# Python

# PYTHON

# GENERATORS

# Python generators

- Python generators generate iterators
- They are more powerful and convenient
- Write a regular function and instead of calling return to produce a value, call yield instead
- When another value is needed, the generator function picks up where it left off
- Raise the StopIteration exception or call return when you are done

## Generators in Python

Prerequisites: Yield Keyword and Iterators There are two terms involved when we discuss generators.

**Generator-Function:** A generator-function is defined like a normal function, but whenever it needs to generate a value, it does so with the yield keyword rather than return. If the body of a def contains yield, the function automatically becomes a generator function.

Python3

```
# A generator function that yields 1 for first time,
# 2 second time and 3 third time
def simpleGeneratorFun():
    yield 1
    yield 2
    yield 3

# Driver code to check above generator function
for value in simpleGeneratorFun():
    print(value)
```

## Output

```
1
2
3
```

**Generator-Object :** Generator functions return a generator object. Generator objects are used either by calling the next method on the generator object or using the generator object in a "for in" loop (as shown in the above program).

Python3

```
# A Python program to demonstrate use of
# generator object with next()

# A generator function
def simpleGeneratorFun():
    yield 1
    yield 2
    yield 3

# x is a generator object
x = simpleGeneratorFun()

# Iterating over the generator object using next
print(next(x)) # In Python 3, __next__()
print(next(x))
print(next(x))
```

## Output

```
1

2

3
```

So a generator function returns an generator object that is iterable, i.e., can be used as an Iterators . As another example, below is a generator for Fibonacci Numbers.

Python3

```
# A simple generator for Fibonacci Numbers
def fib(limit):

    # Initialize first two Fibonacci Numbers
    a, b = 0, 1

    # One by one yield next Fibonacci Number
    while a < limit:
        yield a
        a, b = b, a + b

# Create a generator object
x = fib(5)

# Iterating over the generator object using next
print(next(x)) # In Python 3, __next__()
print(next(x))
print(next(x))
print(next(x))
print(next(x))

# Iterating over the generator object using for
# in loop.
print("\nUsing for in loop")
for i in fib(5):
    print(i)
```

## Output

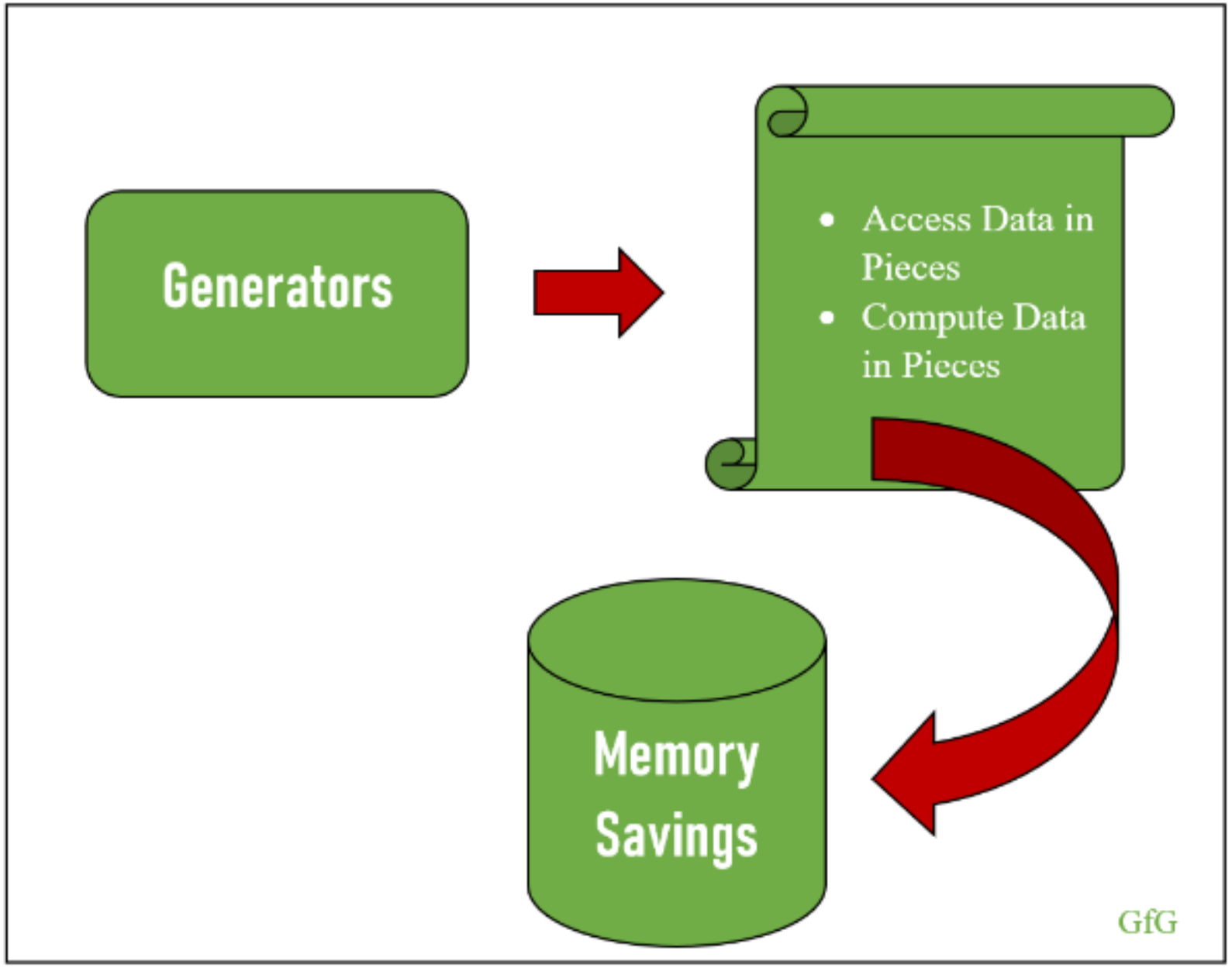
```
0
1
1
2
3


Using for in loop
0
1
1
2
3
```

