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D20A - 55

Experiment.4

Aim: Hands-on Solidity Programming Assignments for creating Smart Contracts

Theory:

Solidity and Smart Contract Fundamentals
1. Primitive Data Types, Variables, and Functions (pure, view)

Solidity is a high-level, statically typed programming language used for developing smart contracts on the Ethereum blockchain. Primitive data types serve as the fundamental building blocks of Solidity and play a crucial role in defining variables, performing computations, and managing data within a contract.

Commonly used primitive data types include:

- **uint / int**: Used to represent unsigned and signed integers of different sizes, such as uint256 or int128. These are widely used for financial calculations, counters, and token balances.
- **bool**: Represents logical values (true or false) and is commonly used in decision-making statements such as access control and validations.
- **address**: Stores a 20-byte Ethereum account or contract address, which is essential for identifying users and interacting with other contracts.
- **bytes / string**: Used for storing binary and textual data, respectively, such as user names or encrypted information.

Variables in Solidity are categorized into three types based on their scope and lifetime:

- **State Variables**: Stored permanently on the blockchain and consume gas when modified. Example: storing the contract owner's address.
- **Local Variables**: Temporary variables that exist only during function execution and are not stored on-chain.
- **Global Variables**: Predefined variables such as msg.sender, msg.value, and block.timestamp, which provide information about the transaction and blockchain environment.

Functions in Solidity define the logic and behavior of smart contracts. Two important function types include:

- **pure**: Functions that neither read nor modify blockchain state; they operate only on input values. Example: a function that adds two numbers.
- **view**: Functions that can read state variables but cannot modify them. Example: a function that returns an account balance.

These function types help in optimizing gas usage and ensuring secure and predictable contract execution.

2. Inputs and Outputs to Functions

Functions in Solidity can accept input parameters and return output values, enabling interaction between users and smart contracts. Inputs allow external users or other contracts to pass data into a function, while outputs enable the function to return computed results.

For example, a function may accept an amount of Ether as input and return a boolean value indicating whether a transaction was successful. Solidity also supports named return variables, which enhance code readability and simplify debugging.

3. Visibility, Modifiers, and Constructors

Function visibility defines who can access a particular function within or outside the contract:

- **public**: Accessible both internally and externally.
- **private**: Accessible only within the same contract.
- **internal**: Accessible within the contract and its derived contracts.
- **external**: Can only be called by external accounts or other contracts.

Modifiers are special functions that modify the behavior of other functions. They are commonly used for security and access control. For instance, an onlyOwner modifier can restrict certain functions so that only the contract owner can execute them.

A **constructor** is a special function that executes only once during contract deployment. It is primarily used to initialize important variables, such as assigning the deploying account as the contract owner.

4. Control Flow: if-else and Loops

Solidity supports standard control flow structures similar to traditional programming languages.

- **if-else statements** allow conditional decision-making in contract logic. For example, a contract can verify whether a user has sufficient balance before processing a transaction.

- **Loops (for, while, do-while)** enable repeated execution of code, such as iterating through an array of registered users. However, loops must be used carefully, as excessive iterations increase gas consumption and may make transactions costly or even fail due to gas limits.

5. Data Structures: Arrays, Mappings, Structs, and Enums

Solidity provides several data structures to efficiently manage and organize data within smart contracts.

- **Arrays**: Used to store ordered collections of elements. They can be fixed-size or dynamic. Example: an array storing addresses of registered users.
- **Mappings**: Key-value storage structures that allow fast data retrieval. Example: mapping(address => uint) to store user balances. Unlike arrays, mappings do not support iteration.

Structs: Allow grouping of related data into a single entity. Example:

```
 struct Player {
    string name;
    uint score;
}
```

- This structure helps store multiple attributes of a player in an organized manner.

Enums: Used to define a set of predefined constants, improving code clarity and readability. Example:

```
 enum Status { Pending, Active, Closed }
```

6. Data Locations

Solidity defines three primary data locations that determine where variables are stored and how they behave in memory:

- storage: Permanent data stored on the blockchain. Used for state variables.
- memory: Temporary data that exists only during function execution. Used for local variables and function inputs.
- calldata: A non-modifiable and non-persistent location used for external function parameters. It is more gas-efficient than memory.

Understanding data locations is essential because they directly impact gas costs, efficiency, and contract performance.

7. Transactions: Ether, Wei, Gas, and Sending Transactions

Ether and Wei:
Ether is the native cryptocurrency of the Ethereum blockchain. The smallest unit of Ether is Wei, where:
1 Ether = 10^{18} Wei.
This ensures high precision in financial and smart contract transactions.

Gas and Gas Price:
Every transaction on Ethereum consumes gas, which represents the computational cost of executing operations. The gas price determines how much Ether is paid per unit of gas. A higher gas price results in faster transaction processing.

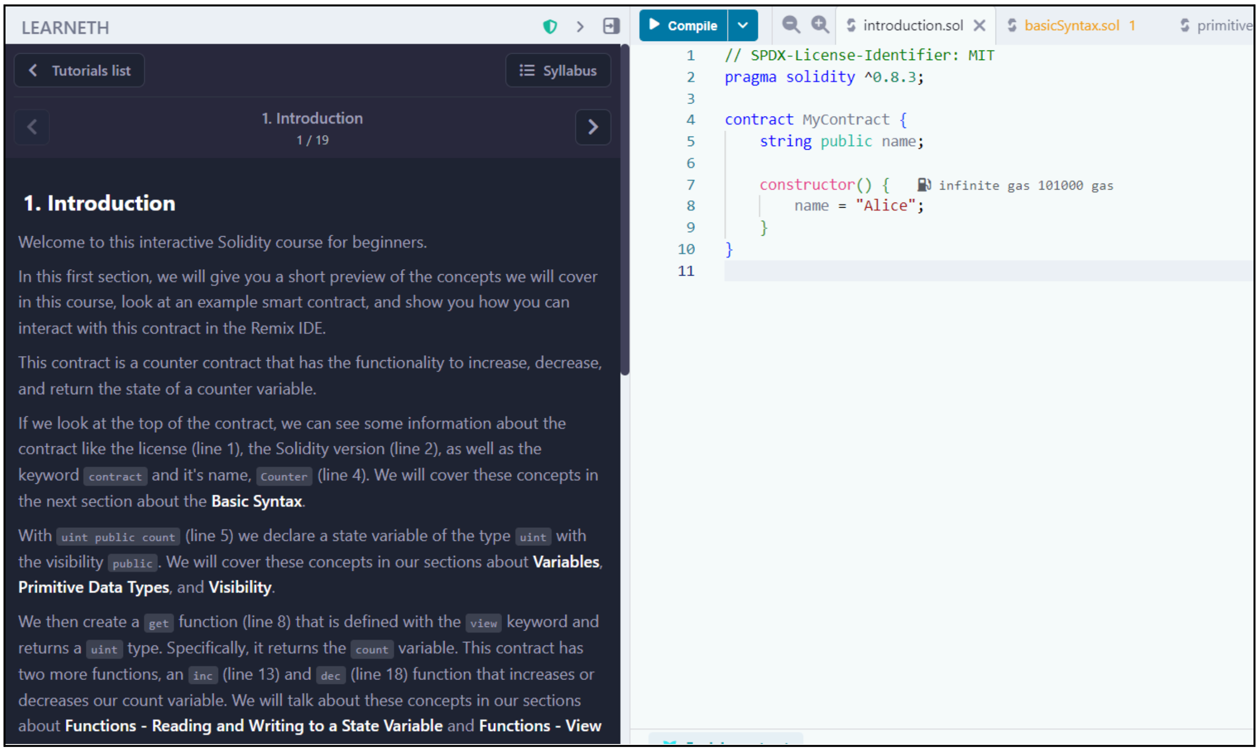
Sending Transactions:
Transactions are used to transfer Ether or interact with smart contracts. Common methods include:

- transfer() – Safe but limited in gas usage.
- send() – Returns a boolean value indicating success or failure.
- call() – More flexible and recommended for modern Solidity development.

Efficient contract design is necessary to minimize gas consumption and reduce transaction costs.

Output -

1.introduction.sol



1. Introduction

Welcome to this interactive Solidity course for beginners.

In this first section, we will give you a short preview of the concepts we will cover in this course, look at an example smart contract, and show you how you can interact with this contract in the Remix IDE.

This contract is a counter contract that has the functionality to increase, decrease, and return the state of a counter variable.

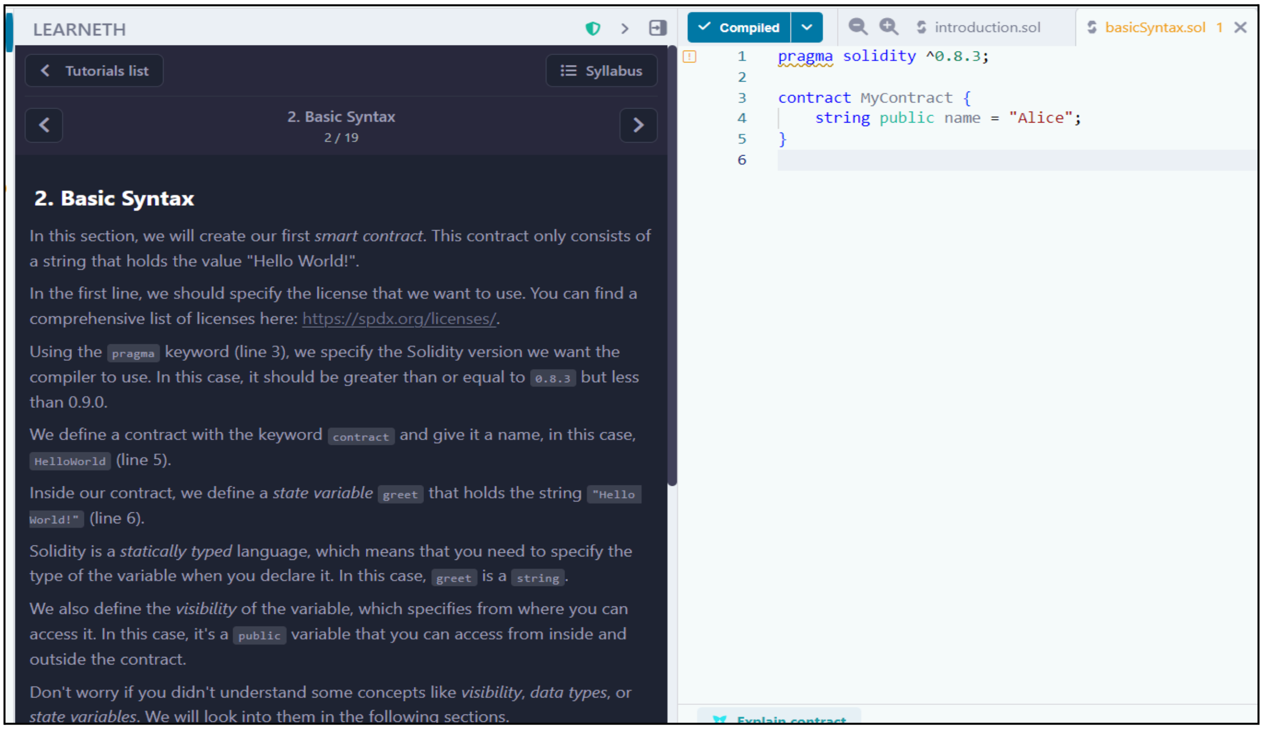
If we look at the top of the contract, we can see some information about the contract like the license (line 1), the Solidity version (line 2), as well as the keyword `contract` and it's name, `Counter` (line 4). We will cover these concepts in the next section about the **Basic Syntax**.

