C Data Types

Data Types, Variables, Declaring and Initializing Variables

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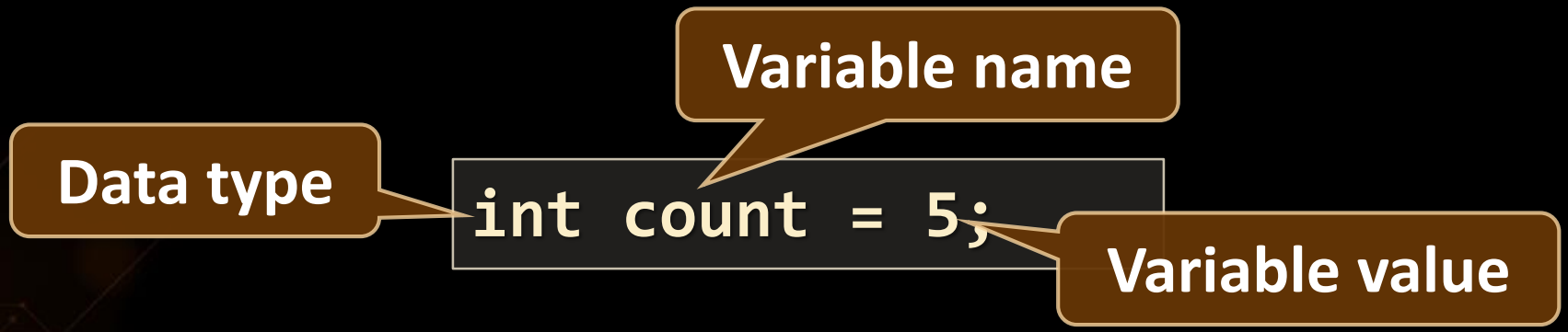
Table of Contents

How Computing Works?

- Computers are machines that process data
  - Data is stored in the computer memory in variables
  - Variables have name, data type and value
- Example of variable definition and assignment in C



- When processed, data is stored back into variables

What Is a Data Type?

- A data type:
  - Is a domain of values of similar characteristics
  - Defines the type of information stored in the computer memory (in a variable)
- Examples:
  - Positive integers: `1`, `2`, `3`, …
  - Alphabetical characters: `a`, `b`, `c`, …
  - Days of week: `Monday`, `Tuesday`, …

Data Type Characteristics

- A data type has:
  - Name (C keyword)
  - Size (how much memory is used)
- Example:
  - Characters in C
  - Name: `char`
  - Size: `8 bits` (1 byte)

`char`: sequence of 8 bits in memory

`char`: 1 byte of memory

int sbyte uint byte long short ulong ushort

Integer Types

char, short, int, unsigned int, long

What are Integer Types?

- Integer types:
  - Represent whole numbers
  - May be signed or unsigned
  - Have range of values, depending on the size of memory used

int
long
short

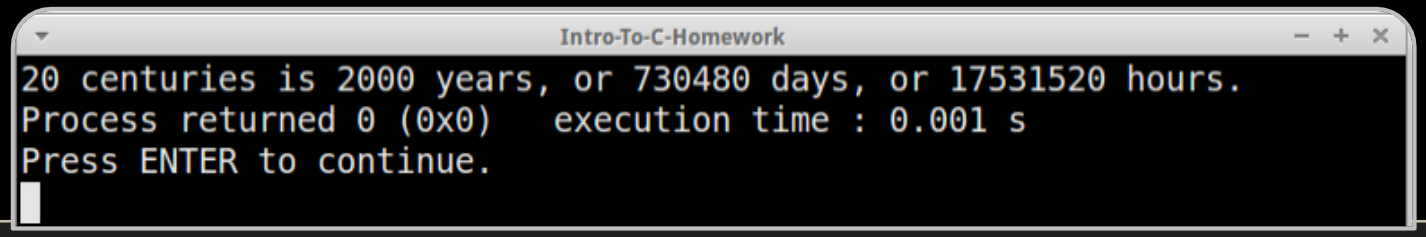
- The default value of integer types is:
  - `0` – for integer types, except
  - `0L` – for the `long` type

Integer Types

Type	Storage Size	Value Range
`char`	8-bit	-128 to 127
`unsigned char`	8-bit	0 to 255
`short`	16-bit	-32,768 to 32,767
`unsigned short`	16-bit	0 to 65,535
`int`	16- or 32-bit	$-2^{15}+1$ to $2^{15}-1$ or $-2^{31}+1$ to $2^{31}-1$
`unsigned int`	16- or 32-bit	0 to $(2*2^{15})-1$ or 0 to $(2*2^{31})-1$
`long`	32- or 64-bit	$-2^{31}+1$ to $2^{31}-1$ or $-2^{63}+1$ to $2^{63}-1$
`unsigned long`	32- or 64-bit	0 to $(2*2^{31})-1$ or $(2*2^{63})-1$
`long long`	64-bit	$-2^{63}+1$ to $2^{63}-1$
`unsigned long long`	64-bit	0 to $(2*2^{63})-1$

Measuring Time – Example

- Depending on the unit of measure we may use different data types:




```
char centuries = 20;           // A small number (up to 255)
unsigned short years = 2000;   // A small number (up to 32767)
unsigned int days = 730480;    // A large number (up to 4.3 billion)
unsigned long hours = 17531520; // A very big number (up to 18.4*10^18)
printf("%c centuries is %hu years, or %du days, or %lu hours.",
    centuries, years, days, hours);
```

- Note: Type range of **`int`** and **`long`** varies according to platform!

