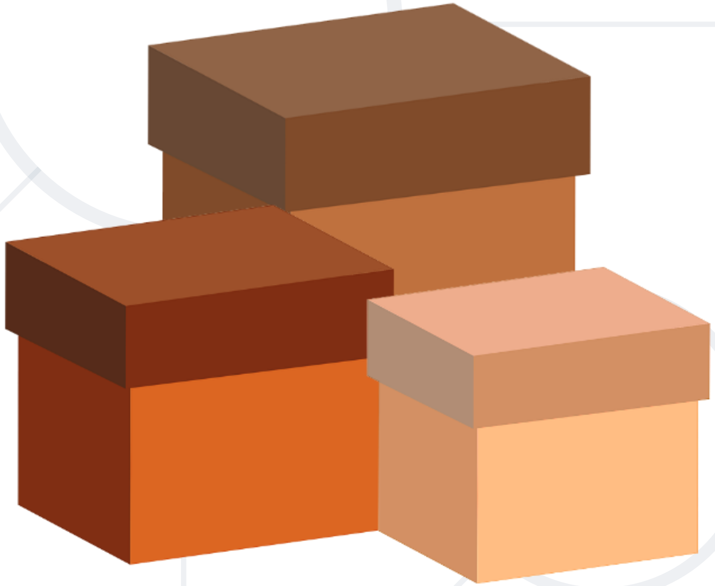
Data Types and Variables

Numeral Types, Text Types and Type Conversion



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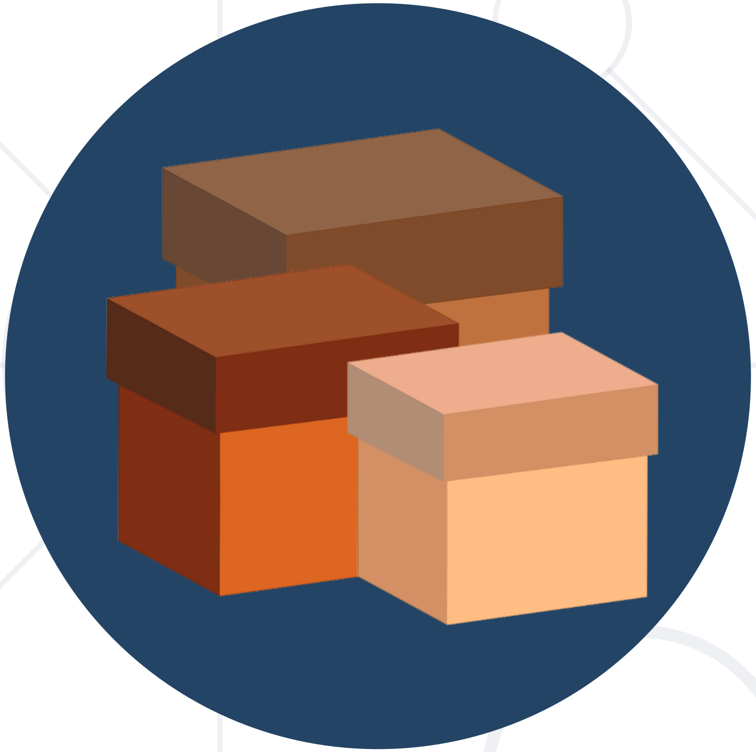
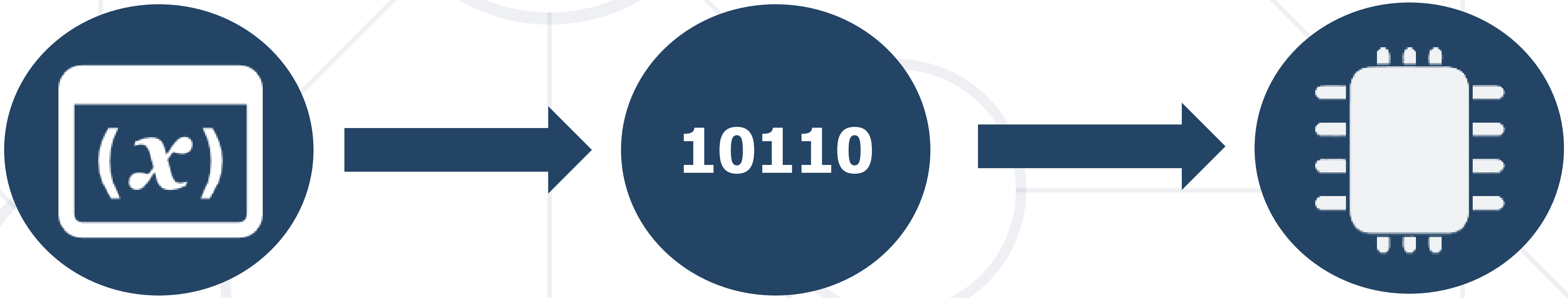


