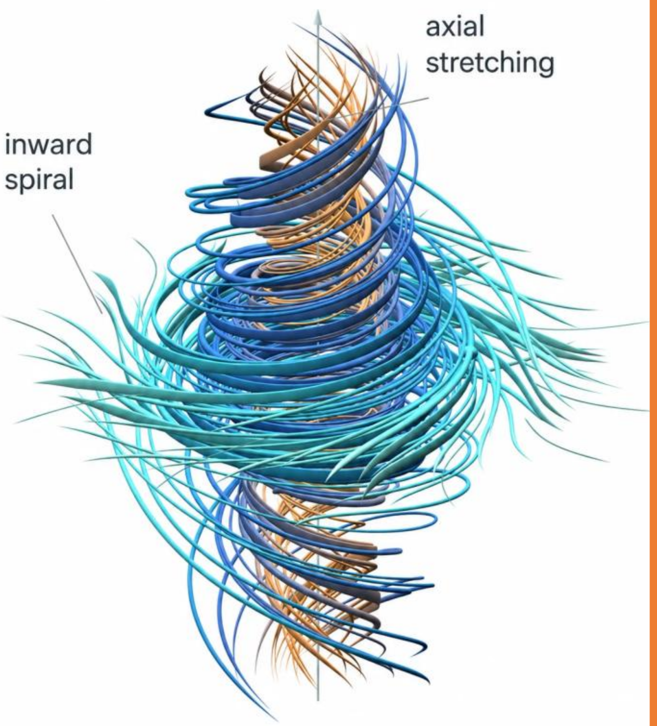
Bonus Slide

OpenAI Solves Navier-Stokes?

Tue 09/08/26: OpenAI announced that they have solved the Navier-Stokes existence and smoothness problem, one of the Millenium Prize problems. They used a new internal AI model and approximately 10,000 concurrent agents to do this. Their proof has not yet been verified by external mathematicians.

The Millenium Prize problems are seven incredibly hard open math problems that people have been working to solve for decades. The Navier-Stokes problem in particular is related to the question of how fluids move and has been an open problem since ~1850.

There has been some controversary as two other mathematicians (one who works at Anthropic) made progress on a similar problem using a similar approach very recently. They have raised questions about whether their AI data was used to train the OpenAI model that solved the problem. OpenAI has denied direct use of their data.



Unit 1: Fundamentals of Programming

Conditionals and Errors

15-110 – Wednesday 09/09

Quizlet1

Learning Goals

- Use **logical operators** on Booleans to compute whether an expression is True or False
- Use **conditionals** when reading and writing algorithms that make choices based on data
- Use **nesting** of control structures to create complex control flow
- Recognize the different types of **errors** that can be raised when you run Python code

Logical Operators

Booleans are values that can be True or False

In week 1, we learned about the **Boolean** type, which can be one of two values: `True` or `False`.

Until now, we've made Boolean values by comparing different values, such as:

```
x < 5
s == "Hello"
7 >= 2
```

Logical Operations Combine Booleans

We aren't limited to only evaluating a single Boolean comparison! We can **combine** Boolean values using **logical operations.** We'll learn about three – **and, or,** and **not**.

Combining Boolean values will let us check complex requirements while running code.

and Operation Checks Both

The and operation takes two Boolean values and evaluates to True if **both** values are True. In other words, it evaluates to False if **either** value is False.

We use and when we want to require that both conditions be met at the same time.

Example:

```
(x >= 0) and (x < 10)
```

a	b	a and b
True	True	**True**
True	False	False
False	True	False
False	False	False

`or` Operation Checks Either

The `or` operation takes two Boolean values and evaluates to `True` if **either** value is `True`. In other words, it only evaluates to `False` if **both** values are `False`.

We use `or` when there are multiple valid conditions to choose from.

a	b	a or b
True	True	True
True	False	True
False	True	True
False	False	**False**

Example:

```
(day == "Saturday") or (day == "Sunday")
```

`not` Operation Reverses Result

Finally, the `not` operation takes a single Boolean value and switches it to the opposite value (negates it). `not True` becomes `False`, and `not False` becomes `True`.