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Integer Types

Live Demo

int

ushort

unsigned int

long

short

unsigned long

char

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Floating-Point

double

float

What are Floating-Point Types?

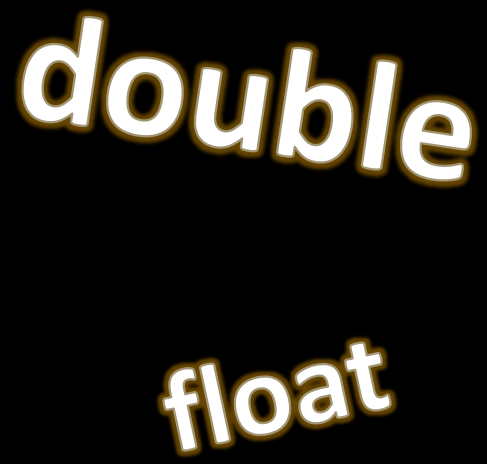
- Floating-point types:
  - Represent real numbers
  - May be signed or unsigned
  - Have range of values and different precision depending on the used memory
  - Can behave abnormally in the calculations

double

float

Floating-Point Types

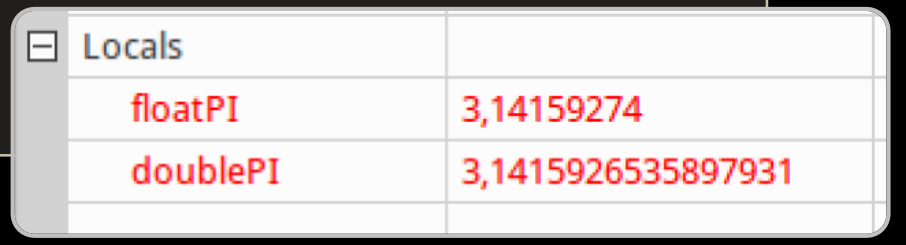
- Floating-point types are:
  - `float` ($\pm 1.2 \times 10^{-38}$ to $\pm 3.4 \times 10^{38}$)
    - 32-bit, precision of 6 digits
  - `double` ($\pm 2.3 \times 10^{-308}$ to $\pm 1.7 \times 10^{308}$)
    - 64-bit, precision of 15 digits
  - `long double` ($\pm 3.4 \times 10^{-4932}$ to $\pm 1.1 \times 10^{4932}$)
    - 80-bit, precision of 19 digits



PI Precision – Example

- Difference in precision when using **float** and **double**:

```
float floatPI = 3.14159265358793238f;
double doublePI = 3.14159265358793238d;
```



  - The default value of floating-point types:
    - Is **0.0F** for the **float** type
    - Is **0.0D** for the **double** type
- NOTE: The "**f**" suffix in the first statement!
  - Real numbers are by default interpreted as **double**!
  - One should explicitly convert them to **float**

Abnormalities in the Floating-Point Calculations

- Sometimes abnormalities can be observed when using floating-point numbers
  - Comparing floating-point numbers can not be performed directly with the == operator

```
double a = 1.0f;
double b = 0.33f;
double correctSum = 1.33f;
double actualSum = a + b;
```

Locals	
a	1
b	0,33000001311302185
correctSum	1,3300000429153442
actualSum	1,3300000131130219

Floating-Point and Decimal Floating-Point Types

Live Demo

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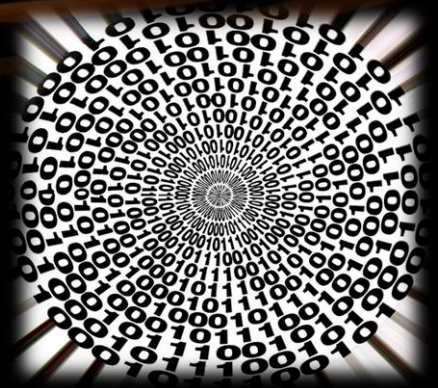
Boolean Type

true

false

The Boolean Type

- The Boolean data type:
  - Has two possible values: **`true`** and **`false`**
  - Is useful in logical expressions



- In C there is no native boolean data type (no **`bool`** keyword)
  - **`int`** variables are used instead (**`1`** for true, **`0`** for false)

```
int isHappy = 1;
int hasMoney = 0;
```

