `\a` |
| Backspace | `\b` |
| Form feed | `\f` |
| New line | `\n` |
| Carriage return | `\r` |
| Horizontal tab | `\t` |
| Vertical tab | `\v` |
| Backslash | `\\` |
| Question mark | `\?` |
| Single quote | `\'` |
| Double quote | `\"` |

# Numeric Escapes

- Character escapes
  - don't exist for all nonprinting ASCII characters.
  - useless for representing characters beyond the basic 128 ASCII characters.
- Numeric escapes can represent any character.
- A numeric escape for a particular character uses the character's octal or hexadecimal value.
- For example, the ASCII escape character (decimal value: 27) has the value 33 in octal and 1B in hex.

# Escape Sequences

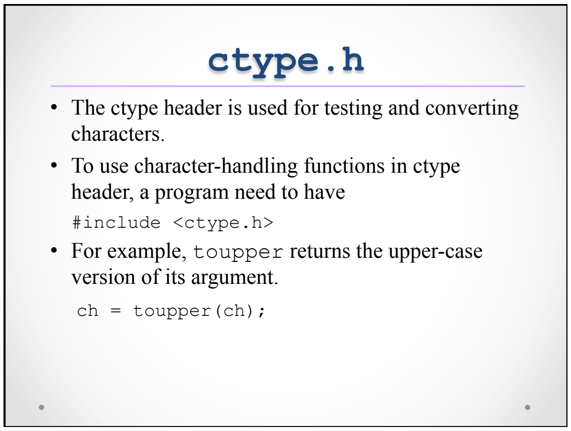
- An ***octal escape sequence*** consists of the `\` character followed by an octal number with at most three digits, such as `\33` or `\033`.
- A ***hexadecimal escape sequence*** consists of `\x` followed by a hexadecimal number, such as `\x1b` or `\x1B`.
- The `x` must be in lower case, but the hex digits can be upper or lower case.

# Escape Sequences

- When used as a character constant, an escape sequence must be enclosed in single quotes.
  - E.g., `'\33'` (or `'\x1b'`) for decimal value 27.
- It's often a good idea to use `#define` to give them names:

```
#define ESC '\33'
```

- Escape sequences can also be embedded in strings.



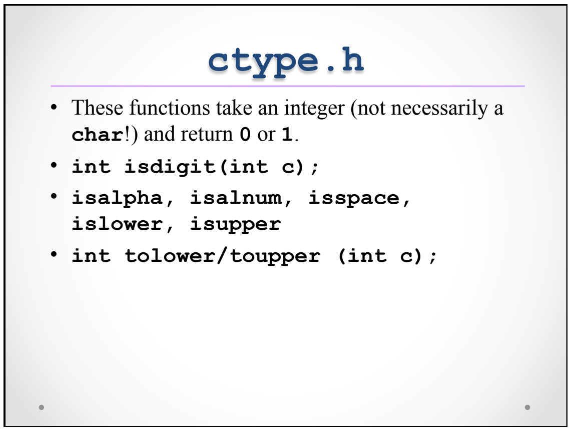
## ctype.h

- The ctype header is used for testing and converting characters.
- To use character-handling functions in ctype header, a program need to have

```
#include <ctype.h>
```

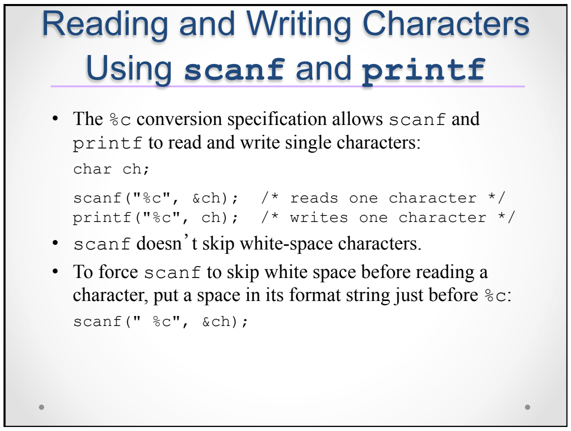
- For example, `toupper` returns the upper-case version of its argument.

```
ch = toupper(ch);
```