With `uint public count` (line 5) we declare a state variable of the type `uint` with the visibility `public`. We will cover these concepts in our sections about **Variables**, **Primitive Data Types**, and **Visibility**.

We then create a `get` function (line 8) that is defined with the `view` keyword and returns a `uint` type. Specifically, it returns the `count` variable. This contract has two more functions, an `inc` (line 13) and `dec` (line 18) function that increases or decreases our count variable. We will talk about these concepts in our sections about **Functions - Reading and Writing to a State Variable** and **Functions - View**

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.3;

contract MyContract {
    string public name;

    constructor() {    infinite gas 101000 gas
        name = "Alice";
    }
}
```

2. basicSyntax.sol



2. Basic Syntax

In this section, we will create our first *smart contract*. This contract only consists of a string that holds the value "Hello World!".

In the first line, we should specify the license that we want to use. You can find a comprehensive list of licenses here: https://spdx.org/licenses/.

Using the `pragma` keyword (line 3), we specify the Solidity version we want the compiler to use. In this case, it should be greater than or equal to `0.8.3` but less than 0.9.0.

We define a contract with the keyword `contract` and give it a name, in this case, `HelloWorld` (line 5).

Inside our contract, we define a *state variable* `greet` that holds the string `"Hello World!"` (line 6).

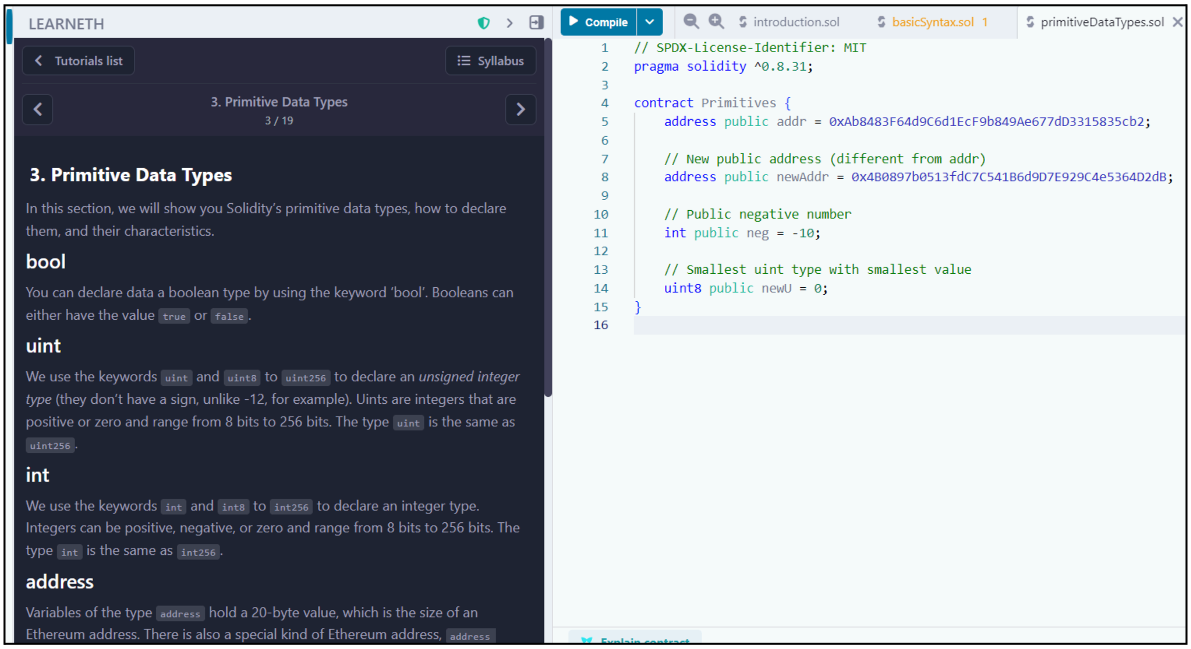
Solidity is a *statically typed* language, which means that you need to specify the type of the variable when you declare it. In this case, `greet` is a `string`.

We also define the *visibility* of the variable, which specifies from where you can access it. In this case, it's a `public` variable that you can access from inside and outside the contract.

Don't worry if you didn't understand some concepts like *visibility*, *data types*, or *state variables*. We will look into them in the following sections.

```
pragma solidity ^0.8.3;

contract MyContract {
    string public name = "Alice";
}
```

3. primitiveDataTypes.sol



3. Primitive Data Types

In this section, we will show you Solidity's primitive data types, how to declare them, and their characteristics.

bool

You can declare data a boolean type by using the keyword 'bool'. Booleans can either have the value `true` or `false`.

uint

We use the keywords `uint` and `uint8` to `uint256` to declare an *unsigned integer type* (they don't have a sign, unlike -12, for example). Uints are integers that are positive or zero and range from 8 bits to 256 bits. The type `uint` is the same as `uint256`.

int

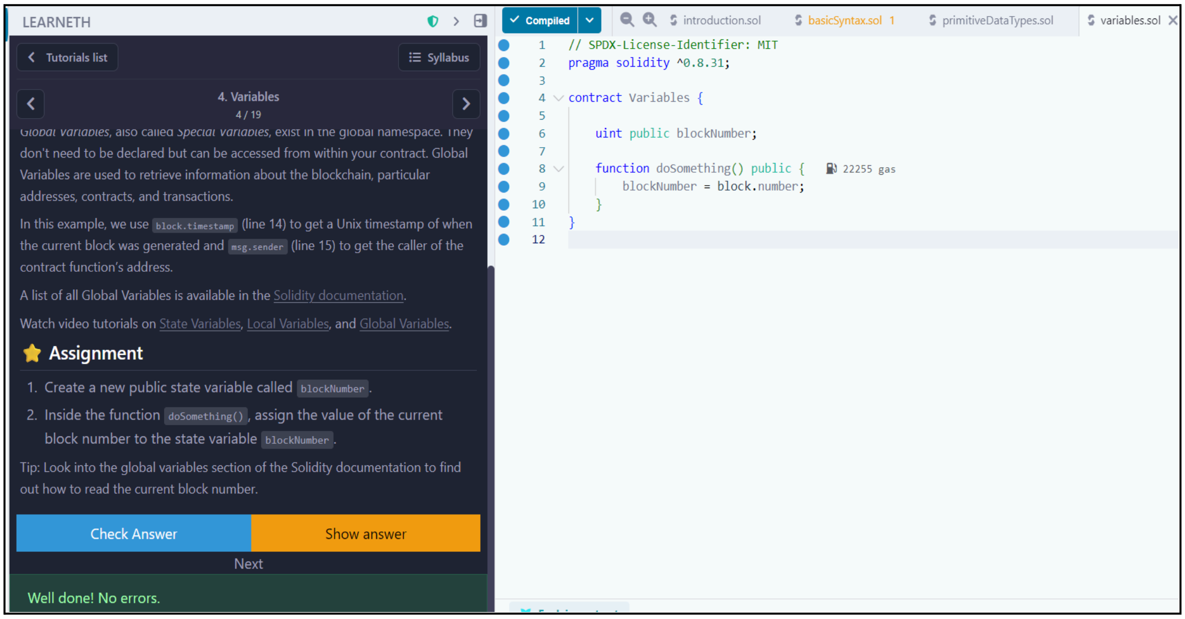
We use the keywords `int` and `int8` to `int256` to declare an integer type. Integers can be positive, negative, or zero and range from 8 bits to 256 bits. The type `int` is the same as `int256`.

address

Variables of the type `address` hold a 20-byte value, which is the size of an Ethereum address. There is also a special kind of Ethereum address, `address`

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.31;

contract Primitives {
    address public addr = 0xAb8483F64d9C6d1EcF9b849Ae677dD3315835cb2;

    // New public address (different from addr)
    address public newAddr = 0x4B0897b0513fdC7C541B6d9D7E929C4e5364D2dB;

    // Public negative number
    int public neg = -10;

    // Smallest uint type with smallest value
    uint8 public newU = 0;
}

```

4. variables.sol



Global variables, also called *Special variables*, exist in the global namespace. They don't need to be declared but can be accessed from within your contract. Global Variables are used to retrieve information about the blockchain, particular addresses, contracts, and transactions.

In this example, we use `block.timestamp` (line 14) to get a Unix timestamp of when the current block was generated and `msg.sender` (line 15) to get the caller of the contract function's address.

A list of all Global Variables is available in the Solidity documentation.