Boolean in C

- As an alternative **bool** can be defined as a macro

```
typedef int bool;
#define true 1
#define false 0

int main()
{
    bool isHappy = true;
    bool hasMoney = false;
    return 0;
}
```

- Or simply `#include <stdbool.h>`

Note: Compiler must support C99 standard

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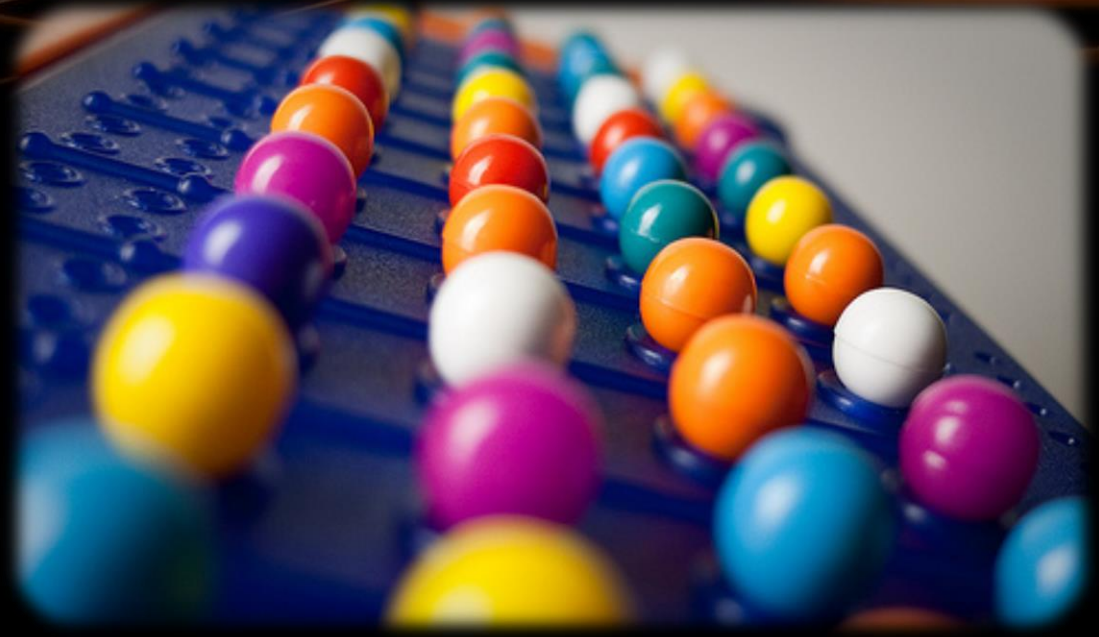
true



false

Boolean Type

Live Demo

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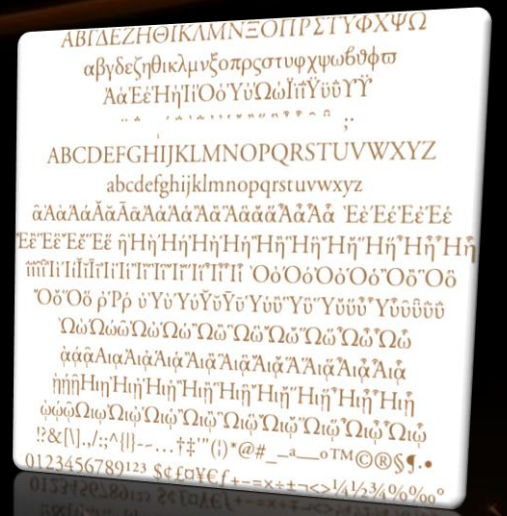


Character Type

char

The Character Data Type

- The character data type:
  - Represents symbolic information
  - Is declared by the **char** keyword
  - Can be assigned either a letter or an integer:

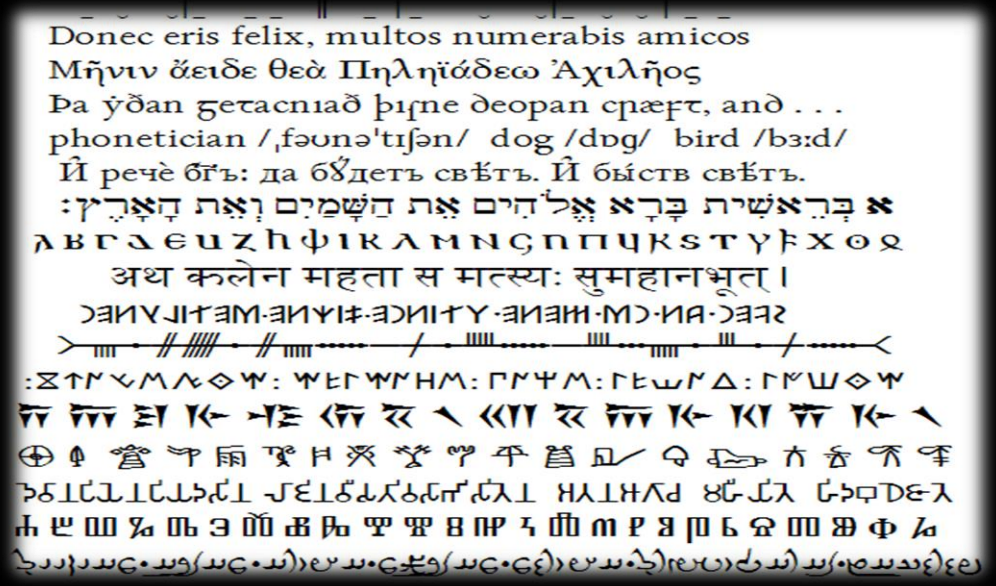
```
char letterA = 'A';
char letterB = 66;

printf("%c", letterA);
printf("%c", letterB);
```

char

Character Type

Live Demo

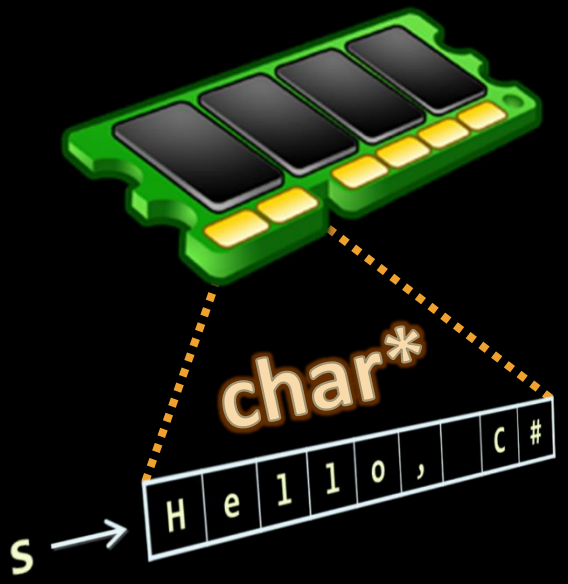
String Type



char*

The String Data Type

- The string data type represents a sequence of characters
  - Declared as a **char** array
  - Size should be string length + 1
  - Should always end with null terminator (**'\0'**)




```
char name[6] = "Pesho";
```

0	1	2	3	4	5
80	101	115	104	111	0
'P'	'e'	's'	'h'	'o'	'\0'

Null terminator character

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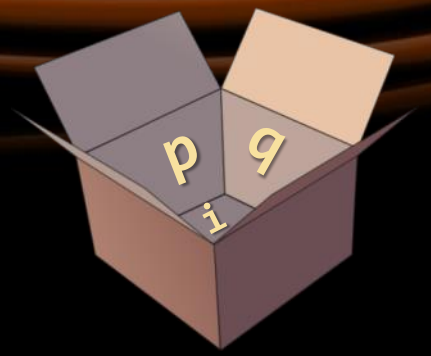
String Type

Live Demo

char*



Introducing Variables

What Is a Variable?

- Variables keep data in the computer memory
- A variable is a:
  - Placeholder of information that can be changed at run-time
- Variables allow you to:
  - Store information
  - Retrieve the stored information
  - Change the stored information

Variable Characteristics

- A variable has:
  - Name
  - Type (of stored data)
  - Value
- Example:

```
int counter = 5;
```

  - Name: **counter**
  - Type: **int**
  - Value: **5**

Declaring and Using Variables

$$f(x) = e^x$$

$$f(x) = \sqrt[3]{x} * sin(x)$$

$$(x) = 1 + x + x^2 + x^3 + x$$

$$f(x) = arctan(tan(x))$$

$$f(x) = cos(\pi - x)$$

Declaring Variables

- When declaring a variable we:
  - Specify its type
  - Specify its name (called identifier)
  - May give it an initial value

- The syntax is the following:

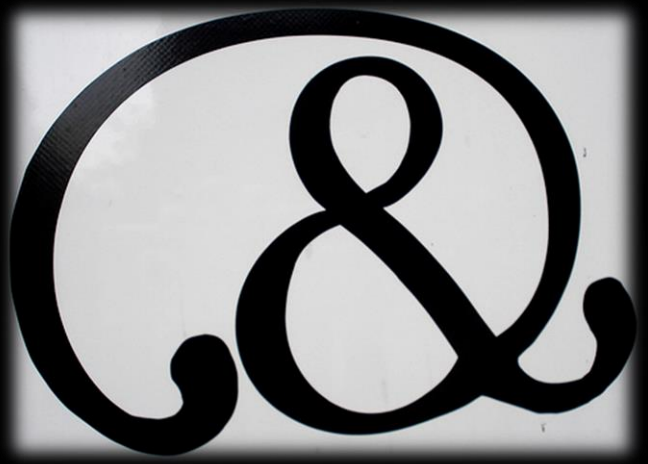
```
<data_type> <identifier> [= <initialization>];
```