## ctype.h

- These functions take an integer (not necessarily a **`char`**!) and return **`0`** or **`1`**.
- **`int isdigit(int c);`**
- **`isalpha, isalnum, isspace, islower, isupper`**
- **`int tolower/toupper (int c);`**



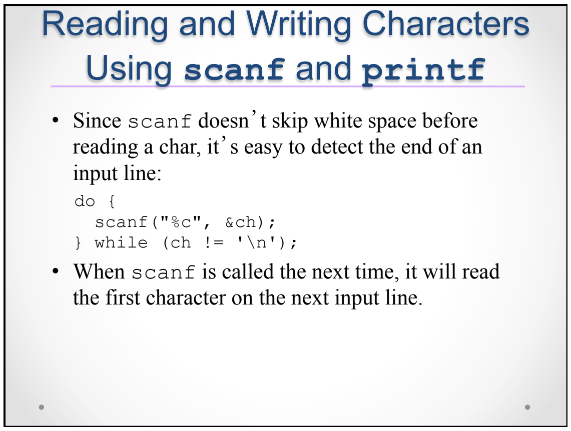
## Reading and Writing Characters Using **`scanf`** and **`printf`**

- The `%c` conversion specification allows `scanf` and `printf` to read and write single characters:

```
char ch;
scanf("%c", &ch);  /* reads one character */
printf("%c", ch);  /* writes one character */
```

- `scanf` doesn't skip white-space characters.
- To force `scanf` to skip white space before reading a character, put a space in its format string just before `%c`:

```
scanf(" %c", &ch);
```

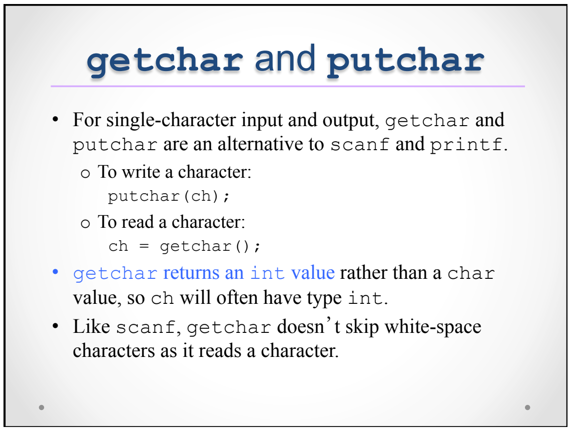


## Reading and Writing Characters Using **`scanf`** and **`printf`**

- Since `scanf` doesn't skip white space before reading a char, it's easy to detect the end of an input line:

```
do {
  scanf("%c", &ch);
} while (ch != '\n');
```

- When `scanf` is called the next time, it will read the first character on the next input line.



## **`getchar`** and **`putchar`**

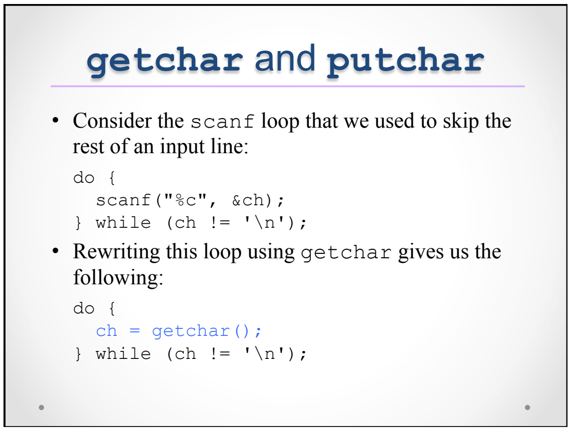
- For single-character input and output, `getchar` and `putchar` are an alternative to `scanf` and `printf`.
  - To write a character:

    ```
    putchar(ch);
    ```

  - To read a character:

    ```
    ch = getchar();
    ```

- `getchar` returns an `int` value rather than a `char` value, so `ch` will often have type `int`.
- Like `scanf`, `getchar` doesn't skip white-space characters as it reads a character.