Watch video tutorials on State Variables, Local Variables, and Global Variables.

⭐ Assignment

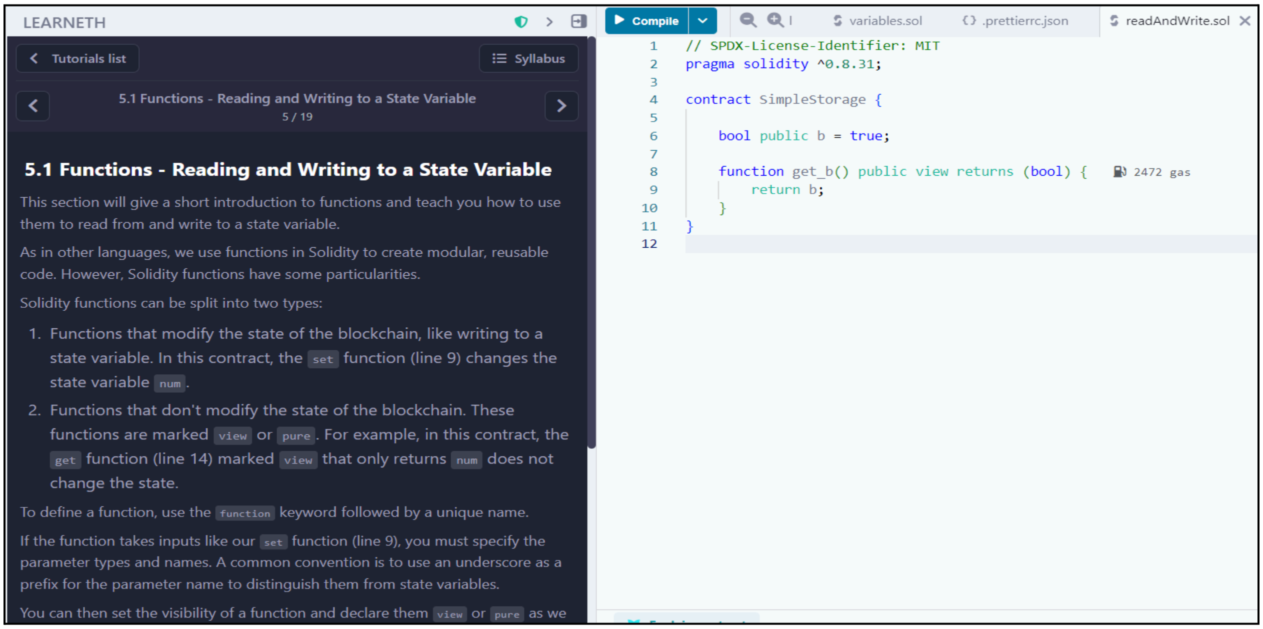
1. Create a new public state variable called `blockNumber`.
2. Inside the function `doSomething()`, assign the value of the current block number to the state variable `blockNumber`.

Tip: Look into the global variables section of the Solidity documentation to find out how to read the current block number.

Well done! No errors.

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.31;

contract Variables {

    uint public blockNumber;

    function doSomething() public {
        blockNumber = block.number;
    }
}

```

5.1 readAndWrite.sol



5.1 Functions - Reading and Writing to a State Variable
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5.1 Functions - Reading and Writing to a State Variable

This section will give a short introduction to functions and teach you how to use them to read from and write to a state variable.

As in other languages, we use functions in Solidity to create modular, reusable code. However, Solidity functions have some particularities.

Solidity functions can be split into two types:

1. Functions that modify the state of the blockchain, like writing to a state variable. In this contract, the `set` function (line 9) changes the state variable `num`.
2. Functions that don't modify the state of the blockchain. These functions are marked `view` or `pure`. For example, in this contract, the `get` function (line 14) marked `view` that only returns `num` does not change the state.

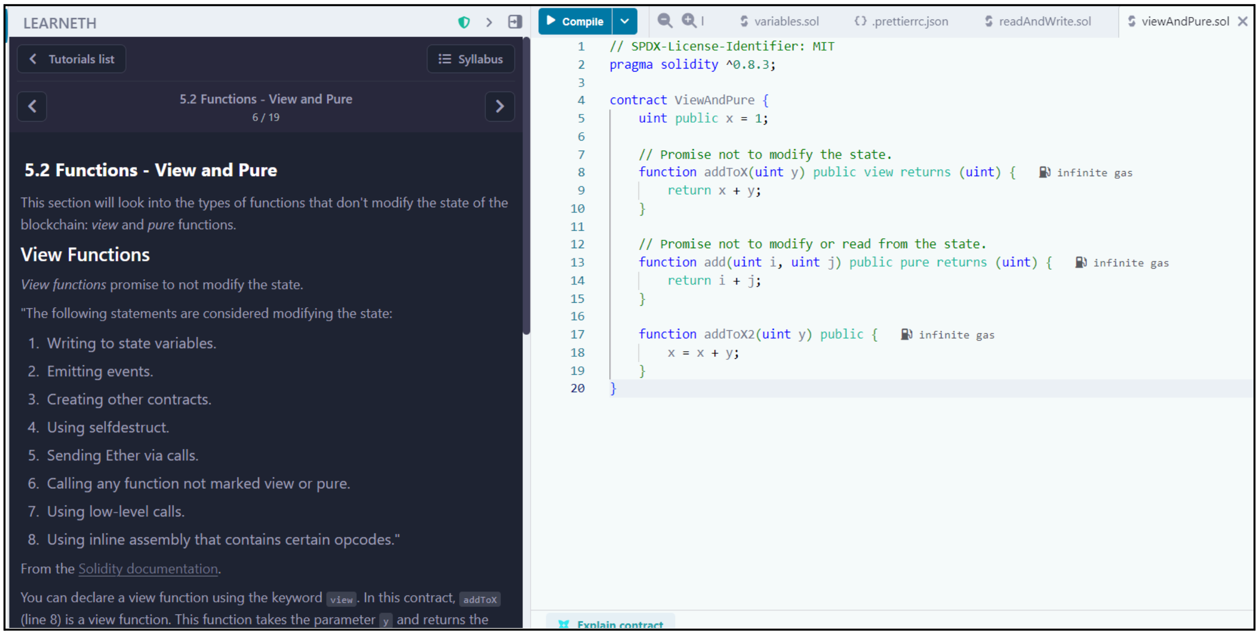
To define a function, use the `function` keyword followed by a unique name.

If the function takes inputs like our `set` function (line 9), you must specify the parameter types and names. A common convention is to use an underscore as a prefix for the parameter name to distinguish them from state variables.

You can then set the visibility of a function and declare them `view` or `pure` as we

```
1   // SPDX-License-Identifier: MIT
2   pragma solidity ^0.8.31;
3
4   contract SimpleStorage {
5
6       bool public b = true;
7
8       function get_b() public view returns (bool) {    2472 gas
9           return b;
10      }
11  }
12
```

5.2 viewAndPure.sol



5.2 Functions - View and Pure
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5.2 Functions - View and Pure

This section will look into the types of functions that don't modify the state of the blockchain: *view* and *pure* functions.

View Functions

View functions promise to not modify the state.

"The following statements are considered modifying the state:

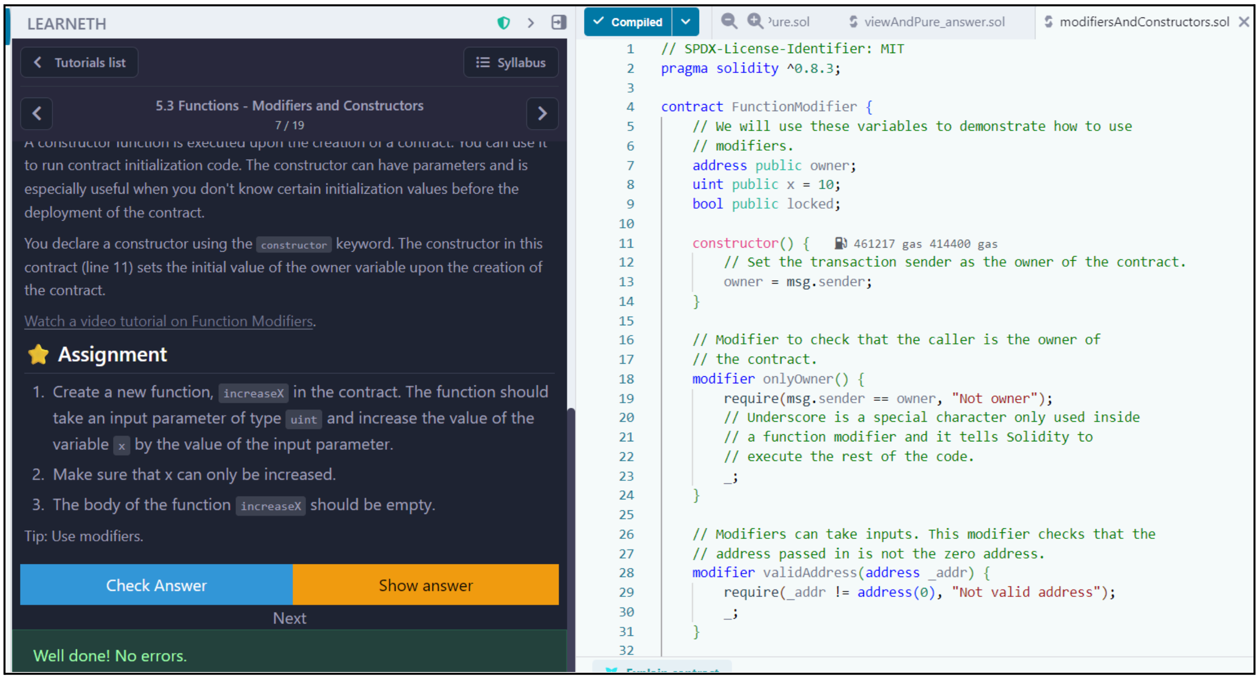
1. Writing to state variables.
2. Emitting events.
3. Creating other contracts.
4. Using selfdestruct.
5. Sending Ether via calls.
6. Calling any function not marked view or pure.
7. Using low-level calls.
8. Using inline assembly that contains certain opcodes."

From the Solidity documentation.

You can declare a view function using the keyword `view`. In this contract, `addToX` (line 8) is a view function. This function takes the parameter `y` and returns the

