Today: foreach loop instead of for/i/range, start lists, how to write main()

Recall: String

- String is probably the most complicated type
- We've seen the most important features (used in examples below)
  `len(s)` `s[i]` `s +=`
  `for i in range(len(s)):`
  `s.isalpha()` `s.isdigit()` `s.isupper()` `s.islower()`
  `s.upper()` `s.lower()`
  `s.find()`
  Convert to int: `int('123')`

Q: How To Loop Over Chars in s?

A: for/i/range

```
for i in range(len(s)):
    # Use s[i]
```

We've used this many times and we'll continue to.

for/i/range Forms - We've Had a Good Run

So many memories! Looping over string index numbers.

```
for i in range(len(s)):
```

Looping over x values in an image

```
for x in range(image.width):
```

Looping over y values in an grid:

```
for y in range(grid.height):
```

Looping over index numbers like this is an important code pattern and we'll continue to use it.

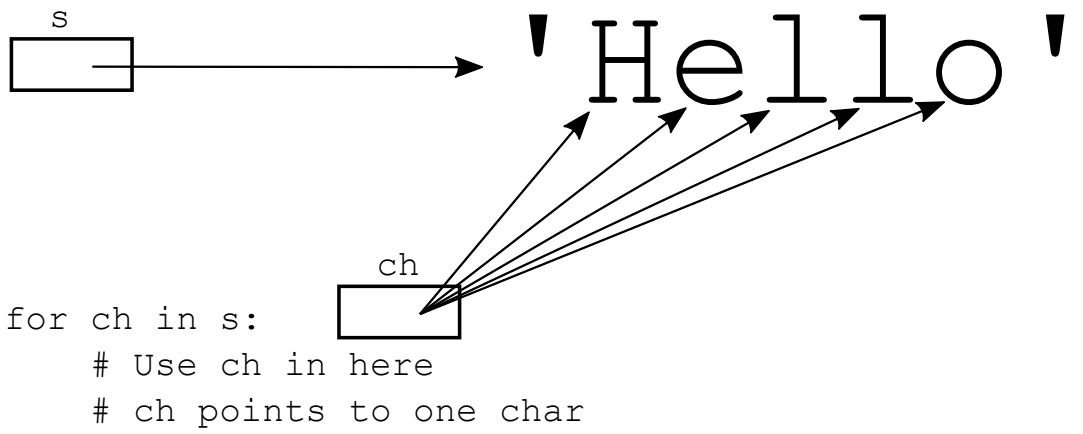
BUT now we're going to see another way to do it!

Foreach loop: `for ch in s:`

A "foreach" loop can loop over a string and access each char directly. We are not bothering with index numbers, but pointing the variable at each char directly. This is **easier** than the for/i/range form above. In the loop, the `ch` variable points to each char, one per iteration:

`'H' 'e' 'l' 'l' 'o'`

```
s = 'Hello'
for ch in s:
    # Use ch in here
```



- **Easier** way to loop over the chars in a string,
- More direct - on each iteration, variable `ch` points to the next char
- No `i`, no `s[i]`
- **But** we do not get the index numbers here, just the chars
- Known as "foreach"

Foreach Example: double_char2()

> double_char2()

Like earlier double_char(), but using the foreach for/ch/s loop form. The variable `ch` points to one char for each iteration.

Note: no index numbers, no `[]`

```
def double_char2(s):
    result = ''
    for ch in s:
        result = result + ch + ch
    return result
```

Which Loop To Use?

We have `for ch in s:` - "foreach"

We have `for i in range(len(s)):` - "for/i/range"

We will end up using both of these in different situations. How do you know which loop to use?

1. Use `for ch in s:` if you need each char but not its index number. This is the easier option, so we are happy to use it where it's good enough.

Above double_char(s) is an example - needed each char but did not need index numbers.

2. Use the `for i in range(len(s)):` if you need each char and also its index number. The find_alpha() function below is an example.

(optional) Example: find_alpha(s)

> find_alpha()

```
'66abc77' -> 2
'!777' -> -1
```

find_alpha(s): Given a string s, return the index of the first alphabetic char in s, or -1 if there are none. Use a for/i/range loop.

Q: Do we need index numbers for this? Yes. We need the index number in the loop so we can return it, just having `'a'` from `'66abc77'` is not enough. Need the `2`. Therefore use for/i/range.