**Applications**:

Suppose we create a stream of Fibonacci numbers, adopting the generator approach makes it trivial; we just have to call next(x) to get the next Fibonacci number without bothering about where or when the stream of numbers ends. A more practical type of stream processing is handling large data files such as log files. Generators provide a space-efficient method for such data processing as only parts of the file are handled at one given point in time. We can also use Iterators for these purposes, but Generator provides a quick way (We don't need to write __next__ and __iter__ methods here).

## Using Generators for substantial memory savings in Python

When memory management and maintaining state between the value generated become a tough job for programmers, Python implemented a friendly solution called **Generators**.

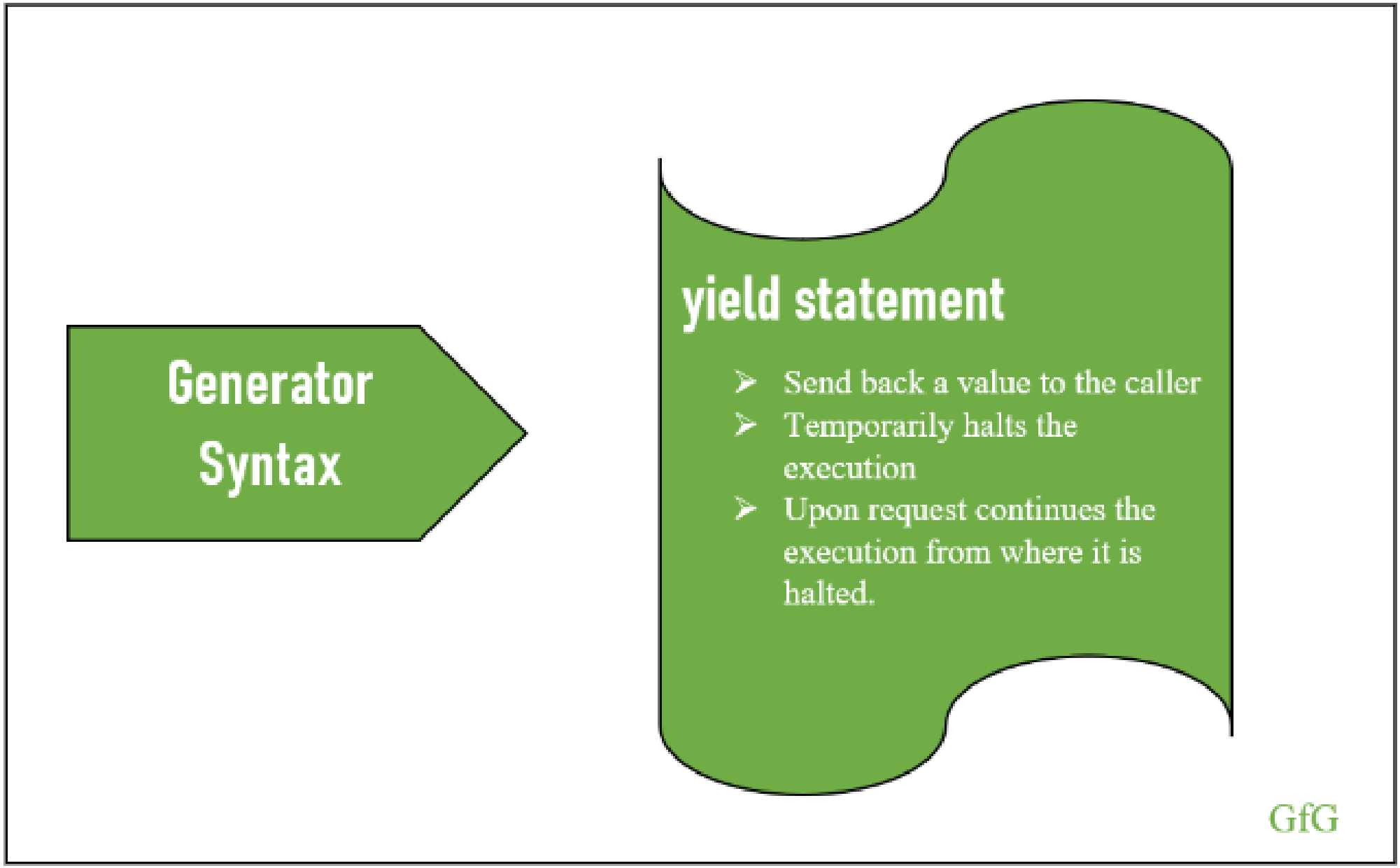


Generators

With Generators, functions evolve to **access and compute data in pieces**. Hence functions can return the result to its caller upon request and can maintain its state. **Generators maintain the function state by halting the code after producing the value to the caller and upon request, it continues execution from where it is left off.**