```
1   // SPDX-License-Identifier: MIT
2   pragma solidity ^0.8.3;
3
4   contract ViewAndPure {
5       uint public x = 1;
6
7       // Promise not to modify the state.
8       function addToX(uint y) public view returns (uint) {    infinite gas
9           return x + y;
10      }
11
12      // Promise not to modify or read from the state.
13      function add(uint i, uint j) public pure returns (uint) {    infinite gas
14          return i + j;
15      }
16
17      function addToX2(uint y) public {    infinite gas
18          x = x + y;
19      }
20  }
```

5.3 modifiersAndConstructor.sol



5.3 Functions - Modifiers and Constructors
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A constructor function is executed upon the creation of a contract. You can use it to run contract initialization code. The constructor can have parameters and is especially useful when you don't know certain initialization values before the deployment of the contract.

You declare a constructor using the `constructor` keyword. The constructor in this contract (line 11) sets the initial value of the owner variable upon the creation of the contract.

Watch a video tutorial on Function Modifiers.

⭐ Assignment

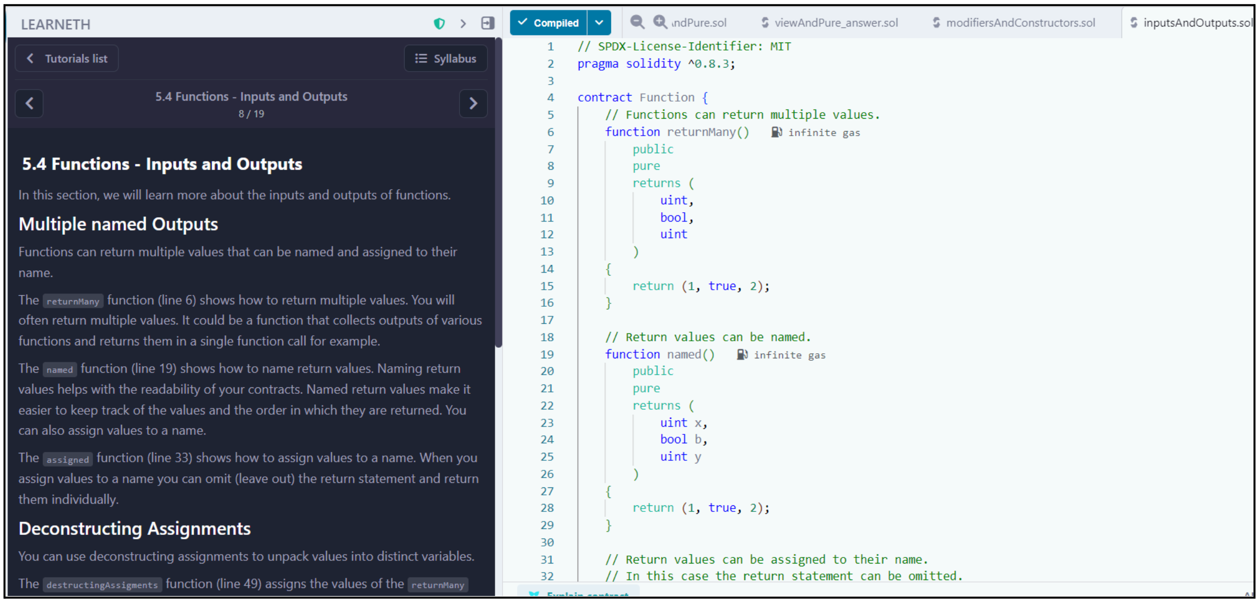
1. Create a new function, `increaseX` in the contract. The function should take an input parameter of type `uint` and increase the value of the variable `x` by the value of the input parameter.
2. Make sure that x can only be increased.
3. The body of the function `increaseX` should be empty.

Tip: Use modifiers.

Well done! No errors.

```
1   // SPDX-License-Identifier: MIT
2   pragma solidity ^0.8.3;
3
4   contract FunctionModifier {
5       // We will use these variables to demonstrate how to use
6       // modifiers.
7       address public owner;
8       uint public x = 10;
9       bool public locked;
10
11      constructor() {    461217 gas 414400 gas
12          // Set the transaction sender as the owner of the contract.
13          owner = msg.sender;
14      }
15
16      // Modifier to check that the caller is the owner of
17      // the contract.
18      modifier onlyOwner() {
19          require(msg.sender == owner, "Not owner");
20          // Underscore is a special character only used inside
21          // a function modifier and it tells Solidity to
22          // execute the rest of the code.
23          _;
24      }
25
26      // Modifiers can take inputs. This modifier checks that the
27      // address passed in is not the zero address.
28      modifier validAddress(address _addr) {
29          require(_addr != address(0), "Not valid address");
30          _;
31      }
32
```

5.4 inputsAndOutputs.sol



5.4 Functions - Inputs and Outputs
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5.4 Functions - Inputs and Outputs

In this section, we will learn more about the inputs and outputs of functions.

Multiple named Outputs

Functions can return multiple values that can be named and assigned to their name.

The `returnMany` function (line 6) shows how to return multiple values. You will often return multiple values. It could be a function that collects outputs of various functions and returns them in a single function call for example.

The `named` function (line 19) shows how to name return values. Naming return values helps with the readability of your contracts. Named return values make it easier to keep track of the values and the order in which they are returned. You can also assign values to a name.

The `assigned` function (line 33) shows how to assign values to a name. When you assign values to a name you can omit (leave out) the return statement and return them individually.

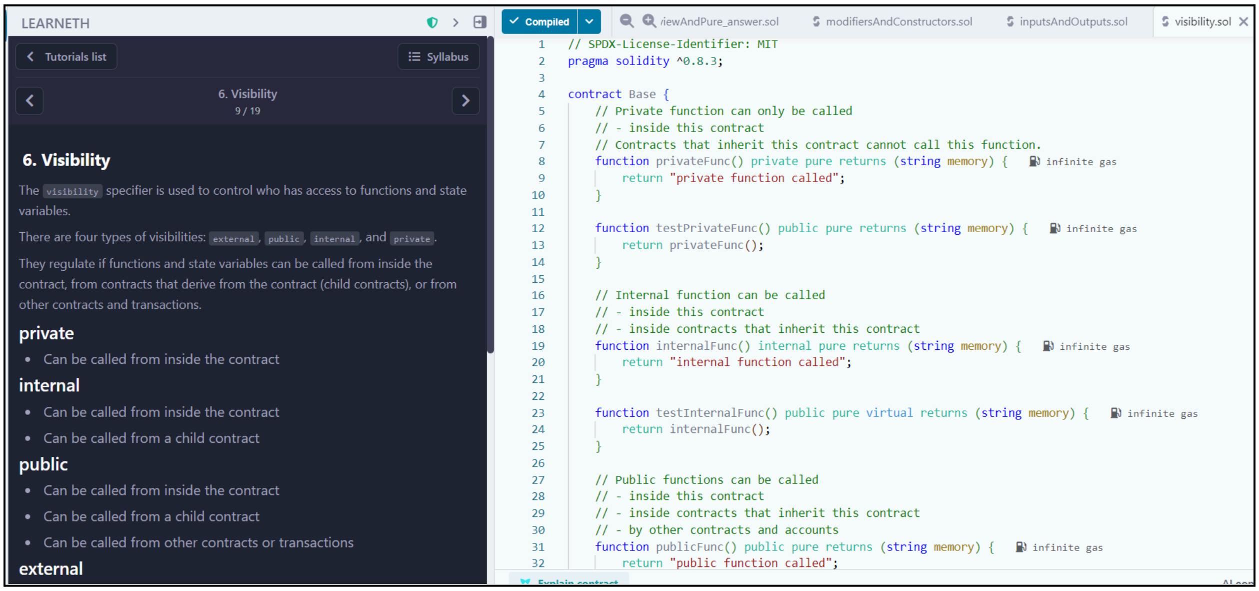
Deconstructing Assignments

You can use deconstructing assignments to unpack values into distinct variables.

The `destructingAssigments` function (line 49) assigns the values of the `returnMany`