Data Types and Variables

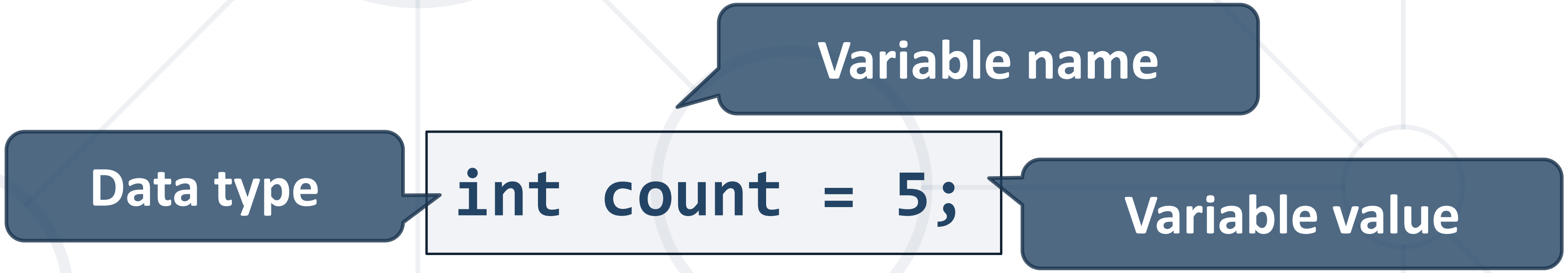
How Computing Works?

- Computers are machines that process data
  - Instructions and data are stored in the computer memory



Variables

- Variables have **name**, **data type** and **value**
  - **Assignment** is done by the operator "**=**"
  - Example of variable definition and assignment in C#



```
int count = 5;
```

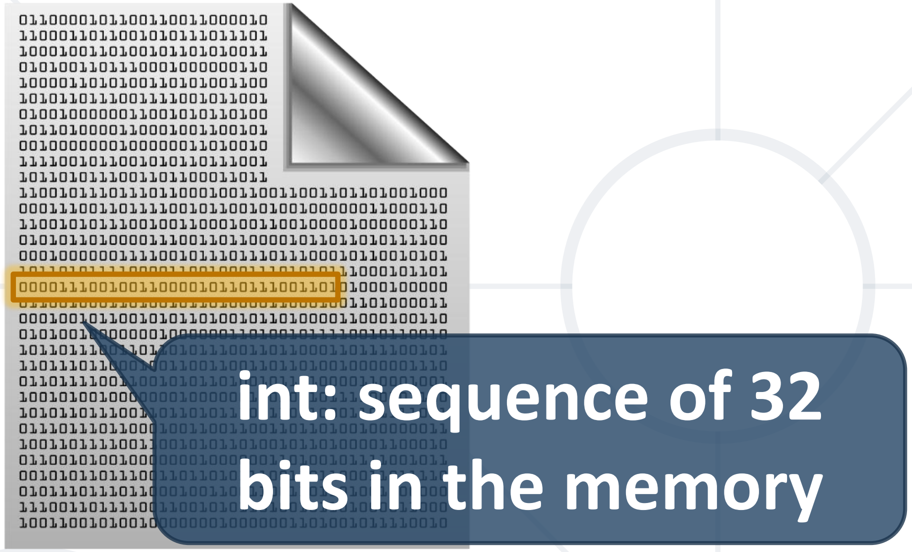
- When processed, **data** is **stored** back **into variables**