This is also an example of an early return strategy — return out of the middle of the loop if we find the answer, not doing the rest of the iterations. Then the return after the end of loop is for the did-not-find case.

find_alpha(s) Solution

```
def find_alpha(s):
    for i in range(len(s)):
        if s[i].isalpha():
            return i  # need index here
    return -1
```

(optional) Example: sum_digits2()

> sum_digits2()

```
'12ab3' -> 6
'777' -> 21
'abcd' -> 0
```

Revisit this problem, now do it with foreach. Recall also str/int conversion.

sum_digits2(s): Given a string s. Consider the digit chars in s. Return the arithmetic sum of all those digits, so for example, '12abc3' returns 6. Return 0 if s does not contain any digits.

Q: Do we need the index number of each char to compute this? No, we just need each char. Therefore foreach is sufficient.

sum_digits() Solution

```
def sum_digits2(s):
    sum = 0
    for ch in s:
        if ch.isdigit():
            num = int(ch)  # '7' -> int 7
            sum += num
    return sum
```

(optional) Exercise: difference(a, b)

> difference()

Does not need index numbers. Demonstrates both **foreach** and **in**

difference(a, b): Given two strings, **a** and **b**. Return a version of a, including only those chars which are not in b. Use case-sensitive comparisons. Use a for/ch/s loop.

difference(a, b) Solution

```
def difference(a, b):
    result = ''
    # Look at all chars in a.
    # Check each against b.
    for ch in a:
        if ch not in b:
            result += ch
    return result
```

Additional exercise - string intersect:

> intersect2()

Python Lists

See the guide: Python List for more details about lists

- A list is a linear collection of any type of python value
  The formal name of the type is "list"
- A very common type, up there with int and string
- Use list to store many elements
  e.g. a thousand urls - a list of url strings
  e.g. a million temperature readings - a list of float values
- Things in a list are called "elements"
- Generic list variable name: `lst`

Lists are like Strings

- The design of Python tries to be consistent
- The syntax for strings .. largely re-used for lists

- So you already know much of the list syntax!
- Same as string:
  elements indexed: 0 .. len-1
  `len()`
  `[i]` to access elements
  `in`
  foreach loop
- Differences:
  Lists can contain any type of element
  Lists are "mutable", can be changed

Examples on Server list1

See the "list1" for examples below on the experimental server

1. List Literal: `['aa, 'bb', 'cc', 'dd']` `len(lst)`

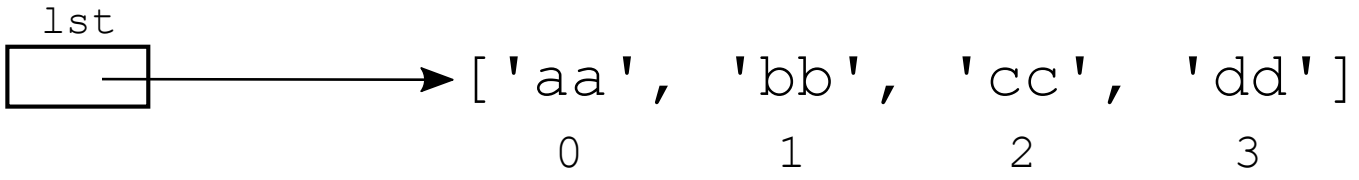
Use square brackets `[..]` to write a list in code (a "literal" list value), separating elements with commas. Python will print out a list value using this same square bracket format.

The `len()` function works on lists, same as strings.

The "empty list" is just 2 square brackets with nothing within: `[]`

```
>>> lst = ['aa, 'bb', 'cc', 'dd']
>>> lst
['aa, 'bb', 'cc', 'dd']
>>>
>>> len(lst)
4
>>> lst = []    # empty list
>>> len(lst)
```

```
0
>>>
```



2. Square Brackets to access/change element

Use square brackets to access an element in a list. Valid index numbers are 0..len-1. Unlike string, you can assign = to change an element within the list.

```
>>> lst = ['aa, 'bb', 'cc', 'dd']
>>> lst[0]
'aa'
>>> lst[2]
'cc'
>>>
>>> lst[0] = 'apple'    # Change elem
>>> lst
['apple', 'bb', 'cc', 'dd']
>>>
>>>
>>> lst[9]
Error:list index out of range
>>>
```

Lists are Mutable

The big difference from strings is that lists are **mutable** - lists can be changed. Elements can be added, removed, changed over time.