- Example:

```
int height = 200;
```

Identifiers

- Identifiers may consist of:
  - Letters (Unicode)
  - Digits [`0-9`]
  - Underscore "`_`"
- Examples: `count`, `firstName`, `Page`
- Identifiers
  - Can begin only with a letter or an underscore
  - Cannot be a C keyword (like `int` and `void`)



Identifiers (2)

- Identifiers
  - Should have a descriptive name
    - E.g. `firstName`, not `dasfas` or `p17`
  - It is recommended to use only Latin letters
  - Should be neither too long nor too short
- Note:
  - In C small letters are considered different than the capital letters (case sensitivity)

Identifiers – Examples

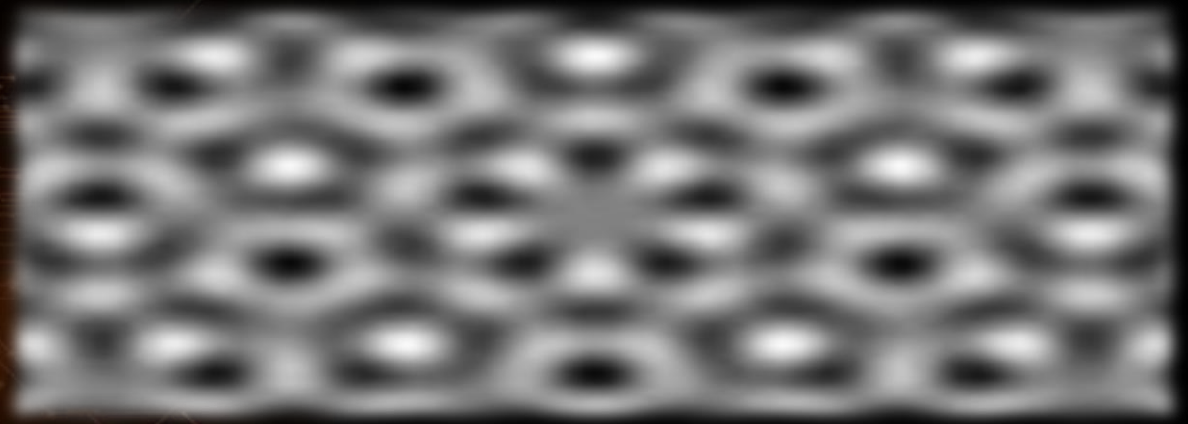
- Examples of syntactically correct identifiers:

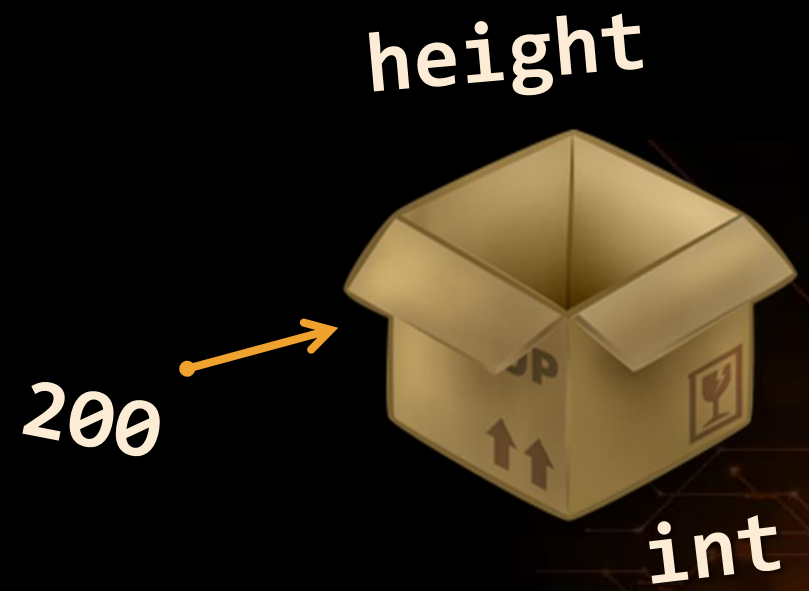
```
int New = 2; // here N is capital
int _2Pac;   // this identifier begins with underscore _

char greeting[] = "Hello"; // more appropriate name

int n = 100; // undescriptive
int numberOfClients = 100; // good, descriptive name

int numberOfPrivateClientsOfTheFirm = 100; // overdescriptive
```

- Examples of syntactically incorrect identifiers:

```
int char;   // char is a keyword
int 2Pac;   // cannot begin with a digit
```