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 or .NET type)
  - Size (how much memory is used)
  - Default value
- Example
  - Integer numbers in C#
  - Name: **`int`**
  - Size: **`32 bits`** (4 bytes)
  - Default value: **`0`**



int: sequence of 32 bits in the memory

int: 4 sequential bytes in the memory

Naming Variables

- Always refer to the naming **conventions** of a programming language – for C# use **camelCase**
- Preferred form: **[Noun]** or **[Adjective]** + **[Noun]**
- Should explain the purpose of the variable (Always ask yourself "**What does this variable contain?**")

✓

```
firstName, report, config, fontSize, maxSpeed
```

🚫

```
foo, bar, p, p1, LastName, last_name, LAST_NAME
```

Variable Scope and Lifetime

- **Scope** == where you can access a variable (global, local)
- **Lifetime** == for how long a variable stays in memory

Accessible in the `Main()`

```
string outer = "I'm inside the Main()";
for (int i = 0; i < 10; i++)
{
   string inner = "I'm inside the loop";
}
Console.WriteLine(outer);
// Console.WriteLine(inner); Error
```

Accessible only in the loop

Variable Span

- Variable span is how long before a variable is called
- Always declare a variable as late as possible (e.g., shorter span)

```
static void Main()
{
  string outer = "I'm inside the Main()";
  for (int i = 0; i < 10; i++)
    string inner = "I'm inside the loop";
  Console.WriteLine(outer);
  // Console.WriteLine(inner); Error
}
```

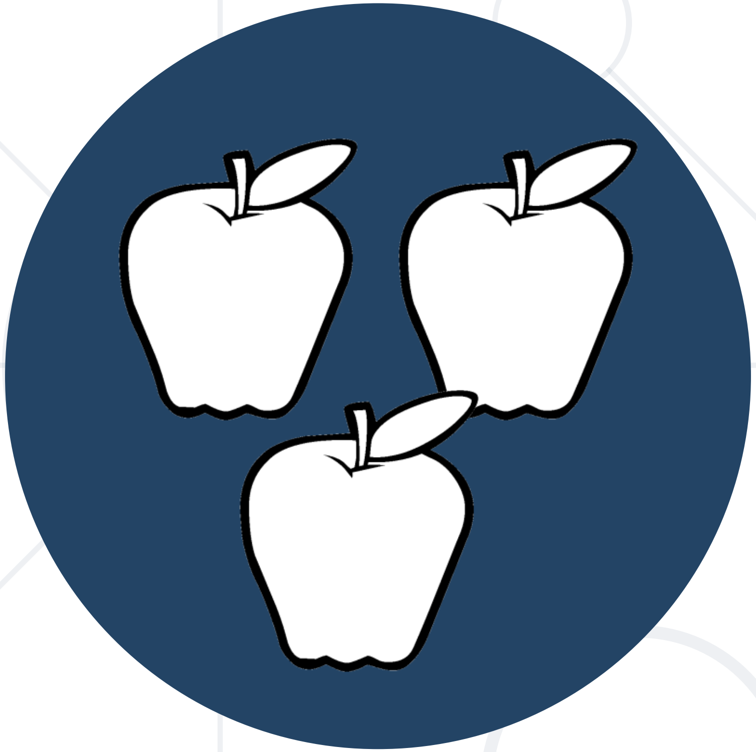
"outer" variable span

Keep Variable Span Short

- Shorter span simplifies the code
  - Improves its readability and maintainability

```
for (int i = 0; i < 10; i++)
{
   string inner = "I'm inside the loop";
}
string outer = "I'm inside the Main()";
Console.WriteLine(outer);
// Console.WriteLine(inner); Error
```