```
1   // SPDX-License-Identifier: MIT
2   pragma solidity ^0.8.3;
3
4   contract Function {
5       // Functions can return multiple values.
6       function returnMany()    infinite gas
7           public
8           pure
9           returns (
10              uint,
11              bool,
12              uint
13          )
14      {
15          return (1, true, 2);
16      }
17
18      // Return values can be named.
19      function named()    infinite gas
20          public
21          pure
22          returns (
23              uint x,
24              bool b,
25              uint y
26          )
27      {
28          return (1, true, 2);
29      }
30
31      // Return values can be assigned to their name.
32      // In this case the return statement can be omitted.
```

6. visibility.sol



6. Visibility

The `visibility` specifier is used to control who has access to functions and state variables.

There are four types of visibilities: `external`, `public`, `internal`, and `private`.

They regulate if functions and state variables can be called from inside the contract, from contracts that derive from the contract (child contracts), or from other contracts and transactions.

private

- Can be called from inside the contract

internal

- Can be called from inside the contract
- Can be called from a child contract

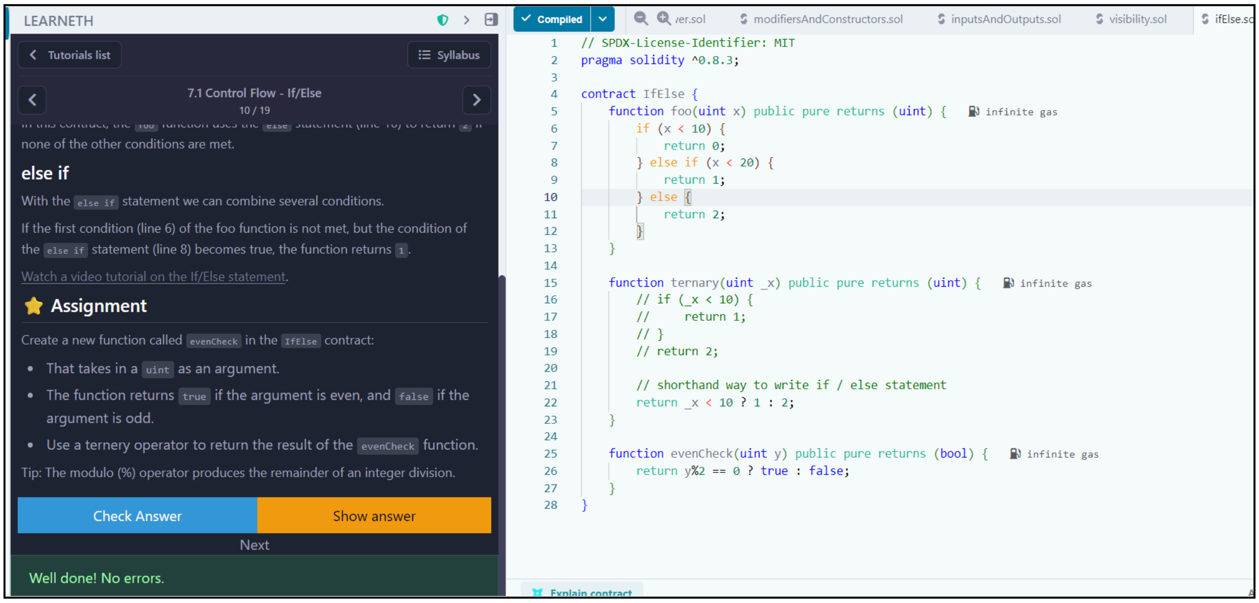
public

- Can be called from inside the contract
- Can be called from a child contract
- Can be called from other contracts or transactions

external

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.3;

contract Base {
    // Private function can only be called
    // - inside this contract
    // Contracts that inherit this contract cannot call this function.
    function privateFunc() private pure returns (string memory) {
        return "private function called";
    }

    function testPrivateFunc() public pure returns (string memory) {
        return privateFunc();
    }

    // Internal function can be called
    // - inside this contract
    // - inside contracts that inherit this contract
    function internalFunc() internal pure returns (string memory) {
        return "internal function called";
    }

    function testInternalFunc() public pure virtual returns (string memory) {
        return internalFunc();
    }

    // Public functions can be called
    // - inside this contract
    // - inside contracts that inherit this contract
    // - by other contracts and accounts
    function publicFunc() public pure returns (string memory) {
        return "public function called";
```

7.1 ControlFlow.sol



In this contract, the `foo` function uses the `else` statement (line 10) to return `2` if none of the other conditions are met.

else if

With the `else if` statement we can combine several conditions.

If the first condition (line 6) of the foo function is not met, but the condition of the `else if` statement (line 8) becomes true, the function returns `1`.

Watch a video tutorial on the If/Else statement.

⭐ Assignment

Create a new function called `evenCheck` in the `IfElse` contract:

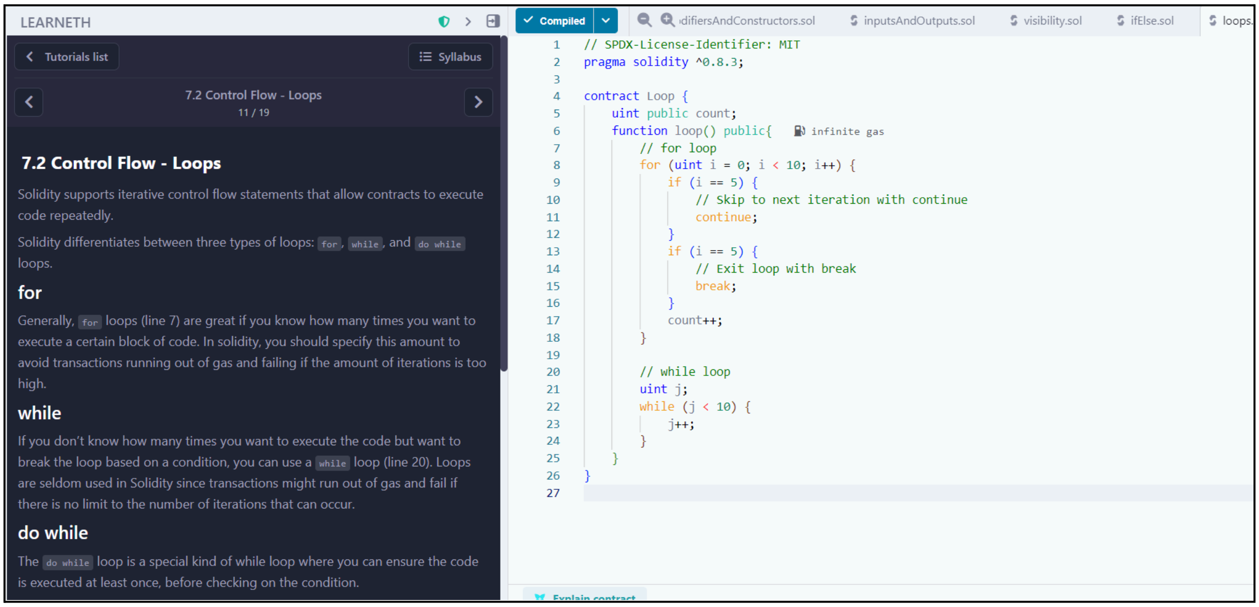
- That takes in a `uint` as an argument.
- The function returns `true` if the argument is even, and `false` if the argument is odd.
- Use a ternery operator to return the result of the `evenCheck` function.

Tip: The modulo (%) operator produces the remainder of an integer division.

Well done! No errors.

```
1   // SPDX-License-Identifier: MIT
2   pragma solidity ^0.8.3;
3
4   contract IfElse {
5       function foo(uint x) public pure returns (uint) {
6           if (x < 10) {
7               return 0;
8           } else if (x < 20) {
9               return 1;
10          } else {
11              return 2;
12          }
13      }
14
15      function ternary(uint _x) public pure returns (uint) {
16          // if (_x < 10) {
17          //     return 1;
18          // }
19          // return 2;
20
21          // shorthand way to write if / else statement
22          return _x < 10 ? 1 : 2;
23      }
24
25      function evenCheck(uint y) public pure returns (bool) {
26          return y%2 == 0 ? true : false;
27      }
28  }
```

7.2 loops.sol



7.2 Control Flow - Loops

Solidity supports iterative control flow statements that allow contracts to execute code repeatedly.

Solidity differentiates between three types of loops: `for`, `while`, and `do while` loops.

for

Generally, `for` loops (line 7) are great if you know how many times you want to execute a certain block of code. In solidity, you should specify this amount to avoid transactions running out of gas and failing if the amount of iterations is too high.

while

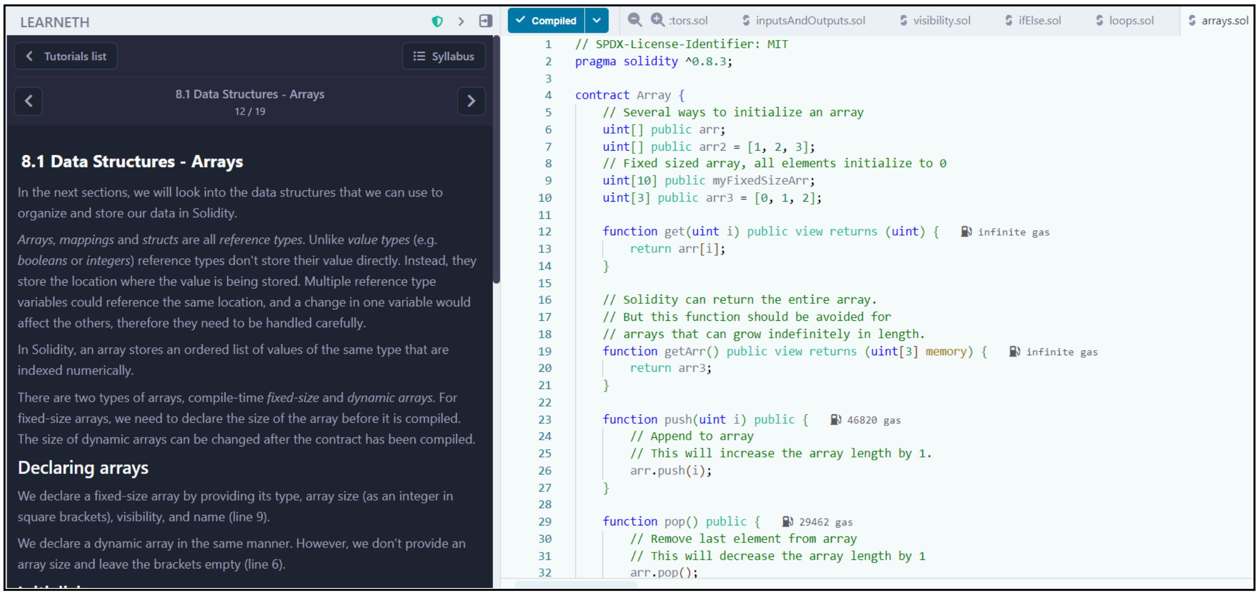
If you don't know how many times you want to execute the code but want to break the loop based on a condition, you can use a `while` loop (line 20). Loops are seldom used in Solidity since transactions might run out of gas and fail if there is no limit to the number of iterations that can occur.

do while

The `do while` loop is a special kind of while loop where you can ensure the code is executed at least once, before checking on the condition.

```
1   // SPDX-License-Identifier: MIT
2   pragma solidity ^0.8.3;
3
4   contract Loop {
5       uint public count;
6       function loop() public{
7           // for loop
8           for (uint i = 0; i < 10; i++) {
9               if (i == 5) {
10                  // Skip to next iteration with continue
11                  continue;
12              }
13              if (i == 5) {
14                  // Exit loop with break
15                  break;
16              }
17              count++;
18          }
19
20          // while loop
21          uint j;
22          while (j < 10) {
23              j++;
24          }
25      }
26  }
27
```

8.1 arrays.sol



8.1 Data Structures - Arrays

In the next sections, we will look into the data structures that we can use to organize and store our data in Solidity.