3. List `lst.append('thing')`

- `lst.append('thing')` - add an element to the end of the list
- The most important list function
- Lists can contain any type (today int, str)
- Modifies the list, returns nothing

```
# Common list-build pattern:
# Make empty list, then call .append() on
it
>>> lst = []
>>> lst.append(1)
>>> lst.append(2)
>>> lst.append(3)
>>>
>>> lst
[1, 2, 3]
>>> len(lst)
3
>>> lst[0]
1
>>> lst[2]
3
>>>
>>> # 2. Say we want a list of 0, 10, 20 ..
90
>>> # Write for/i/range loop, use append()
inside
>>> nums = []
>>> for i in range(10):
```

```
...     nums.append(i * 10)
...
>>> nums
[0, 10, 20, 30, 40, 50, 60, 70, 80, 90]
>>> len(nums)
10
>>> nums[5]
50
```

Example: list_n()

> list_n()

list_n(n): Given non-negative int n, return a list of the form [0, 1, 2, ... n-1]. e.g. n=4 returns [0, 1, 2, 3] For n=0 return the empty list. Use for/i/range and append().

Note: This is a case of using for/i/range to generate a bunch of numbers

list_n() Solution

```
def list_n(n):
    nums = []
    for i in range(n):
        nums.append(i)
    return nums
```

Experiment: `'nom'`

Change the list_n code to append `'nom'` in the loop instead of a number. what does the resulting list look like for each value of n? This also shows that the list can as easily contain a bunch of strings as a bunch of ints.

List Mistake #1: `lst = lst.append()`

The list.append() function modifies the existing list. **It returns `None`**. Therefore the following code pattern will not work, setting lst to `None`:

```
# NO does not work
lst = []
lst = lst.append(1)
lst = lst.append(2)

# Correct form
lst = []
lst.append(1)
lst.append(2)
# lst points to changed list
```

Why would someone write `lst = lst.append(1)`? Because we are accustomed to `x = change(x)` for **strings**, but that pattern does not work for **lists**.

List Mistake #2: +=

Don't use += on lists for now. It works for strings, but += is **not** the same as .append() for list. We may show what it does later, but for now just avoid it.

Correct way to add to list:

```
lst.append('thing')
```

4. List "in" / "not in" Tests

- How to tell if a value is in a list?
  Hint: like string!
- **`in`** operator tests if a value is in a list
- **`not in`** works too, reads nicely, preferred style

```
>>> lst = ['aa', 'bb', 'cc', 'dd']
>>> 'cc' in lst
True
>>> 'x' in lst
False
>>> 'x' not in lst  # preferred form to
check not-in
True
>>> not 'x' in lst  # equivalent, not
preferred
True
```

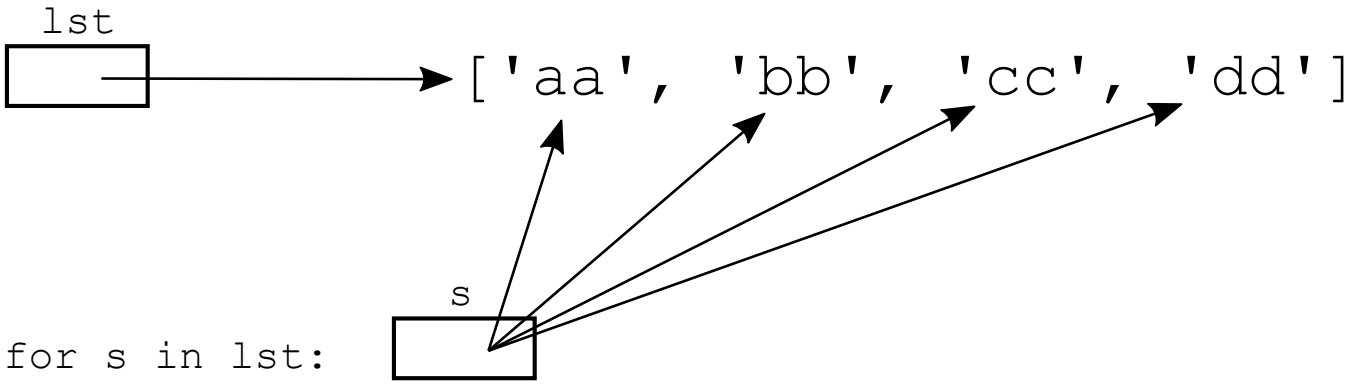
5. Foreach On List

How to loop over the elements in a list? The foreach loop works.