We use `not` to switch the result of a Boolean expression. For example, `not (x < 5)` is the same as `x >= 5`.

Example:

```
not (x == 0)
```

a	not a
True	False
False	True

Activity: Guess the Result

If `x = 10`, what will each of the following expressions evaluate to?

```
x < 25 or x > 15
```

```
not (x > 5 and x <= 10)
```

```
(x > 5) or ((x**2 > 50) and (x == 20))
```

Conditionals

Conditionals Make Decisions

With Booleans, we can make a new type of code called a **conditional**. Conditionals are a form of a **control structure** – they let us change the direction of the code based on the value that we provide.

To write a conditional (`if` **statement**), we use the following structure:

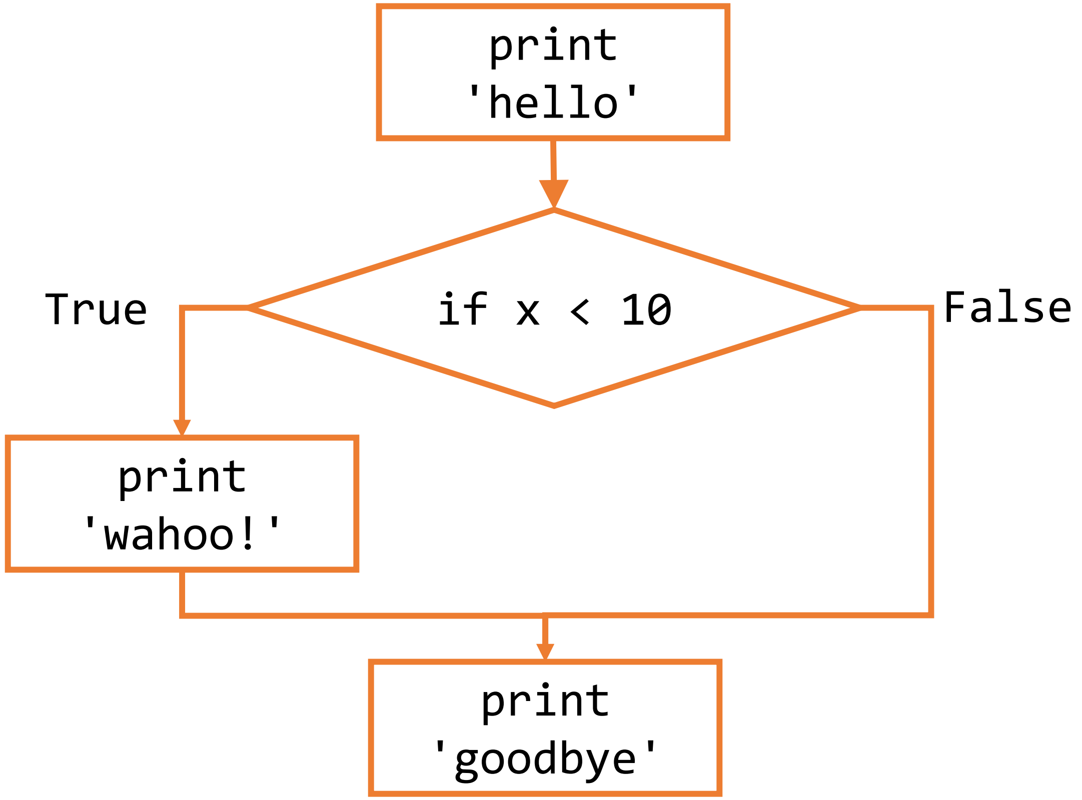
```
if <BooleanExpression>:
    <bodyIfTrue>
```

Note that, like a function definition, the top line of the `if` statement ends with a colon, and the **body** of the if statement is indented. The body must have at least one line and can have as many more lines as it needs.