"outer" variable span – reduced



Integer Types

Integer Types

Type	Default Value	Min Value	Max Value	Size
`sbyte`	0	-128 (-2^{7})	127 (2^{7}-1)	8 bit
`byte`	0	0	255 (2^{8}-1)	8 bit
`short`	0	-32768 (-2^{15})	32767 (2^{15} - 1)	16 bit
`ushort`	0	0	65535 (2^{16}-1)	16 bit
`int`	0	-2147483648 (-2^{31})	2147483647 (2^{31} – 1)	32 bit
`uint`	0	0	4294967295 (2^{32}-1)	32 bit
`long`	0	-9223372036854775808 (-2^{63})	9223372036854775807 (2^{63}-1)	64 bit
`ulong`	0	0	18446744073709551615 (2^{64}-1)	64 bit

Centuries – Example

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

```
byte centuries = 20;
ushort years = 2000;
uint days = 730484;
ulong hours = 17531616;
Console.WriteLine(
  "{0} centuries = {1} years = {2} days = {3} hours.",
  centuries, years, days, hours);
// 20 centuries = 2000 years = 730484 days = 17531616
hours.
```

Beware of Integer Overflow!

- Integers have **range** (minimal and maximal value)
- Integers could overflow – this leads to incorrect values

```
byte counter = 0;
for (int i = 0; i < 260; i++)
{
  counter++;
  Console.WriteLine(counter);
}
```

```
1
2
…
255
0
1
```

Integer Literals

- Examples of integer literals
  - The '0x' and '0X' prefixes indicate a hexadecimal value
    - e.g., 0xFE, 0xA8F1, 0xFFFFFFFF
  - The 'u' and 'U' suffixes indicate a ulong or uint type
    - e.g., 12345678U, 0U
  - The 'l' and 'L' suffixes indicate long type
    - e.g., 9876543L, 0L

Real Number Types

What Are Floating-Point Types?

- Floating-point types
  - Represent real numbers, e.g., `1.25`, `-0.38`
  - Have range and precision depending on the memory used
  - Sometimes behave abnormally in the calculations
  - May hold very small and very big values like `0.00000000000001` and `10000000000000000000000000000000000.0`

Floating-Point Numbers

- Floating-point types are
  - `float` (±1.5 × 10^{-45} to ±3.4 × 10^{38})
    - 32-bits, precision of 7 digits
  - `double` (±5.0 × 10^{-324} to ±1.7 × 10^{308})
    - 64-bits, precision of 15-16 digits
- The default value for floating-point types
  - `0.0F` for the `float` type
  - `0.0D` for the `double` type

PI Precision – Example

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

```
float floatPI = 3.14159265358979323 8f;
double doublePI = 3.141592653589793238;
Console.WriteLine("Float PI is: {0}", floatPI);
Console.WriteLine("Double PI is: {0}", doublePI);
```

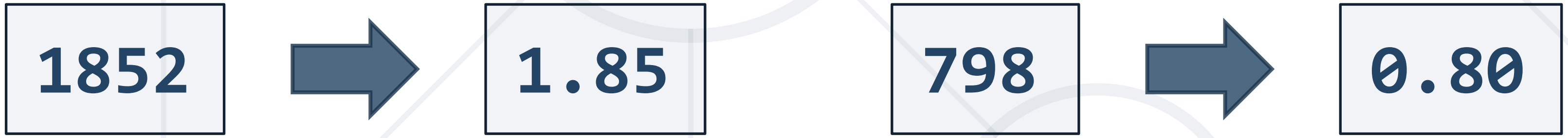
3.141593

3.14159265358979

- NOTE: The "**f**" suffix in the first statement
  - Real numbers are by default interpreted as **double**
  - One should explicitly convert them to **float**

Problem: Convert Meters to Kilometres

- Write a program that converts meters to kilometers formatted to the second decimal point
- Examples:



1852 → 1.85

798 → 0.80

```
int meters = int.Parse(Console.ReadLine());
float kilometers = meters / 1000.0f;
Console.WriteLine($"{kilometers:f2}");
```