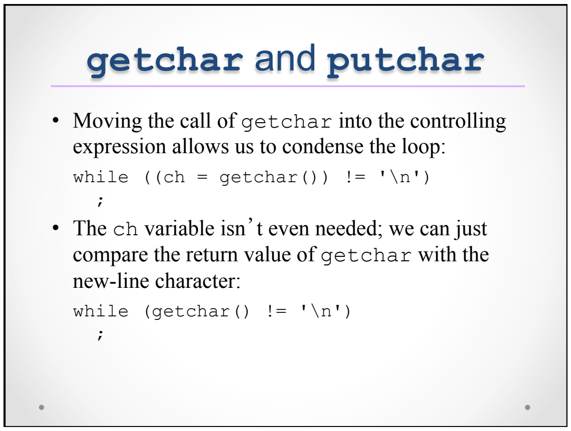
## **`getchar`** and **`putchar`**

- Consider the `scanf` loop that we used to skip the rest of an input line:

```
do {
  scanf("%c", &ch);
} while (ch != '\n');
```

- Rewriting this loop using `getchar` gives us the following:

```
do {
  ch = getchar();
} while (ch != '\n');
```



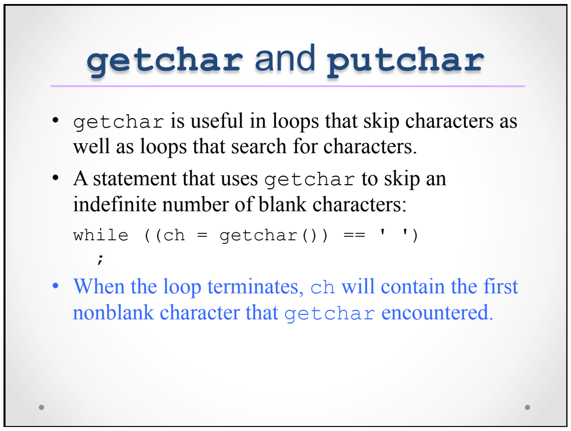
## getchar and putchar

- Moving the call of getchar into the controlling expression allows us to condense the loop:

```
while ((ch = getchar()) != '\n')
  ;
```

- The ch variable isn’t even needed; we can just compare the return value of getchar with the new-line character:

```
while (getchar() != '\n')
  ;
```

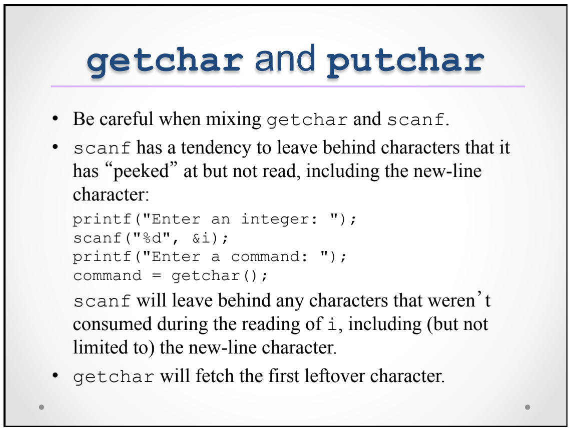


## getchar and putchar

- getchar is useful in loops that skip characters as well as loops that search for characters.
- A statement that uses getchar to skip an indefinite number of blank characters:

```
while ((ch = getchar()) == ' ')
  ;
```

- When the loop terminates, ch will contain the first nonblank character that getchar encountered.

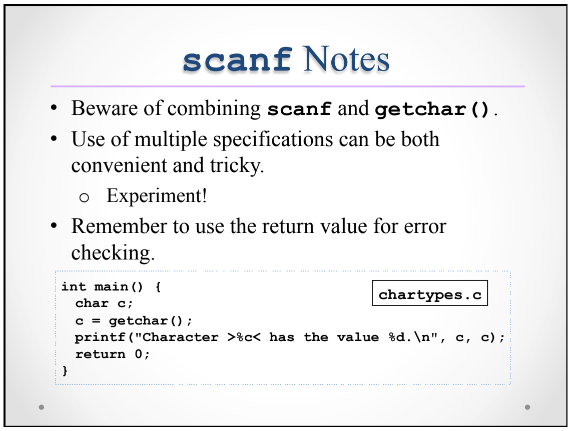


## getchar and putchar

- Be careful when mixing getchar and scanf.
- scanf has a tendency to leave behind characters that it has “peeked” at but not read, including the new-line character:

```
printf("Enter an integer: ");
scanf("%d", &i);
printf("Enter a command: ");
command = getchar();
```

  scanf will leave behind any characters that weren’t consumed during the reading of i, including (but not limited to) the new-line character.
- getchar will fetch the first leftover character.