Flow Charts Show Code Choices

We'll use a **flow chart** to demonstrate how Python executes an `if` statement based on the values provided.

```
print("hello")
if x < 10:
    print("wahoo!")
print("goodbye")
```



`wahoo!` is only printed if `x` is less than `10`. But `hello` and `goodbye` are always printed.

Example: Print Number of Digits

For example, we could use the following code to print whether a number has one digit or more than one digit:

```
x = 24
if -10 < x and x < 10:
    print("Only one digit")
if x <= -10 or x >= 10:
    print("More than one digit")
```

Else Clauses Allow Alternatives

Sometimes we want a program to do one of two alternative actions based on the condition. In this case, instead of writing two `if` statements, we can write a single `if` statement and add an **`else`**.

The `else` is executed when the Boolean expression is `False`.

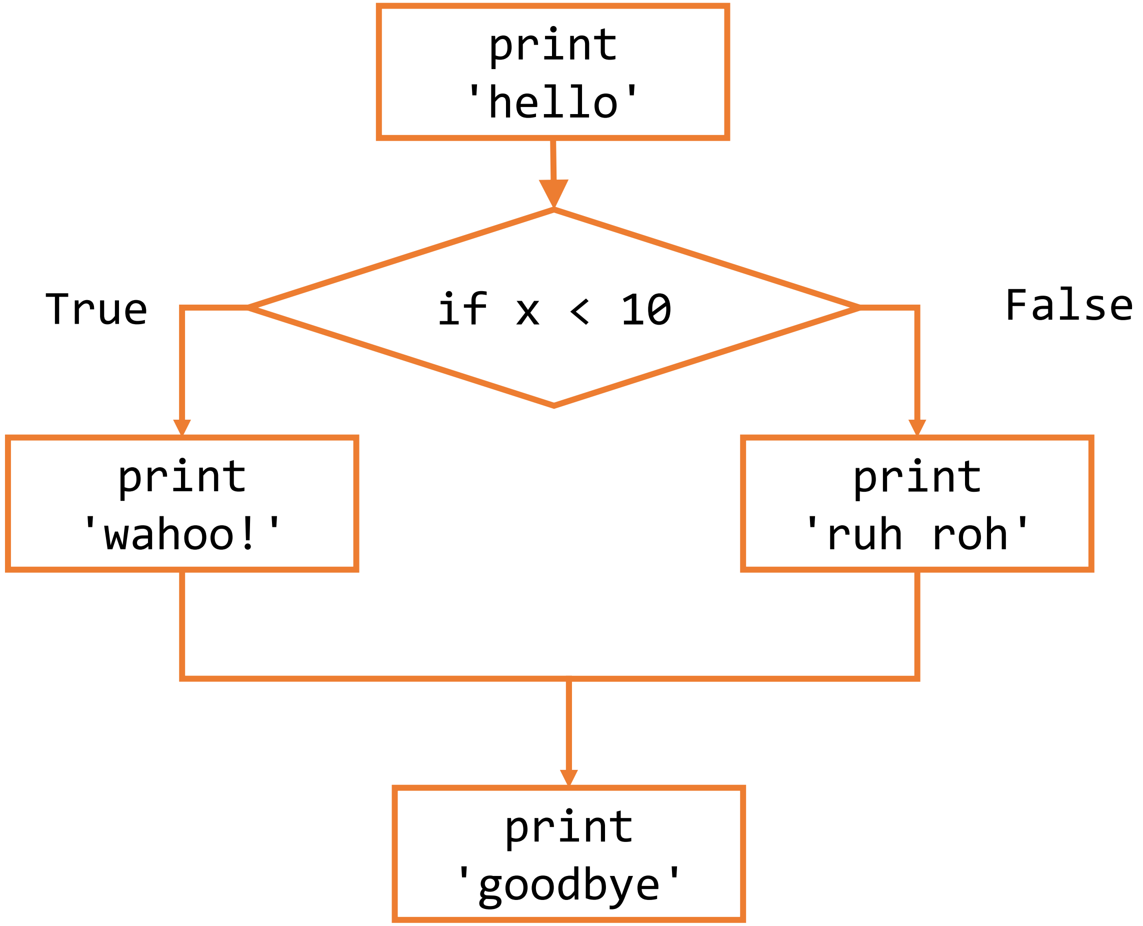
```
if <BooleanExpression>:
    <bodyIfTrue>
else:
    <bodyIfFalse>
```