Since Generator access and compute value on-demand, a large chunk of data doesn't need to be saved in memory entirely and results in substantial memory savings.

# Generator Syntax



yield statement

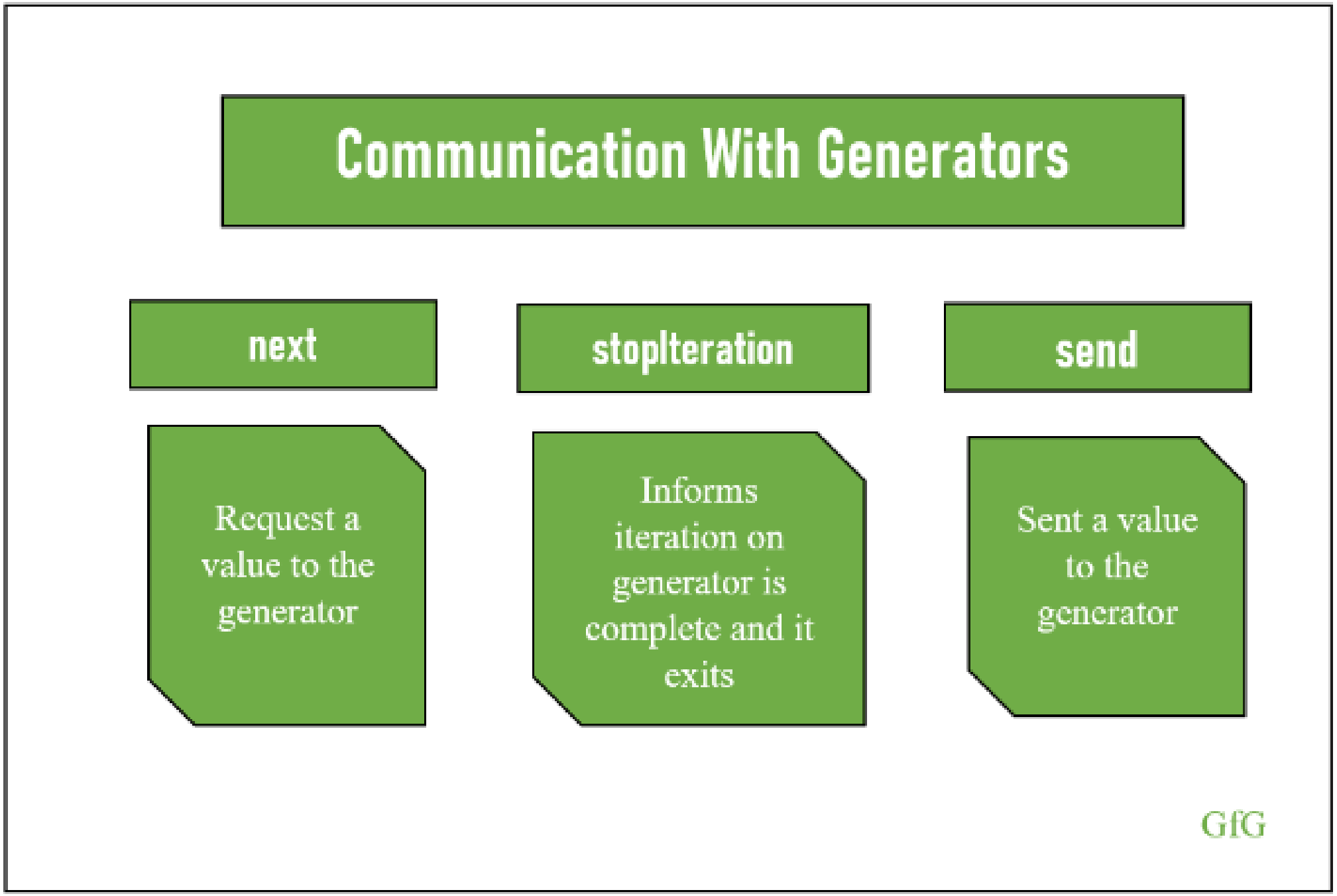
We can say that a function is a generator when it has a yield statement within the code. Like in a return statement, the yield statement also sends a value to the caller, but it doesn't exit the function's execution. **Instead, it halts the execution until the next request is received. Upon request, the generator continues executing from where it is left off.**

```
def primeFunction():
    prime = None
    num = 1
    while True:
        num = num + 1

        for i in range(2, num):
            if(num % i) == 0:
                prime = False
                break
            else:
                prime = True

        if prime:

            # yields the value to the caller
            # and halts the execution
            yield num

def main():

    # returns the generator object.
    prime = primeFunction()

    # generator executes upon request
    for i in prime:
        print(i)
        if i > 50:
            break

if __name__ == "__main__":
    main()
```