Arrays, *mappings* and *structs* are all *reference types*. Unlike *value types* (e.g. *booleans* or *integers*) reference types don't store their value directly. Instead, they store the location where the value is being stored. Multiple reference type variables could reference the same location, and a change in one variable would affect the others, therefore they need to be handled carefully.

In Solidity, an array stores an ordered list of values of the same type that are indexed numerically.

There are two types of arrays, compile-time *fixed-size* and *dynamic arrays*. For fixed-size arrays, we need to declare the size of the array before it is compiled. The size of dynamic arrays can be changed after the contract has been compiled.

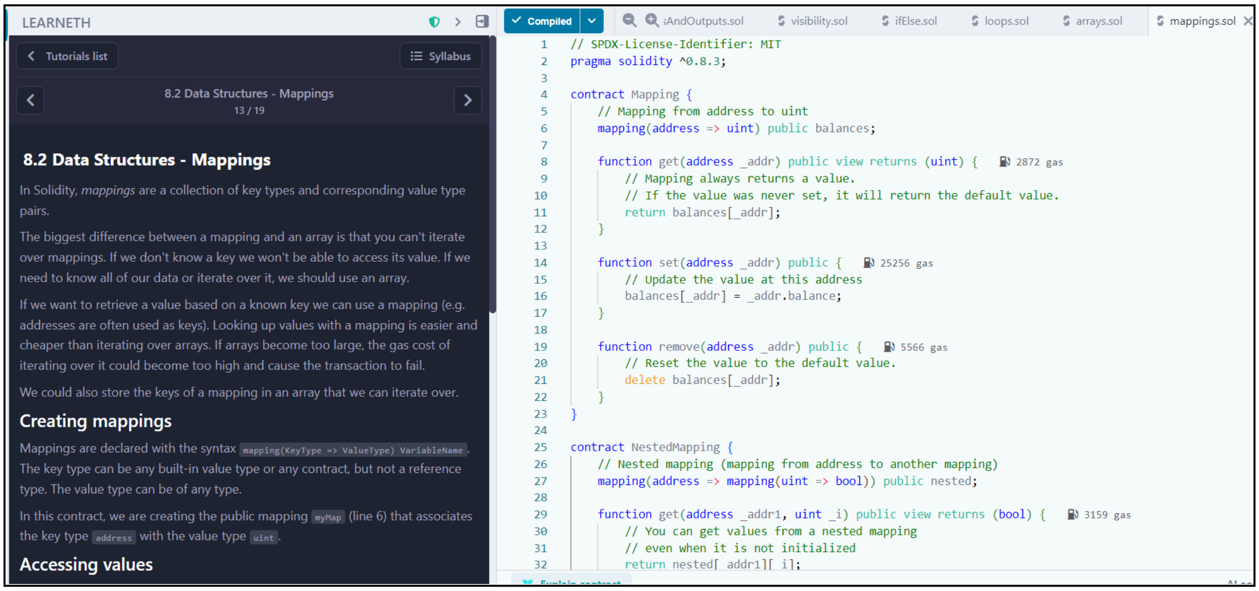
Declaring arrays

We declare a fixed-size array by providing its type, array size (as an integer in square brackets), visibility, and name (line 9).

We declare a dynamic array in the same manner. However, we don't provide an array size and leave the brackets empty (line 6).

```
1   // SPDX-License-Identifier: MIT
2   pragma solidity ^0.8.3;
3
4   contract Array {
5       // Several ways to initialize an array
6       uint[] public arr;
7       uint[] public arr2 = [1, 2, 3];
8       // Fixed sized array, all elements initialize to 0
9       uint[10] public myFixedSizeArr;
10      uint[3] public arr3 = [0, 1, 2];
11
12      function get(uint i) public view returns (uint) {
13          return arr[i];
14      }
15
16      // Solidity can return the entire array.
17      // But this function should be avoided for
18      // arrays that can grow indefinitely in length.
19      function getArr() public view returns (uint[3] memory) {
20          return arr3;
21      }
22
23      function push(uint i) public {
24          // Append to array
25          // This will increase the array length by 1.
26          arr.push(i);
27      }
28
29      function pop() public {
30          // Remove last element from array
31          // This will decrease the array length by 1
32          arr.pop();
```

8.2 mapping.sol



8.2 Data Structures - Mappings
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8.2 Data Structures - Mappings

In Solidity, *mappings* are a collection of key types and corresponding value type pairs.

The biggest difference between a mapping and an array is that you can't iterate over mappings. If we don't know a key we won't be able to access its value. If we need to know all of our data or iterate over it, we should use an array.

If we want to retrieve a value based on a known key we can use a mapping (e.g. addresses are often used as keys). Looking up values with a mapping is easier and cheaper than iterating over arrays. If arrays become too large, the gas cost of iterating over it could become too high and cause the transaction to fail.

We could also store the keys of a mapping in an array that we can iterate over.

Creating mappings

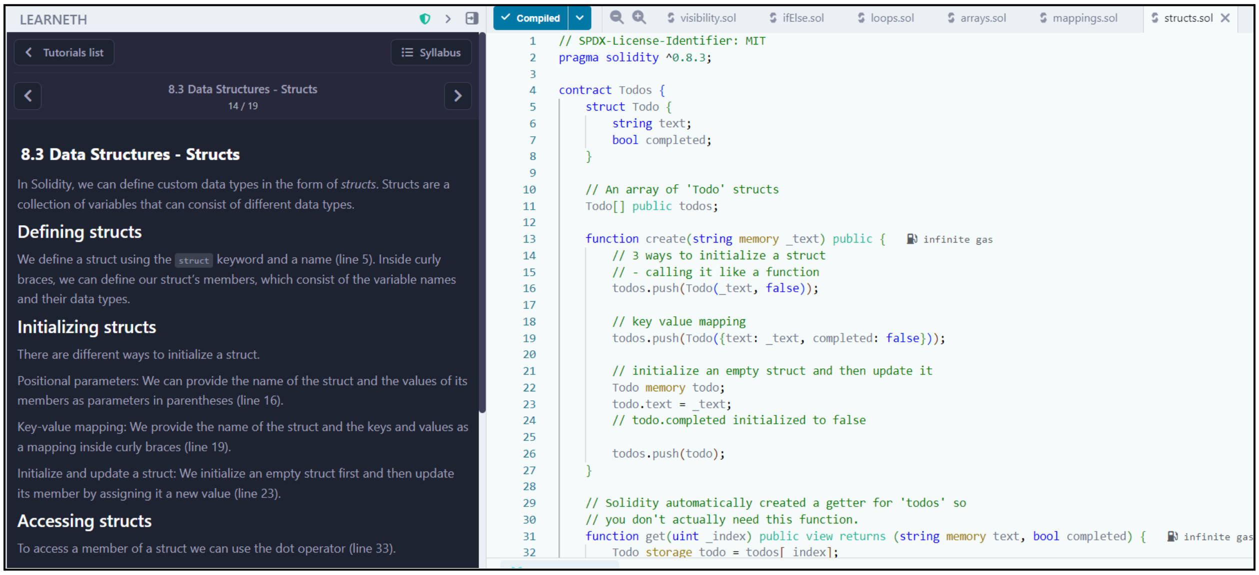
Mappings are declared with the syntax `mapping(KeyType => ValueType) VariableName`. The key type can be any built-in value type or any contract, but not a reference type. The value type can be of any type.

In this contract, we are creating the public mapping `myMap` (line 6) that associates the key type `address` with the value type `uint`.

Accessing values

```
1   // SPDX-License-Identifier: MIT
2   pragma solidity ^0.8.3;
3
4   contract Mapping {
5       // Mapping from address to uint
6       mapping(address => uint) public balances;
7
8       function get(address _addr) public view returns (uint) {    2872 gas
9           // Mapping always returns a value.
10          // If the value was never set, it will return the default value.
11          return balances[_addr];
12      }
13
14      function set(address _addr) public {    25256 gas
15          // Update the value at this address
16          balances[_addr] = _addr.balance;
17      }
18
19      function remove(address _addr) public {    5566 gas
20          // Reset the value to the default value.
21          delete balances[_addr];
22      }
23  }
24
25  contract NestedMapping {
26      // Nested mapping (mapping from address to another mapping)
27      mapping(address => mapping(uint => bool)) public nested;
28
29      function get(address _addr1, uint _i) public view returns (bool) {    3159 gas
30          // You can get values from a nested mapping
31          // even when it is not initialized
32          return nested[_addr1][_i];
```

8.3 structs.sol



8.3 Data Structures - Structs
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8.3 Data Structures - Structs

In Solidity, we can define custom data types in the form of *structs*. Structs are a collection of variables that can consist of different data types.

Defining structs

We define a struct using the `struct` keyword and a name (line 5). Inside curly braces, we can define our struct's members, which consist of the variable names and their data types.

Initializing structs

There are different ways to initialize a struct.

Positional parameters: We can provide the name of the struct and the values of its members as parameters in parentheses (line 16).

Key-value mapping: We provide the name of the struct and the keys and values as a mapping inside curly braces (line 19).