`if` clause

`else` clause

Updated Flow Chart Example

```
print("hello")
if x < 10:
    print("wahoo!")
else:
    print("ruh roh")
print("goodbye")
```



Revised Example: Print Number of Digits

Using an else statement makes our earlier code much easier to write and understand!

```
x = 24
if -10 < x and x < 10:
    print("Only one digit")
else:
    print("More than one digit")
```

Activity: Conditional Prediction

Prediction Exercise: What will the following code print?

```
x = 5
if x > 10:
    print("Up high!")
else:
    print("Down low!")
```

Question: Can we change the program state to print the other string instead?

Question: Can we change the state to make the if/else statement print out both statements?

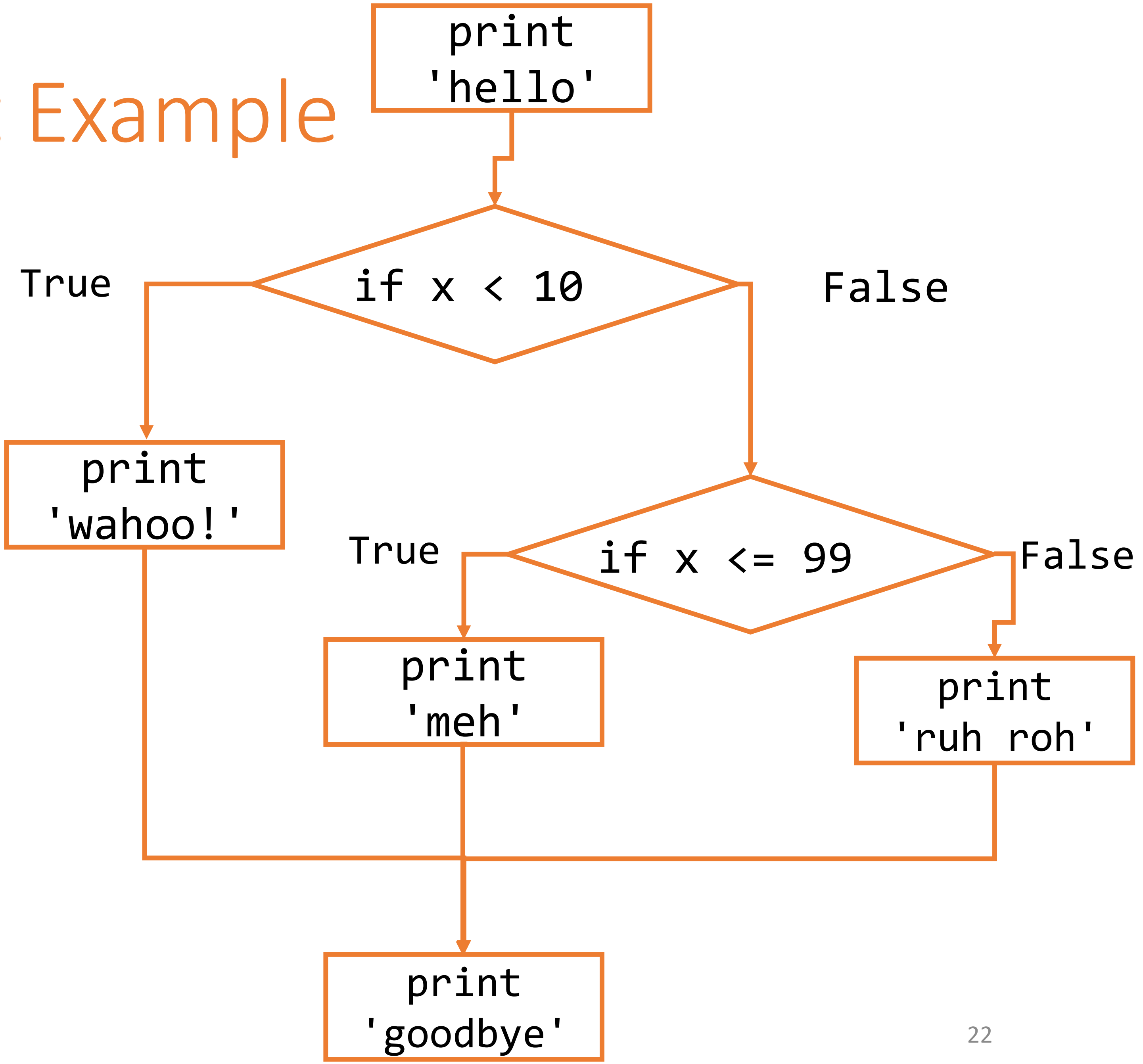
`Elif` Implements Multiple Alternatives

Finally, we can use **`elif`** statements to add alternatives with their own conditions to `if` statements. An `elif` is like an `if`, except that it is checked **only if all previous conditions evaluate to `False`**.

```
if <BooleanExpressionA>:
    <bodyIfATrue>
elif <BooleanExpressionB>:
    <bodyIfAFalseAndBTrue>
else:
    <bodyIfBothFalse>
```

Updated Flow Chart Example

```
print("hello")
if x < 10:
    print("wahoo!")
elif x <= 99:
    print("meh")
else:
    print("ruh roh")
print("goodbye")
```



Conditional Statements Join Clauses Together

A **conditional statement** is a joined group of `if`, `elif`, and `else`. All conditional statements have:

- Exactly one `if` clause
- Followed by zero or more `elif` clauses
- Followed by zero or one `else` clause(s)

These joined clauses can be considered a single **control structure**. Only one clause will have its body executed.

A conditional must start with an `if`. You cannot have an `else` or `elif` clause by itself.

Example: Grade Calculator

The given code asks the user for a number grade, then prints the letter grade that corresponds to that number grade.