- for "foreach" loop works on a list
- `for` *`var`* `in` *`list`*`:`
- Probably the most common loop form
  Many algorithms want to look at every element in a list
- The loop takes control of the variable
  Setting it to point to each element in turn, one element per loop
- **No Change** do not change the list - add/remove/change - during iteration
  Kind of reasonable rule: how would iteration work if elements appeared and disappeared during the iteration

```
>>> lst = ['aa', 'bb', 'cc', 'dd']
>>> for s in lst:
...   # Use s in here
...   print(s)
```

```
...
aa
bb
cc
dd
```



Style - Choose Foreach Var Name

The word after `for` is the name of a variable for the loop to use. Choose the var name to reflect type of element, `s` for a string, `n` for a number. This helps you fill in the loop body correctly.

```
# list of strings
for s in strs:
  ...

# list numbers
for n in nums:
  ...

# list of urls
```

```
for url in urls:
  ...
```

Example: List intersect(a, b)

> intersect()

intersect(a, b): Given two lists of numbers, **a** and **b**. Construct and return a new list made of all the elements in a which are also in b.

This code is similar to string algorithms, using list versions of features such as foreach, "in", and append().

Minor point: since it's a list of numbers, we'll use `num` as the variable name in the foreach over this list.

List intersect(a, b) Solution

The intersect() code is a good example of what people like about Python — - letting us express our algorithmic ideas with minimal fuss. Also shows our preference for using builtin functions, in this case "in", to do the work for us when possible.

```
def intersect(a, b):
    result = []
    for num in a:
        if num in b:
            result.append(num)
    return result
```

6. list.index(target) - Find Index of Target

- Similar to str.find(), **but with one big difference**

- `list.index(target)` - returns int index of target if found
- **BUT** `list.index(target)` fails with a runtime error if the target is not in
- Code must check with `in` first, only call lst.index() if in is True
- This design is annoying
  It would be easier if list.index() simply returned -1, but it doesn't
- Variant: `list.index(target, start_index)` - begin search at start_index instead of 0

```
>>> lst = ['aa', 'bb', 'cc', 'dd']
>>> lst.index('cc')
2
>>> lst.index('x')
ValueError: 'x' is not in list
>>> 'x' in lst
False
>>> 'cc' in lst
True
>>>
>>> # Like this:
>>> # check "in" before .index()
>>> if 'x' in lst:
      print(lst.index('x'))
>>>
```

Example: donut_index(foods)

> donut_index()

donut_index(foods): Given "foods" list of food name strings. If 'donut' appears in the list return its int index. Otherwise return -1. No loops, use .index(). The solution is quite short.

e.g. `foods = ['apple', 'donut', 'banana']`.

Return index in the list of `'donut'`, or -1 if not found?

donut_index() Solution

```
def donut_index(foods):
    if 'donut' in foods:
        return foods.index('donut')
    return -1
```

Optional: list_censor()

> list_censor()

list_censor(n, censor): Given non-negative int n, and a list of "censored" int values, return a list of the form [1, 2, 3, .. n], except omit any numbers which are in the censor list. e.g. n=5 and censor=[1, 3] return [2, 4, 5]. For n=0 return the empty list.

Solution

```
def list_censor(n, censor):
    nums = []
    for i in range(n):
        # Introduce "num" var since we use it twice
        # Use "in" to check censor
        num = i + 1
        if num not in censor:
            nums.append(num)
    return nums
```

Style Note: Lists and the letter "s"

As your algorithms grow more complicated, with three or four variables running through your code, it can become difficult to keep straight in your mind which variable, say, is the number and which variable is the list of numbers. Many little bugs have the form of wrong-variable mixups like that.