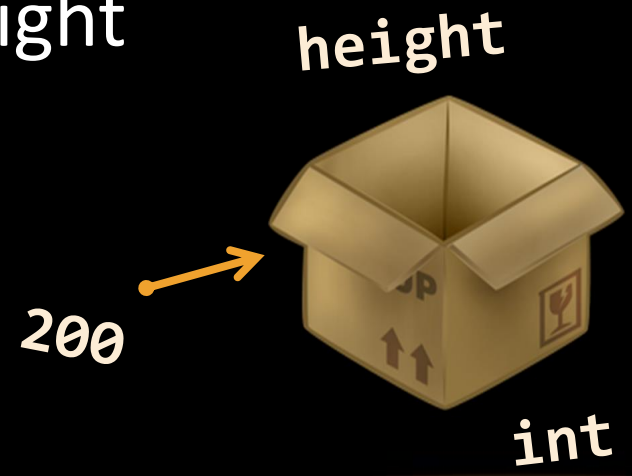
Assigning Values To Variables





Assigning Values

- Assigning values to variables
  - Use the = operator
- The = operator
  - Holds a variable identifier on the left
  - Value of the corresponding data type on the right
    - Or expression of compatible type
  - Could be used in a cascade calling
    - Where assigning is done from right to left



Assigning Values – Examples

```
int firstValue = 5;
int secondValue;
int thirdValue;

// Using an already declared variable:
secondValue = firstValue;

// The following cascade calling assigns
// 3 to firstValue and then firstValue
// to thirdValue, so both variables have
// the value 3 as a result:

thirdValue = firstValue = 3; // Avoid cascading assignments!
```

Initializing Variables

- Initializing
  - Means "to assign an initial value"
  - Must be done before the variable is used!
- Two ways of initializing:
  - By using a literal expression
  - By referring to an already initialized variable

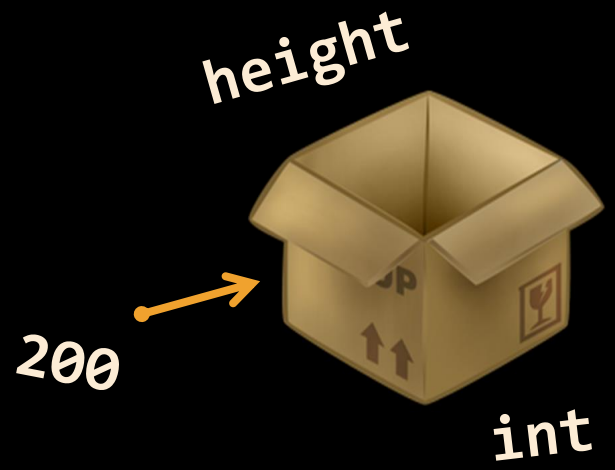
Initialization – Examples

- Example of variable initializations:

```
// The following would assign the default
// value of the int type to num:
int num; // num = 0

// This is how we use a literal expression:
float heightInMeters = 1.74f;

// Here we use an already initialized variable:
char greeting[] = "Hello World!";
char *message = greeting;
```

Assigning and Initializing Variables

Live Demo



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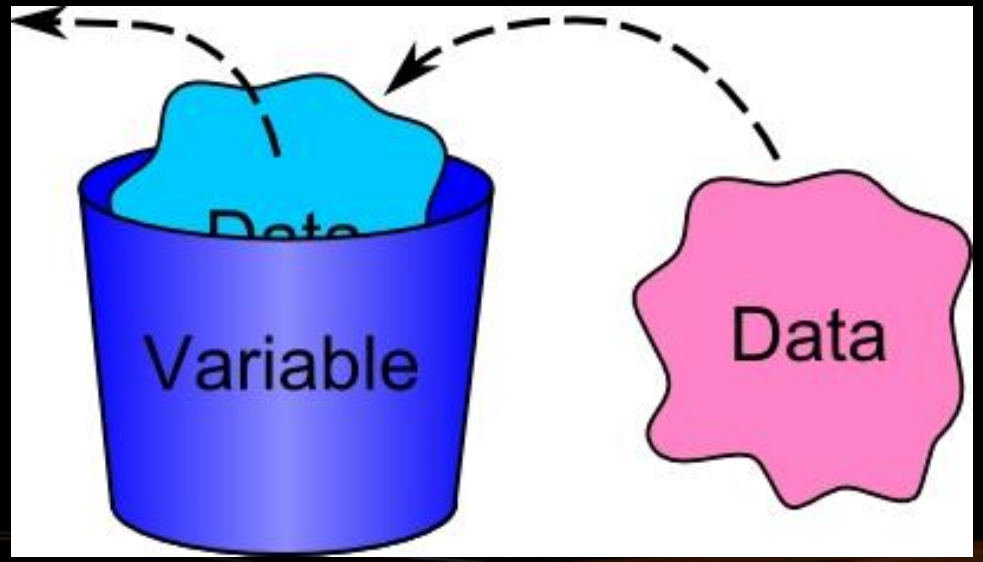
Assigning and Initializing Variables