Fill in the blanks so the function works correctly.

90+ is an A, 80-90 is a B, 70-80 is a C, 60-70 is a D, and below 60 is an R.

```
grade = int(input("Enter grade:"))

if grade ____ 90:
    print("A")
______ grade ____ 80:
    print("B")
elif grade >= ____:
    print(____)
elif ____ >= 60:
    print("D")
______ :
    print("R")
```

Short-Circuit Evaluation

When Python evaluates a logical expression, it acts lazily. It only evaluates the second part **if it needs to**. This is called **short-circuit evaluation**.

When checking `x and y`, if `x` is `False`, **the expression can never be** `True`. Therefore, Python doesn't even evaluate `y`.

When checking `x or y`, if `x` is `True`, **the expression can never be** `False`. Python doesn't evaluate `y`.

This is a handy method for keeping errors from happening. For example:

```
if type(x) == type(y) and x < y:
    print("Smaller:", x)
```

Two New Math Operators

Now that we have conditionals, we may want to check whether a number has certain properties (like being even or a multiple of ten). We can do this using some new operators.

Modulo, or **mod** (`%`) finds the remainder when one number is divided by another.

For example, `7 % 4` is equal to `3`.

Check if a number is even with `x % 2 == 0`.

Floor division, or **div** (`//`) divides numbers by rounding down to nearest whole number. This cuts off any digits after the decimal point.

For example, `7 // 4` is equal to `1`, not `1.75`.

Cut off the last digit of a number with `x // 10`.

Nesting Control Structures

Nesting Creates More Complex Control Flow

Now that we've learned more, **we can put `if` statements inside of `if` statements**.

In general, we'll be able to **nest** control structures inside other control structures. This can currently be done with conditional statements and function definitions.