Check your solution here: https://alpha.judge.softuni.org/contests/data-types-and-variables-lab/1192/practice#0

Problem: Pounds to Dollars

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- Write a program that converts British pounds to US dollars formatted to 3th decimal point
  - 1 British Pound = 1.31 Dollars

```
80 → 104.800
```

```
39 → 51.090
```

```
double num = double.Parse(Console.ReadLine());
double result = num * 1.31;
Console.WriteLine($"{result:f3}");
```

Check your solution here: https://alpha.judge.softuni.org/contests/data-types-and-variables-lab/1192/practice#1

Scientific Notation

- Floating-point numbers can use scientific notation
  - 1e+34, 1E34, 20e-3, 1e-12, -6.02e28

```
double d = 10000000000000000000000000000000000.0;
Console.WriteLine(d); // 1E+34

double d2 = 20e-3;
Console.WriteLine(d2); // 0.02

double d3 = double.MaxValue;
Console.WriteLine(d3); // 1.79769313486232E+308
```

Floating-Point Division

- Integral division and floating-point division are different

```
Console.WriteLine(10 / 4);    // 2 (integral division)
Console.WriteLine(10 / 4.0);  // 2.5 (real division)

Console.WriteLine(10 / 0.0);  // Infinity
Console.WriteLine(-10 / 0.0); // -Infinity

Console.WriteLine(0 / 0.0);   // NaN (not a number)
Console.WriteLine(8 % 2.5);   // 0.5 (3 * 2.5 + 0.5 = 8)
```

Floating-Point Calculations – Abnormalities

- Sometimes floating-point numbers work incorrectly!

```
Console.WriteLine(100000000000000.0 + 0.3);
// 100000000000000 (loss of precision)
double a = 1.0f, b = 0.33f, sum = 1.33;
Console.WriteLine("a+b={0} sum={1} equal={2}",
  a+b, sum, (a+b == sum));
// a+b = 1.33000001311302 sum=1.33 equal = False
double one = 0;
for (int i = 0; i < 10000; i++) one += 0.0001;
  Console.WriteLine(one); // 0.9999999999999906
```

Decimal Floating-Point Type

- There is a special decimal floating-point real number type in C#
  - `decimal` (±1,0 × 10^{-28} to ±7,9 × 10^{28})
    - 128-bits, precision of 28-29 digits
  - Used for financial calculations
  - Almost no round-off errors
  - Almost no loss of precision
  - The default value of decimal type is
  - `0.0M` (`M` is the suffix for decimal numbers)

Problem: Exact Sum of Real Numbers

- Write program to enter **n** numbers and print their exact sum:

```
2
1000000000000000000
5
```

→

```
1000000000000000005
```

```
2
0.00000000003
333333333333.3
```

→

```
333333333333.30000000003
```

Check your solution here: https://alpha.judge.softuni.org/contests/data-types-and-variables-lab/1192/practice#2

Solution: Exact Sum of Real Numbers

- This code works, but makes rounding mistakes sometimes:

```
int n = int.Parse(Console.ReadLine());
double sum = 0;
for (int i = 0; i < n; i++)
  sum += double.Parse(Console.ReadLine());
Console.WriteLine(sum);
```

- Change **double** with **decimal** and check the differences

Check your solution here: https://alpha.judge.softuni.org/contests/data-types-and-variables-lab/1192/practice#2

Integer and Real Numbers

Live Exercises

Type Conversion

Type Conversion

- Variables hold values of certain type
- Type can be **changed** (**converted**) to another type
  - **Implicit** type conversion (**lossless**): variable of bigger type (e.g., **double**) takes smaller value (e.g., **float**)

```
float heightInMeters = 1.74f;
double maxHeight = heightInMeters;
```

Implicit conversion

  - **Explicit** type conversion (lossy) – when precision can be lost

```
double size = 3.14;
int intSize = (int) size;
```