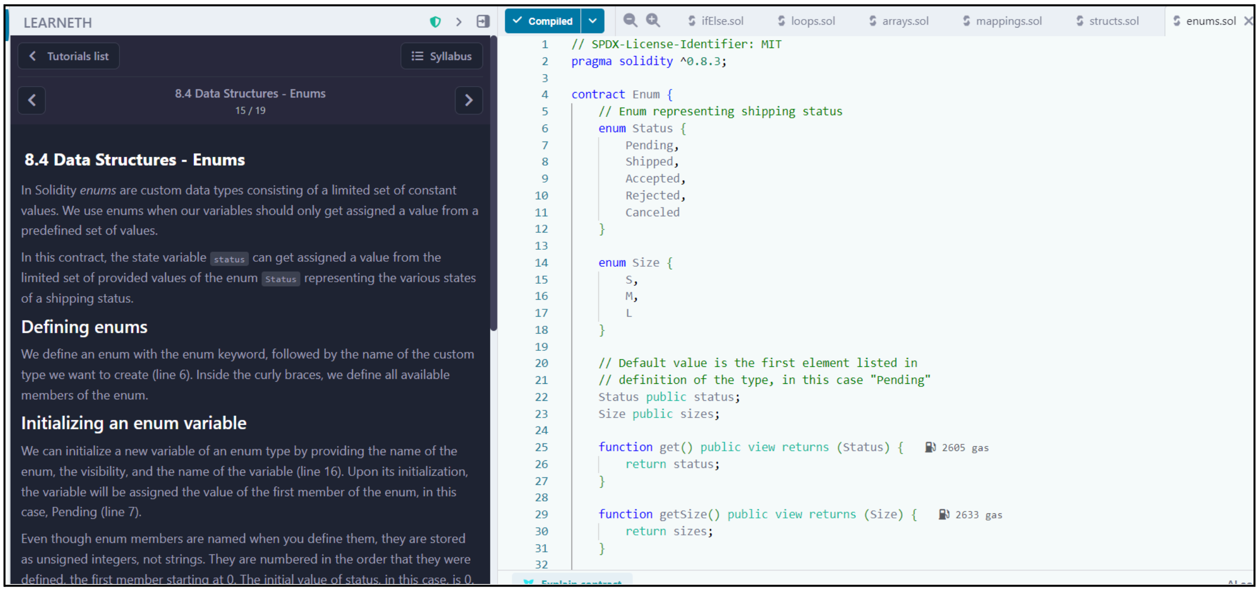
Initialize and update a struct: We initialize an empty struct first and then update its member by assigning it a new value (line 23).

Accessing structs

To access a member of a struct we can use the dot operator (line 33).

```
1   // SPDX-License-Identifier: MIT
2   pragma solidity ^0.8.3;
3
4   contract Todos {
5       struct Todo {
6           string text;
7           bool completed;
8       }
9
10      // An array of 'Todo' structs
11      Todo[] public todos;
12
13      function create(string memory _text) public {    infinite gas
14          // 3 ways to initialize a struct
15          // - calling it like a function
16          todos.push(Todo(_text, false));
17
18          // key value mapping
19          todos.push(Todo({text: _text, completed: false}));
20
21          // initialize an empty struct and then update it
22          Todo memory todo;
23          todo.text = _text;
24          // todo.completed initialized to false
25
26          todos.push(todo);
27      }
28
29      // Solidity automatically created a getter for 'todos' so
30      // you don't actually need this function.
31      function get(uint _index) public view returns (string memory text, bool completed) {    infinite gas
32          Todo storage todo = todos[_index];
```

8.4 enums.sol



8.4 Data Structures - Enums

In Solidity *enums* are custom data types consisting of a limited set of constant values. We use enums when our variables should only get assigned a value from a predefined set of values.

In this contract, the state variable `status` can get assigned a value from the limited set of provided values of the enum `Status` representing the various states of a shipping status.

Defining enums

We define an enum with the enum keyword, followed by the name of the custom type we want to create (line 6). Inside the curly braces, we define all available members of the enum.

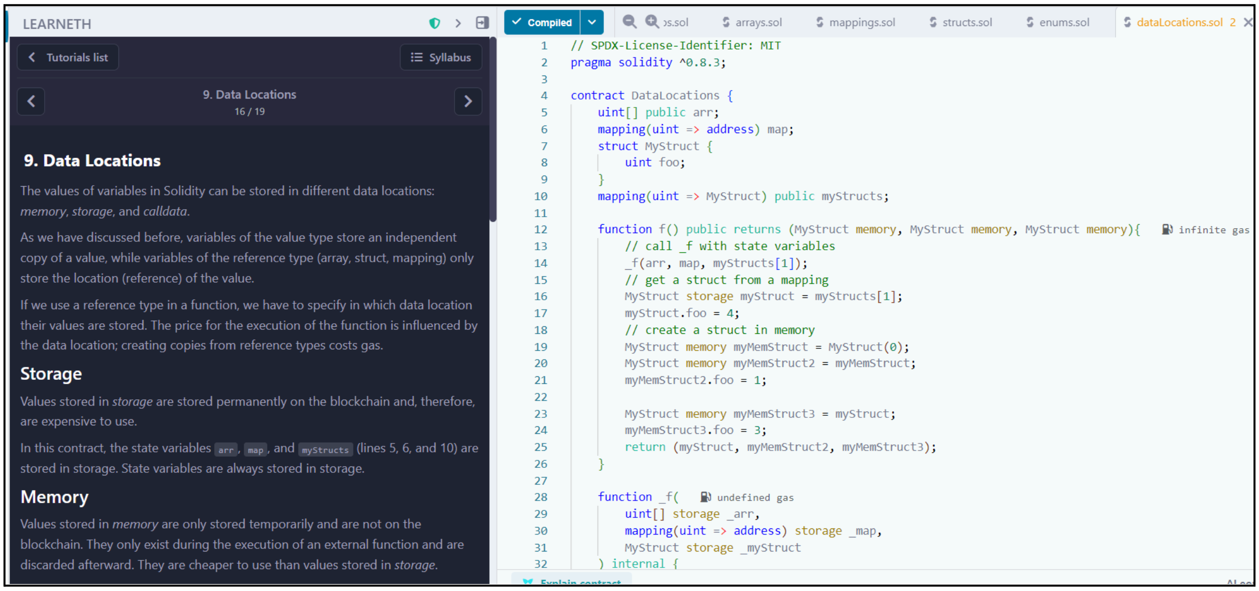
Initializing an enum variable

We can initialize a new variable of an enum type by providing the name of the enum, the visibility, and the name of the variable (line 16). Upon its initialization, the variable will be assigned the value of the first member of the enum, in this case, Pending (line 7).

Even though enum members are named when you define them, they are stored as unsigned integers, not strings. They are numbered in the order that they were defined, the first member starting at 0. The initial value of status, in this case, is 0.

```
1   // SPDX-License-Identifier: MIT
2   pragma solidity ^0.8.3;
3
4   contract Enum {
5       // Enum representing shipping status
6       enum Status {
7           Pending,
8           Shipped,
9           Accepted,
10          Rejected,
11          Canceled
12      }
13
14      enum Size {
15          S,
16          M,
17          L
18      }
19
20      // Default value is the first element listed in
21      // definition of the type, in this case "Pending"
22      Status public status;
23      Size public sizes;
24
25      function get() public view returns (Status) {
26          return status;
27      }
28
29      function getSize() public view returns (Size) {
30          return sizes;
31      }
32
```

9. dataLocations.sol



9. Data Locations

The values of variables in Solidity can be stored in different data locations: *memory*, *storage*, and *calldata*.

As we have discussed before, variables of the value type store an independent copy of a value, while variables of the reference type (array, struct, mapping) only store the location (reference) of the value.

If we use a reference type in a function, we have to specify in which data location their values are stored. The price for the execution of the function is influenced by the data location; creating copies from reference types costs gas.

Storage

Values stored in *storage* are stored permanently on the blockchain and, therefore, are expensive to use.

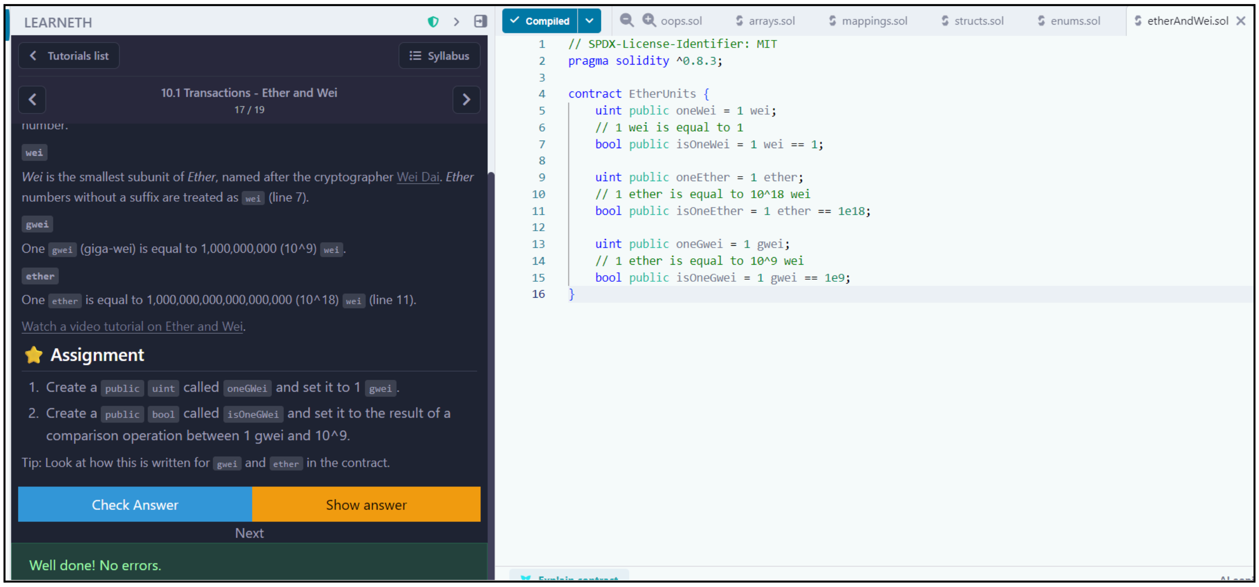
In this contract, the state variables `arr`, `map`, and `myStructs` (lines 5, 6, and 10) are stored in storage. State variables are always stored in storage.