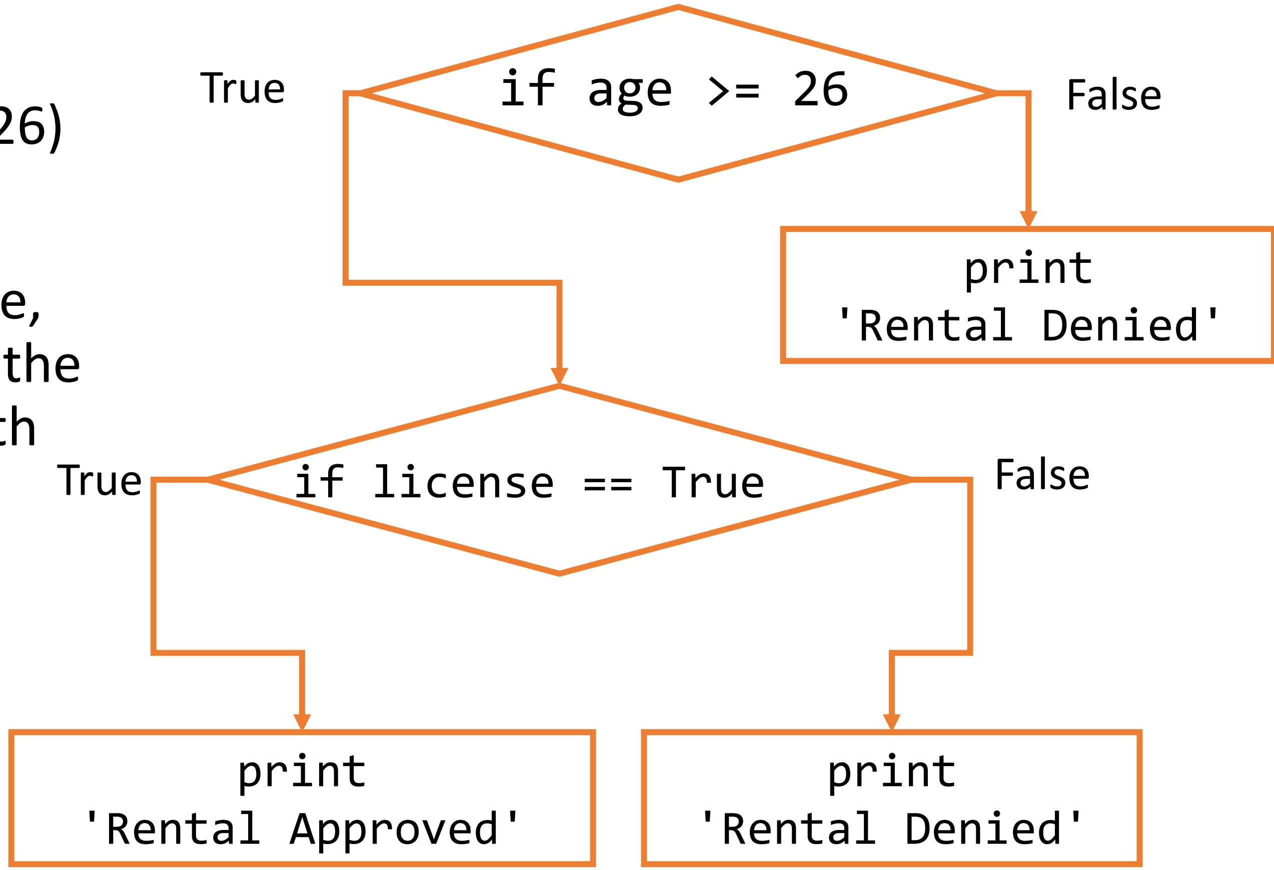
In program syntax, we demonstrate that a control structure is nested by **indenting the code** so that it's in the outer control structure's body.

Example: Car rental program

Consider code that determines if a person can rent a car based on their age (are they at least 26) and whether they have a driver's license.