Therefore, an excellent practice is to name your list variables ending with the letter "s", like "nums" above, or "urls" or "weights".

```
urls = []    # name for list of urls


url = ''     # name for one url
```

Then when you have an append, or a loop, you can see the singular and plural variables next to each other, reinforcing that you have it right.

```
    url = (some crazy computation)
    urls.append(url)
```

Or like this

```
    for url in urls:
```

Constants in Python

```
...
STATES = ['CA, 'NY', 'NV', 'KY', 'OK']
...
...

def some_fn():
    # can use STATES in here
    for state in STATES:
        ...
```

- Simple form name=value at far left, not within a def
- This is a type of "global" variable

- A variable not inside a function
- In this case it is a constant for the program
- Functions can just refer to `STATES` to get its value
- Python Convention: upper case means its a constant
- Style: it's intended to be a read-only value, code should not modify it

ALPHABET Constant in HW4

```
# provided ALPHABET constant - list of the
regular alphabet
# in lowercase. Refer to this simply as
ALPHABET in your code.
# This list should not be modified.
ALPHABET = ['a', 'b', 'c', 'd', 'e', 'f',
'g', 'h', 'i', 'j', 'k', 'l', 'm', 'n',
'o', 'p', 'q', 'r', 's', 't', 'u', 'v',
'w', 'x', 'y', 'z']

...

def foo():
    for ch in ALPHABET:  # this works
        print(ch)
```

Command Line Arguments and main()

You have called your code from the command line many times. The function main() is typically the first function to run in a python program, and its job is looking at the command line arguments and figuring out how to start up the

program. With HW4, it's time for you to write your own main(). You might think it requires some advanced CS trickery, but it's easier than you might think.

How Do Command Line Arguments Work?
How to write main() code?

For details see guide: Python main() (uses affirm example too)

affirm.zip Example/exercise of main() command line args. You can do it yourself here, or just watch the examples below to see the ideas.

1. Run affirm.py See Its Arguments

First run affirm.py, see what the command line arguments (aka "args") it takes: `-affirm` and `-hello` options (aka "flags")

```
$ python3 affirm.py -affirm Lisa
Everything is coming up Lisa
$ python3 affirm.py -affirm Bart
Looking good Bart
$ python3 affirm.py -affirm Maggie
Today is the day for Maggie
$ python3 affirm.py -hello Bob
Hello Bob
$
```

Command Line Argument e.g. `-affirm`

- Often a command line selects certain options or modes of the program
- e.g. `-affirm` tells the program to print an affirmation
- e.g. `-hello` it says hello

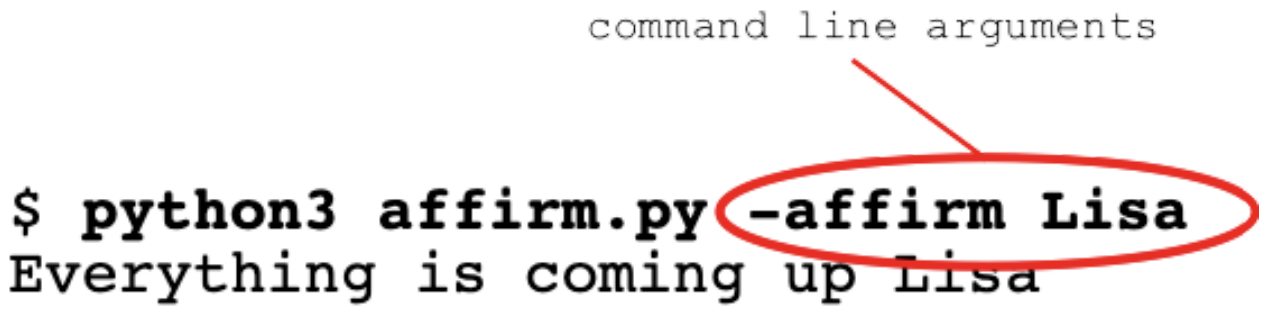
- The program will document which commands it supports
  In the homework handouts, we list the arguments that work
- The convention is that arguments that select an option start with a dash
- These are known as "options" or "flags" of the command

2. The "args" To a Program

The command line arguments, or "args", are the extra words typed on the command line to tell the program what to do. The system is deceptively simple - the command line arguments are just the words after the `program.py` on the command line. So in this command line:

```
$ python3 affirm.py -affirm Lisa
```

The words `-affirm` and `Lisa` are the 2 command line arguments. They are separated from each other by spaces on the command line.