Exercise



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Literals

true

null

12.76m

-0.307f

0xFE

@"Hi\r\n"

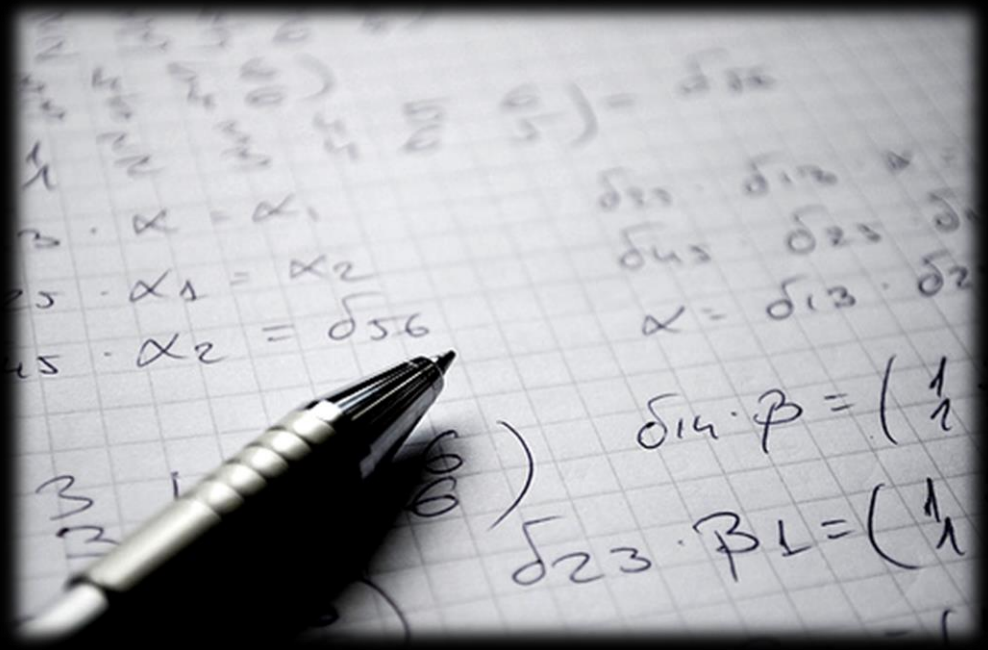
6.02e+23

"\uE52B"

2034567324L

3.14159206

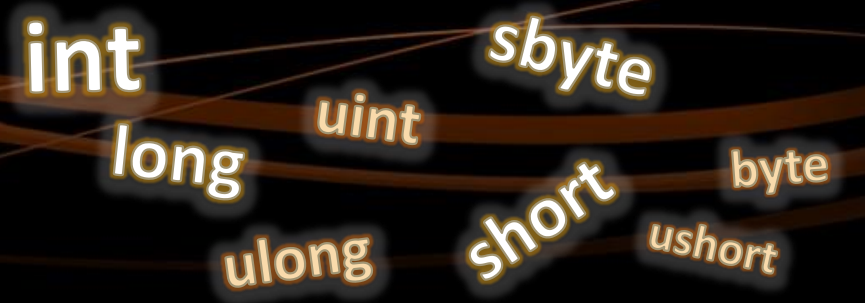
"\t\r\n\r\n\r\n"



What are Literals?

- Literals are:
  - Representations of values in the source code
- There are several types of literals
  - Integer
  - Real
  - Character
  - String
  - The **NULL** definition

Integer Literals



- Examples of integer literals:
  - The `'0x'` and `'0X'` prefixes mean a hexadecimal value
    - E.g. `0xFE`, `0xA8F1`, `0xFFFFFFFF`
  - The `'u'` and `'U'` suffixes mean an `unsigned long` or `unsigned int`
    - E.g. `12345678U`, `0U`
  - The `'l'` and `'L'` suffixes mean a `long` or `unsigned long`
    - E.g. `9876543L`, `0L` , `18532875832583321ULL`