We can use one `if` statement to check their age, then a second (nested inside the first) to check the license. We'll only print 'Rental Approved' if both `if` conditions evaluate to `True`.

```
if age >= 26:
    if license == True:
        print("Rental Approved")
    else:
        print("Rental Denied")
else:
    print("Rental Denied")
```



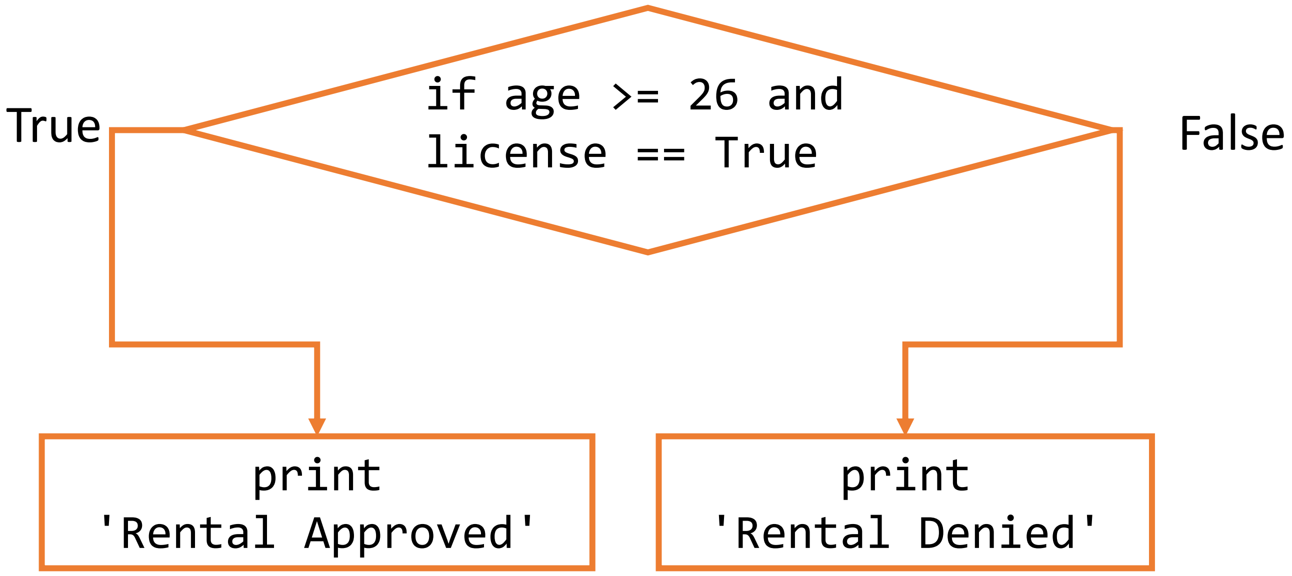
Note that each else is paired with the if at the same indentation level.

Alternative Car Rental Code

In the code below, we accomplish the same result with the and operation.

This won't always work, though – it depends on how many different results you want.

```
if age >= 26 and license == True:
    print("Rental Approved")
else:
    print("Rental Denied")
```



Nesting Conditionals in Functions

When we nest a conditional inside a function definition, we can **return values early** instead of only returning on the last line. Returning early is fine as long as we ensure every possible path the function can take will eventually return a value.

A function will always end as soon as it reaches a `return` statement, even if more lines of code follow it. For example, the following function will not crash when `n` is zero.

```
def findAverage(total, n):
    if n <= 0:
        return -1 # error code
    return total / n
```

Python Errors and Error Messages

Types of Errors

There are three types of errors that we may encounter while coding.

Syntax Error: Python was not able to parse the code

Runtime Error: Something went wrong when the code was running

Logical Error: The code ran, but didn't do what we wanted it to do

Syntax Errors Occur due to Bad Syntax

When Python executes your code, it first must break your text down into **tokens**, then **structure** those tokens into a format that the computer can execute.

The programming language's **syntax** is a set of rules for how code instructions should be written. When syntax is correct, Python can tokenize and structure code without a problem.

If the interpreter runs into an error while tokenizing or structuring, it calls that a **syntax error**. In other words, you get a syntax error when the code you provide does not follow the rules of the Python language's syntax, either because an invalid token is used or because tokens are structured in a way Python cannot understand.