Memory

Values stored in *memory* are only stored temporarily and are not on the blockchain. They only exist during the execution of an external function and are discarded afterward. They are cheaper to use than values stored in *storage*.

```
1   // SPDX-License-Identifier: MIT
2   pragma solidity ^0.8.3;
3
4   contract DataLocations {
5       uint[] public arr;
6       mapping(uint => address) map;
7       struct MyStruct {
8           uint foo;
9       }
10      mapping(uint => MyStruct) public myStructs;
11
12      function f() public returns (MyStruct memory, MyStruct memory, MyStruct memory){
13          // call _f with state variables
14          _f(arr, map, myStructs[1]);
15          // get a struct from a mapping
16          MyStruct storage myStruct = myStructs[1];
17          myStruct.foo = 4;
18          // create a struct in memory
19          MyStruct memory myMemStruct = MyStruct(0);
20          MyStruct memory myMemStruct2 = myMemStruct;
21          myMemStruct2.foo = 1;
22
23          MyStruct memory myMemStruct3 = myStruct;
24          myMemStruct3.foo = 3;
25          return (myStruct, myMemStruct2, myMemStruct3);
26      }
27
28      function _f(
29          uint[] storage _arr,
30          mapping(uint => address) storage _map,
31          MyStruct storage _myStruct
32      ) internal {
```

10.1 etherAndWei.sol



10.1 Transactions - Ether and Wei
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number.

`wei`

Wei is the smallest subunit of *Ether*, named after the cryptographer Wei Dai. *Ether* numbers without a suffix are treated as `wei` (line 7).

`gwei`

One `gwei` (giga-wei) is equal to 1,000,000,000 (10^9) `wei`.

`ether`

One `ether` is equal to 1,000,000,000,000,000,000 (10^18) `wei` (line 11).

Watch a video tutorial on Ether and Wei.

⭐ Assignment

1. Create a `public` `uint` called `oneGWei` and set it to 1 `gwei`.
2. Create a `public` `bool` called `isOneGWei` and set it to the result of a comparison operation between 1 gwei and 10^9.

Tip: Look at how this is written for `gwei` and `ether` in the contract.

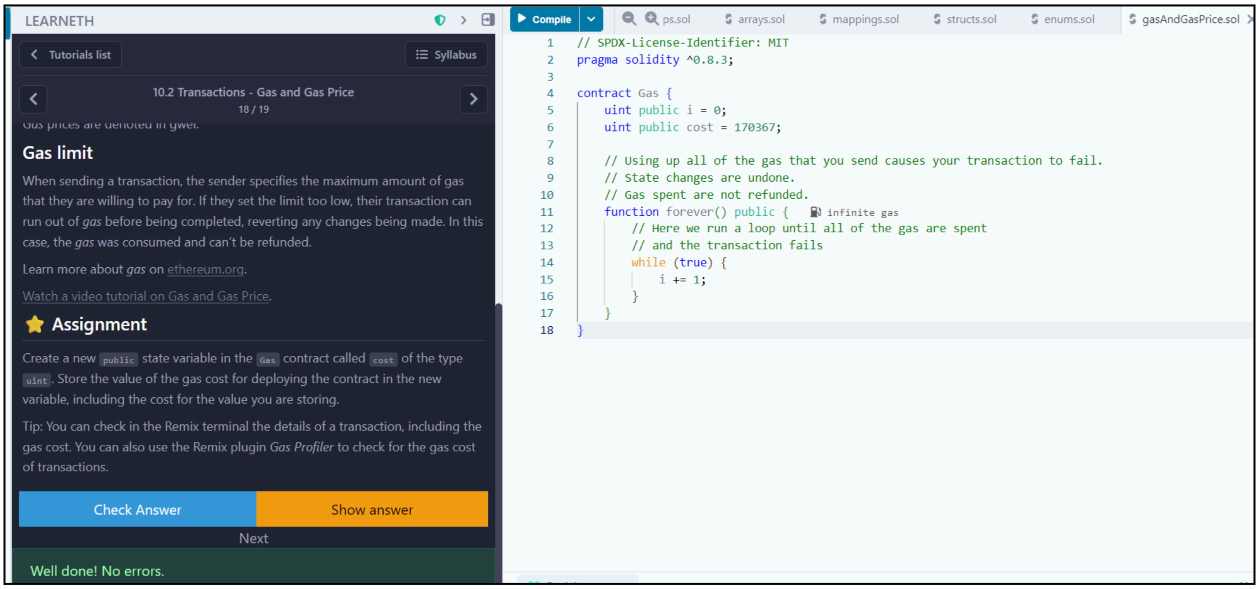
Check Answer | Show answer

Next

Well done! No errors.

```
1   // SPDX-License-Identifier: MIT
2   pragma solidity ^0.8.3;
3
4   contract EtherUnits {
5       uint public oneWei = 1 wei;
6       // 1 wei is equal to 1
7       bool public isOneWei = 1 wei == 1;
8
9       uint public oneEther = 1 ether;
10      // 1 ether is equal to 10^18 wei
11      bool public isOneEther = 1 ether == 1e18;
12
13      uint public oneGwei = 1 gwei;
14      // 1 ether is equal to 10^9 wei
15      bool public isOneGwei = 1 gwei == 1e9;
16  }
```

10.2 gasAndGasPrice.sol



10.2 Transactions - Gas and Gas Price
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Gas prices are denoted in gwei.

Gas limit

When sending a transaction, the sender specifies the maximum amount of gas that they are willing to pay for. If they set the limit too low, their transaction can run out of *gas* before being completed, reverting any changes being made. In this case, the *gas* was consumed and can't be refunded.

Learn more about *gas* on ethereum.org.

Watch a video tutorial on Gas and Gas Price.

⭐ Assignment

Create a new `public` state variable in the `Gas` contract called `cost` of the type `uint`. Store the value of the gas cost for deploying the contract in the new variable, including the cost for the value you are storing.

Tip: You can check in the Remix terminal the details of a transaction, including the gas cost. You can also use the Remix plugin *Gas Profiler* to check for the gas cost of transactions.

Check Answer | Show answer

Next

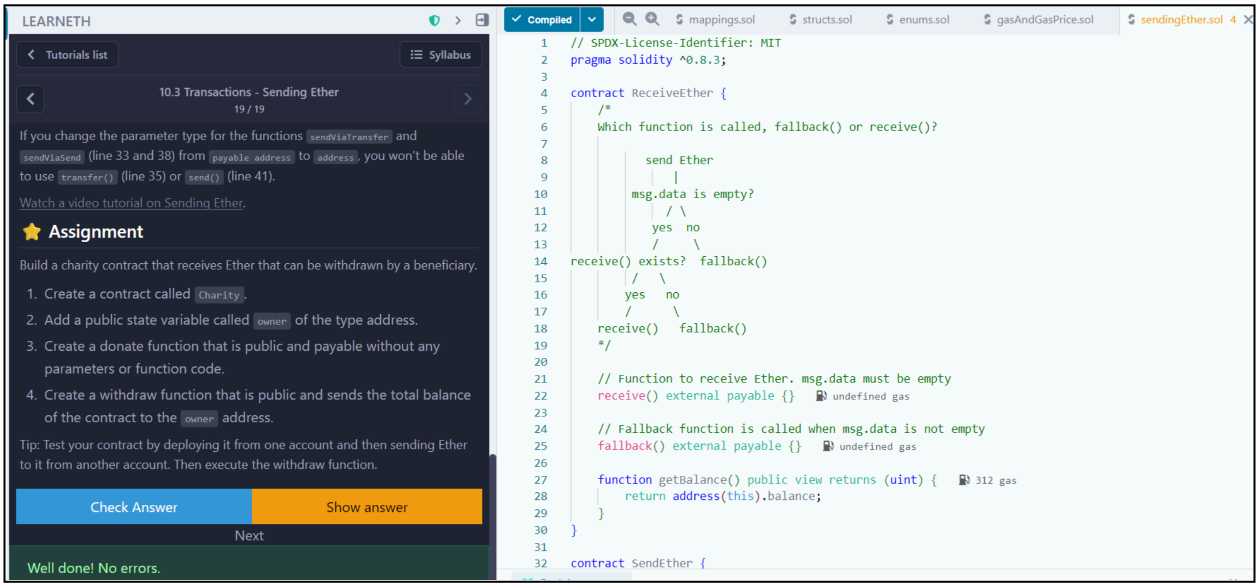
Well done! No errors.

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.3;

contract Gas {
    uint public i = 0;
    uint public cost = 170367;

    // Using up all of the gas that you send causes your transaction to fail.
    // State changes are undone.
    // Gas spent are not refunded.
    function forever() public {    infinite gas
        // Here we run a loop until all of the gas are spent
        // and the transaction fails
        while (true) {
            i += 1;
        }
    }
}
```

10.3 sendingEther.sol



10.3 Transactions - Sending Ether

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If you change the parameter type for the functions `sendViaTransfer` and `sendViaSend` (line 33 and 38) from `payable address` to `address`, you won't be able to use `transfer()` (line 35) or `send()` (line 41).

Watch a video tutorial on Sending Ether.

⭐ Assignment

Build a charity contract that receives Ether that can be withdrawn by a beneficiary.

1. Create a contract called `Charity`.
2. Add a public state variable called `owner` of the type address.
3. Create a donate function that is public and payable without any parameters or function code.
4. Create a withdraw function that is public and sends the total balance of the contract to the `owner` address.

Tip: Test your contract by deploying it from one account and then sending Ether to it from another account. Then execute the withdraw function.

Check Answer | Show answer

Next

Well done! No errors.

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.3;

contract ReceiveEther {
    /*
    Which function is called, fallback() or receive()?

           send Ether
               |
         msg.data is empty?
              / \
            yes  no
            /     \
receive() exists?  fallback()
        /   \
       yes   no
       /      \
    receive()   fallback()
    */

    // Function to receive Ether. msg.data must be empty
    receive() external payable {}

    // Fallback function is called when msg.data is not empty
    fallback() external payable {}

    function getBalance() public view returns (uint) {
        return address(this).balance;
    }
}

contract SendEther {
```

Conclusion - This experiment provides hands-on experience in Solidity programming by exploring core blockchain concepts, data types, control structures, and transaction handling. Understanding these fundamentals enables the design and deployment of secure, efficient, and reliable smart contracts on the Ethereum blockchain.