Explicit conversion

Problem: Centuries to Minutes

- Write program to enter an integer number of centuries and convert it to years, days, hours and minutes

```
Centuries = 1
```

```
1 centuries = 100 years = 36524 days
= 876576 hours = 52594560 minutes
```

```
Centuries = 5
```

```
5 centuries = 500 years = 182621 days
= 4382904 hours = 262974240 minutes
```

The output is on one row

Check your solution here: https://alpha.judge.softuni.org/contests/data-types-and-variables-lab/1192/practice#3

Solution: Centuries to Minutes

```
int centuries = int.Parse(Console.ReadLine());
int years = centuries * 100;
int days = (int) (years * 365.2422);
int hours = 24 * days;
int minutes = 60 * hours;
Console.WriteLine(
  "{0} centuries = {1} years = {2} days = {3} hours = {4}
minutes",
  centuries, years, days, hours, minutes);
```

Tropical year has **365.2422** days

(int) converts double to int

Check your solution here: https://alpha.judge.softuni.org/contests/data-types-and-variables-lab/1192/practice#3

Boolean Type

Boolean Type

- Boolean variables (**bool**) hold **true** or **false**

```
int a = 1;
int b = 2;
bool greaterAB = (a > b);
Console.WriteLine(greaterAB);  // False
bool equalA1 = (a == 1);
Console.WriteLine(equalA1);    // True
```

Problem: Special Numbers

- A number is special when its sum of digits is 5, 7 or 11
  - For all numbers **1…n** print the number and whether it is special or not

```
20
```

```
1 -> False
2 -> False
3 -> False
4 -> False
5 -> True
6 -> False
7 -> True
```

```
8 -> False
9 -> False
10 -> False
11 -> False
12 -> False
13 -> False
14 -> True
```

```
15 -> False
16 -> True
17 -> False
18 -> False
19 -> False
20 -> False
```

Check your solution here: https://alpha.judge.softuni.org/contests/data-types-and-variables-lab/1192/practice#4

Solution: Special Numbers

```
int n = int.Parse(Console.ReadLine());
for (int num = 1; num <= n; num++)
{
  int sumOfDigits = 0;
  int digits = num;
  while (digits > 0)
  {
    sumOfDigits += digits % 10;
    digits = digits / 10;
  }
  // TODO: check whether the sum is special
}
```

Check your solution here: https://alpha.judge.softuni.org/contests/data-types-and-variables-lab/1192/practice#4

'A'

Character Type

The Character Data Type

- The character data type in C#
  - Represents symbolic information
  - Is declared by the **`char`** keyword
  - Gives each symbol a corresponding integer code
  - Has a **`'\0'`** default value
  - Takes 16 bits of memory (from **`U+0000`** to **`U+FFFF`**)
  - Holds a single Unicode character (or part of character)