A syntax error means that **none of your code will run**, because the syntax can't be parsed. Syntax errors should be fixed as quickly as possible!

Syntax Needs to be Exact

Computers aren't very clever. If you change the syntax of code even a little bit, the computer might not understand what you mean and will raise an error.

```
Print("Hello World") # NameError
print "Hello World" # SyntaxError
```

Most syntax errors are called **SyntaxError**, which make them easy to spot. For example:

```
x = @     # SyntaxError: invalid syntax
4 + 5 = x # SyntaxError: cannot assign to expression here. Maybe
            you meant '==' instead of '='?
print(4 + 5 # SyntaxError: '(' was never closed
```

Whitespace is Syntax, Sometimes

Be careful when using whitespace (spaces, tabs, and the return key) – it can sometimes count as syntax too!

In general, whitespace at the **beginning** of a line has meaning. Whitespace in the **middle of tokens** causes errors. Whitespace **between tokens** is okay.

```
    print("Hello World") # IndentationError
p r i n t ( "Hello World" ) # SyntaxError
print ( "Hello World" ) # this is okay!
```

Execution Errors are Runtime Errors

After Python tokenizes and structures the code, the interpreter runs through the control flow of the program line-by-line.

If an error occurs as the code is being executed, it's called a **runtime error**. Everything that happened before that error will execute just fine, but everything afterwards will not run.

Runtime errors have many different names in Python. Each name says something about what kind of error occurred, so reading the name and text can give you additional information about what went wrong.

Examples of Runtime Errors

```
print(Hello)    # NameError: name 'Hello' is not defined

print("2" + 3) # TypeError: can only concatenate str (not "int") to str

x = 5 / 0       # ZeroDivisionError: division by zero
```

We'll see more types of runtime errors as we learn more Python syntax.

Syntax vs Runtime

What's the difference between syntax and runtime errors? Whether **any** of the code gets to run.

Syntax errors: Python cannot correctly parse the syntax of the text, so none of the code will run.

Runtime errors: Python parses the code and starts to run, but gets to a point where the code cannot be executed. Anything after the non-working code will not run.

Debug Errors By Reading the Message

1. Look for the **line number**. This line tells you approximately where the error occurred.
2. Look at the **error type**.
3. If it says SyntaxError, look for the **inline arrow**. The position gives you more information about the location of the problem (though it isn't always right).
4. If it says something else, **read the error message.** The error type and its message give you information about what went wrong.

1-2.py

```
1 print(Hello World)
2 Print("Hello World")
```

```
>>> %Run test.py
 Traceback (most recent call last):
   File "C:\Users\river\Downloads\test.py", line 1
     print(Hello World)
                     ^
 SyntaxError: invalid syntax
>>>
```

inline arrow

line number

1-2.py

```
1 print("Hello World")
2 Print("Hello World")
```

```
>>> %Run test.py
 Hello World
 Traceback (most recent call last):
   File "C:\Users\river\Downloads\test.py", line 2, in <module>
     Print("Hello World")
 NameError: name 'Print' is not defined
>>>
```

error type

Other Errors are Logical Errors

If we manage to run Python code completely, does that mean it's correct?

Not necessarily! **Logical errors** can occur if code runs but produces a result that was not what the user intended. The computer can't catch logical errors because the computer doesn't know what we intend to do.

To catch logical errors, you usually need to **test** your code.

Examples of Logical Errors

```
print("2 + 2 = ", 5) # no error message, but wrong!

def double(x):
    return x + 2 # adding instead of multiplying

assert double(3) == 6, "6 is the intended result"
```

We use `assert` statements to check for logical errors by testing whether the output of a function call is equal to what we expect it to be. If the result is not correct, you get an `AssertionError`.

Logical errors are the hardest to find and fix. We'll talk more about how to debug these in a later lecture.

Learning Goals

- Use **logical operators** on Booleans to compute whether an expression is True or False
- Use **conditionals** when reading and writing algorithms that make choices based on data
- Use **nesting** of control structures to create complex control flow
- Recognize the different types of **errors** that can be raised when you run Python code