Real Literals

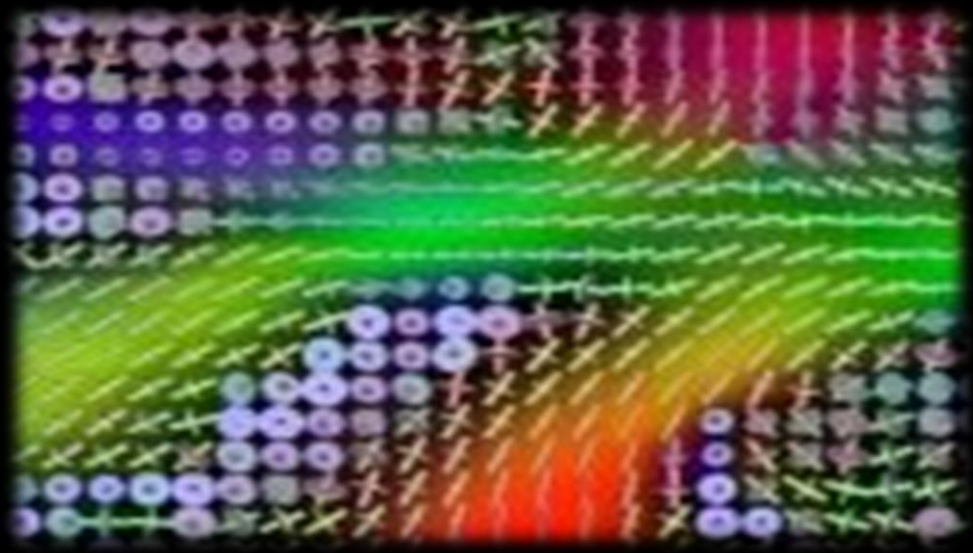
- The real literals:
  - Are used for values of type `float` and `double`
  - May consist of digits, a sign and "`.`"
  - May be in exponential notation: `6.02e+23`
- The "`f`" and "`F`" suffixes mean `float`
- The "`d`" and "`D`" suffixes mean `double`
- The default interpretation is `double`

Character Literals

- The character literals:
  - Are used for values of the `char` type
  - Consist of two single quotes surrounding the character value:

```
'<value>'
```

- The value may be:
  - Symbol
  - The code of the symbol
  - Escaping sequence



Escaping Sequences

- Escaping sequences are:
  - Means of presenting a symbol that is usually interpreted otherwise (like `'`)
  - Means of presenting system symbols (like the new line symbol)
- Common escaping sequences are:
  - `\'` for single quote
  - `\"` for double quote
  - `\\` for backslash
  - `\n` for new line

Character Literals – Example

- Examples of different character literals:

```
char symbol = 'a'; // An ordinary symbol
symbol = '\''; // Assigning the single quote symbol
symbol = '\\'; // Assigning the backslash symbol
symbol = '\n'; // Assigning new line symbol
symbol = '\t'; // Assigning TAB symbol
symbol = "a"; // Incorrect: use single quotes
```

Strings Literals

- Rules when initializing strings in C:
  - Size should be string length + 1
  - Last character is reserved for null terminator character '`\0`' representing end of string
- Strings can be initialized in several ways:
  1. `char` array declaration:

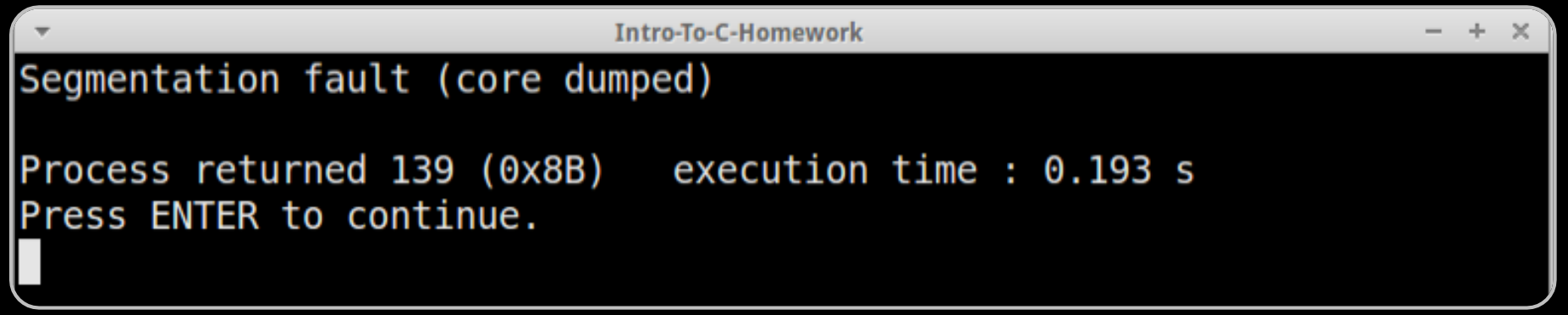
```
char firstName[6] = "Petar";
char lastName[] = "Georgiev";
```

String Literals (2)

2. Pointer declaration:

```
char* name = "Pesho";
name[0] = 'G'; // Will cause segmentation fault
```

- Warning: string cannot be modified, will cause segmentation fault because it is located in read-only memory



String Literals (3)

3. Heap initialization:

```
char *firstName = malloc(6);
if (firstName != NULL) {
    strcpy(firstName, "Pesho");
    // ...
    free(firstName);
}
```

NULL is returned when there is not enough memory

Frees the occupied memory

- Requests 6 bytes from the operating system (OS)
- If the OS finds 6 free bytes, it returns a pointer to their address
- Copies "Pesho" to the address where the pointer points to

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String Literals

Live Demo

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