3. `main()` has `args` Python List

When a Python program starts running, typically the run begins in the function named `main()`. This function can look at the command line arguments, and figure out what functions to call. (Other computer languages also use this convention - main() is the first to run.)

In our main() code, the variable `args` is set up as a Python list containing the command line args. Each arg is a string - just what was typed on the command line. So the `args` list communicates to us what was typed on the command line.

```
$ python3 affirm.py -affirm Lisa
   ....
   e.g. args == ['-affirm', 'Lisa']


$ python3 affirm.py -affirm Bart
   ....
   e.g. args == ['-affirm', 'Bart']
```

4. main()/print() Exercise

Edit the file `affirm-exercise.py`. In the main() function, find the `args = ..` line which sets up the args list. Add the following print() - this just prints out the args list so we can see it. We can remove this print() later.

```
args = sys.argv[1:]

print('args:', args)   # add this
```

Now run the program, trying a few different args, so you see what the args list is depending on what is typed.

```
$ python3 affirm-exercise.py -affirm Bart
args: ['-affirm', 'Bart']
$ python3 affirm-exercise.py -affirm Lisa
args: ['-affirm', 'Lisa']
$ python3 affirm-exercise.py -hello Hermione
args: ['-hello', 'Hermione']
```

Q: For the Hermione line: what is `args[0]`? what is `args[1]`?

5. `print_affirm(name)` Helpers Provided

We have helper functions already defined that do the various printouts:

```
print_affirm(name) - prints affirmation for
name
print_hello(name) - print hello to name
print_n_copies(n, name) - given int n,
                          print n copies of
name
```

Their code is shown below. They are not too complex. Also see that AFFIRMATIONS is defined as a constant - the random affirmation strings to use.

```
AFFIRMATIONS = [
    'Looking good',
    'All hail',
    'Horray for',
    'Today is the day for',
    'I have a good feeling about',
    'A big round of applause for',
    'Everything is coming up',
]

def print_affirm(name):
    """
    Given name, print a random affirmation for that name.
    """
    affirmation = random.choice(AFFIRMATIONS)
    print(affirmation, name)


def print_hello(name):
    """
    Given name, print 'Hello' with that name.
    """
    print('Hello', name)


def print_n_copies(n, name):
    """
    Given int n and name, print n copies of that name.
```

```
    """
    for i in range(n):
        # Print each copy of the name with space instead of \n
after it.
        print(name, end=' ')
    # Print a single \n after the whole thing.
    print()
```

6. How To Write main()

- `args` is a Python list of the args typed on the command line
- Each argument typed on the command line is one string in the list
- Add if-statements in main() look at `args`
- e.g. an if-statement for the "-affirm *some-name*" case
- (affirm.py code is done, use affirm-exercise.py to write the code)
- Look at `len(args)`
- Look at `args[0]`
- Call functions based on args
  Pass in right data for each parameter

Exercise 1: Make -affirm Work

We'll do this one lecture.

Make this command line work, editing the file affirm-exercise.py:

```
$ python3 affirm-exercise.py -affirm Lisa
```

- Recall that `args` is the list of strings
- Write an if-statement to detect:
  2 command line args
  The first word is `'-affirm'`
  Call the print_affirm() function with the name

- The earlier `print(args)` helps show what args list contains

Solution code

```
def main():
    args = sys.argv[1:]
    ....
    ....
    # 1. Check for the -affirm arg pattern:
    #   python3 affirm.py -affirm Bart
    #   e.g. args[0] is '-affirm' and args[1] is 'Bart'
    if len(args) == 2 and args[0] == '-affirm':
        print_affirm(args[1])
```

Solution Notes

- `len(args)` - the number of args
- `args[0]` - the first arg
- Solution: check if `len(args) == 2` and `args[0] == '-affirm'`
- The name to print is in `args[1]`

Exercise 2: Make -hello Work

Write if-logic in main() to looking for the following command line form, call print_hello(name), passing in correct string.

```
$ python3 affirm-exercise.py -hello Bart
```

Solution code

```
    if len(args) == 2 and args[0] == '-hello':
        print_hello(args[1])
```

Exercise 3: Make -n Work

In this case, the function to call is `print_n_copies(n, name)`, where n is an int param, and `name` is the name to print. Note that the command line args are all

strings, so there is a tricky issue there.

```
$ python3 affirm-exercise.py -n 10000 Hermione
```