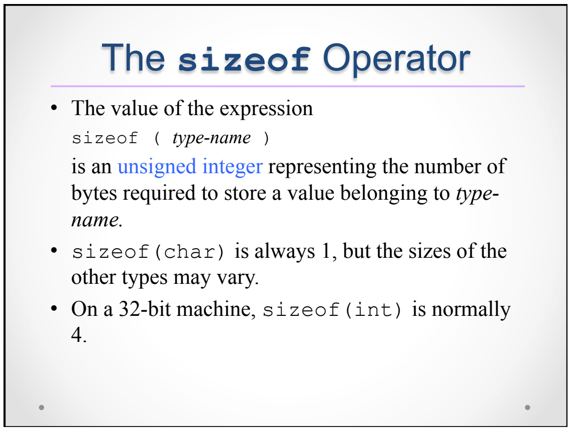


## scanf Notes

- Beware of combining **scanf** and **getchar()**.
- Use of multiple specifications can be both convenient and tricky.
  - o Experiment!
- Remember to use the return value for error checking.

chartypes.c

```
int main() {
  char c;
  c = getchar();
  printf("Character >%c< has the value %d.\n", c, c);
  return 0;
}
```

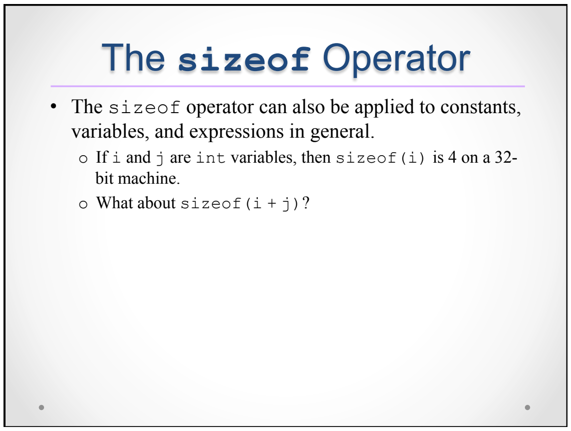


## The sizeof Operator

- The value of the expression

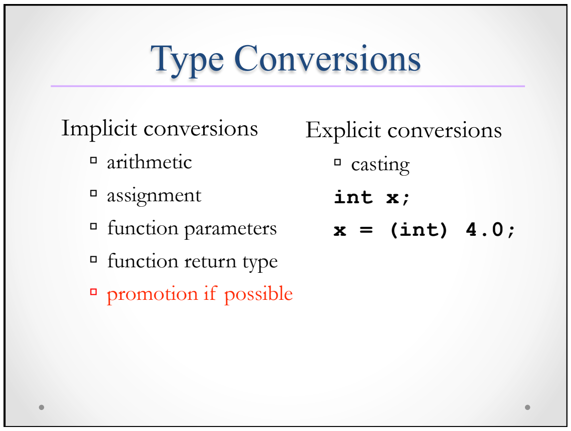
  sizeof ( *type-name* )

  is an unsigned integer representing the number of bytes required to store a value belonging to *type-name.*
- sizeof(char) is always 1, but the sizes of the other types may vary.
- On a 32-bit machine, sizeof(int) is normally 4.



## The sizeof Operator

- The sizeof operator can also be applied to constants, variables, and expressions in general.
  - o If i and j are int variables, then sizeof(i) is 4 on a 32-bit machine.
  - o What about sizeof(i + j)?



# Type Conversions

Implicit conversions

- arithmetic
- assignment
- function parameters
- function return type
- promotion if possible

Explicit conversions

- casting

```
int x;
x = (int) 4.0;
```