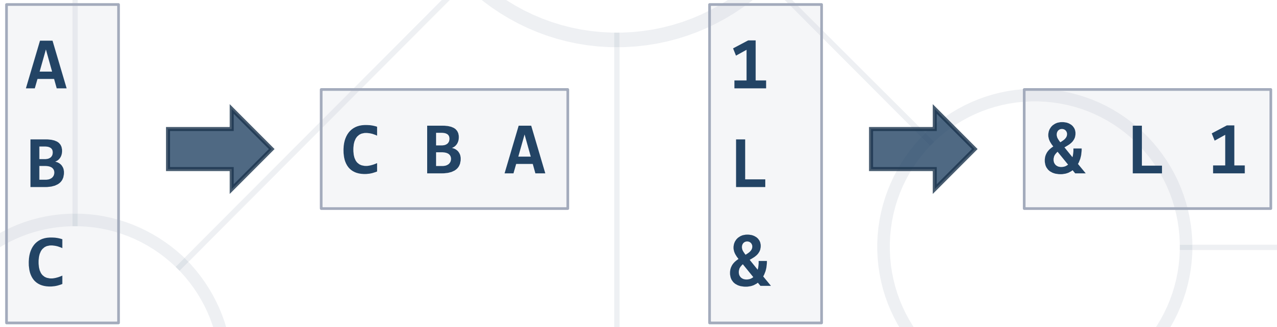
Characters and Codes

- Each **character** has a unique **Unicode** value (**`int`**):

```
char ch = 'a';
Console.WriteLine("The code of '{0}' is: {1}", ch, (int) ch);
ch = 'b';
Console.WriteLine("The code of '{0}' is: {1}", ch, (int) ch);
ch = 'A';
Console.WriteLine("The code of '{0}' is: {1}", ch, (int) ch);
ch = 'щ';  // Cyrillic letter 'sht'
Console.WriteLine("The code of '{0}' is: {1}", ch, (int) ch);
```

Problem: Reversed Chars

- Write a program that takes 3 lines of characters and prints them in reversed order with a space between them
- Examples



A
B
C

C B A

1
L
&

& L 1

Check your solution here: https://alpha.judge.softuni.org/contests/data-types-and-variables-lab/1192/practice#5

Solution: Reversed Chars

```
char firstChar = char.Parse(Console.ReadLine());
char secondChar = char.Parse(Console.ReadLine());
char thirdChar = char.Parse(Console.ReadLine());

Console.WriteLine($"{thirdChar} {secondChar}
{firstChar}");
```

Check your solution here: https://alpha.judge.softuni.org/contests/data-types-and-variables-lab/1192/practice#5

Escaping Characters

- Escaping sequences
  - Represent a special character like `'`, `"` or `\n` (new line)
  - Represent system characters (like the [TAB] character `\t`)
- Commonly used escaping sequences are
  - `\'` → for single quote `\"` → for double quote
  - `\\` → for backslash `\n` → for new line
  - `\uXXXX` → for denoting any other Unicode symbol

Character Literals – Example

```
char symbol = 'a'; // An ordinary character
symbol = '\u006F'; // Unicode character code in a
                   // hexadecimal format (letter 'o')
symbol = '\u8449'; // 葉 (Leaf in Traditional Chinese)
symbol = '\''; // Assigning the single quote character
symbol = '\\'; // Assigning the backslash character
symbol = '\n'; // Assigning new line character
symbol = '\t'; // Assigning TAB character
symbol = "a";  // Incorrect: use single quotes!
```

"ABC"

Sequence of Characters

String

The String Data Type

- The string data type in C#
  - Represents a sequence of characters
  - Is declared by the **string** keyword
  - Has a default value **null** (no value)
- Strings are enclosed in quotes

```
string text = "Hello, C#";
```

- Strings can be concatenated
  - Using the **+** operator

Verbatim and Interpolated Strings

- Strings are enclosed in quotes **""**

```
string file = "C:\\Windows\\win.ini";
```

The backslash \ is **escaped by \\**

- Strings can be **verbatim** (no escaping)

```
string file = @"C:\Windows\win.ini";
```

The backslash \ is **not escaped**

- You can use verbatim strings with interpolation

```
string os = "Windows";
string file = "win.ini";
string path = $@"C:\{os}\{file}";
```

Problem: Concat Names

- Read first and last name and delimiter
- Print the first and last name joined by the delimiter

```
John
Smith
->
```

→

```
John->Smith
```

```
Linda
Terry
=>
```

→

```
Linda=>Terry
```

```
Jan
White
<->
```

→

```
Jan<->White
```

```
Lee
Lewis
---
```

→

```
Lee---Lewis
```

Check your solution here: https://alpha.judge.softuni.org/contests/data-types-and-variables-lab/1192/practice#6

Solution: Concat Names

```
string firstName = Console.ReadLine();
string lastName = Console.ReadLine();
string delimiter = Console.ReadLine();

string result = firstName + delimiter + lastName;
Console.WriteLine(result);
```

```
Jan<->White
```

Live Exercises

Data Types

Summary

- **Variables** – store data
- Numeral types
  - Represent **numbers**
  - Have **specific ranges** for every type
- String and text types
  - Represent **text**
  - **Sequences of Unicode characters**
- Type conversion: **implicit** and **explicit**