## Output

```
3
5
7
11
13
17
19
23
29
31
37
41
43
47
53
```

# Communication With Generator



## next, stopIteration and send

How the caller and generator communicate with each other? Here we will discuss 3 in-built functions in python. They are:

- next
- stopIteration
- send

## next

The next function can **request a generator for its next value.** Upon request, the generator code executes and the yield statement provides the value to the caller. At this point, the generator halts the execution and waits for the next request. Let's dig deeper by considering a Fibonacci function.

```
def fibonacci():
    values = []
    while True:

        if len(values) < 2:
            values.append(1)
        else :

            # sum up the values and
            # append the result
            values.append(sum(values))

            # pop the first value in
            # the list
            values.pop(0)

        # yield the latest value to
        # the caller
        yield values[-1]
        continue

def main():
    fib = fibonacci()
    print(next(fib))  # 1
    print(next(fib))  # 1
    print(next(fib))  # 2
    print(next(fib))  # 3
    print(next(fib))  # 5

if __name__ == "__main__":
    main()
```

## Output

```
1
1
2
3
5
```

- Creating the generator object by calling the fibonacci function and saving its returned value to fib. In this case, the code hasn't run, the python interpreter recognizes the generator and returns the generator object. **Since the function has a yield statement the generator object is returned instead of a value.**

```
fib = fibonacci()
fib
```

**Output**

```
generator object fibonacci at 0x00000157F8AA87C8
```

- Using next function, the caller requests a value to the generator and the execution begins.

  `next(gen)`

  **Output**

```
1
```

- Since the values list is empty the code within the ‘if statement’ is executed and `1` is appended to the values list. Next, the value is yielded to the caller using yield statement and the execution halts. The point to note here is that **the execution halts before executing the continue statement.**

```
# values = []
if len(values) < 2:

    # values = [1]
    values.append(1)

# 1
yield values[-1]
continue
```

- Upon the second request the code continues execution from where it left off. Here it executes from the `continue` statement and passes the control to the while loop.
  Now the values list contains a value from the first request. Since the length of the 'values` is 1 and is less than 2 the code within the 'if statement' executes.

```
# values = [1]
if len(values) < 2:

    # values = [1, 1]
    values.append(1)

# 1 (latest value is provided
# to the caller)
yield values[-1]
continue
```

- Again, the value is requested using next(fib) and the execution starts from `continue` statement. Now the length of the values is not less than 2. Hence it enters the else statement and sums up the values in the list and appends the result. The pop statement removes the first element from the list and yields the latest result.

```
# values = [1, 1]
else:

    # values = [1, 1, 2]
    values.append(sum(values))

    # values = [1, 2]
    values.pop(0)

# 2
yield values[-1]
continue
```

- Your request for more values will repeat the pattern and yield the latest value

## StopIteration

StopIteration is a built-in exception that is used to exit from a Generator. When the generator's iteration is complete, it signals the caller by raising the StopIteration exception and it exits.

Below code explains the scenario.

```
def stopIteration():
    num = 5
    for i in range(1, num):
        yield i

def main():
    f = stopIteration()

    # 1 is generated
    print(next(f))

    # 2 is generated
    print(next(f))

    # 3 is generated
    print(next(f))

    # 4 is generated
    print(next(f))

    # 5th element - raises
    # StopIteration Exception
    next(f)

if __name__ == "__main__":
    main()
```

**Output**

```
1
2
3
4
Traceback (most recent call last):
File “C:\Users\Sonu George\Documents\GeeksforGeeks\Python
Pro\Generators\stopIteration.py”, line 19, in
main()
File “C:\Users\Sonu George\Documents\GeeksforGeeks\Python
Pro\Generators\stopIteration.py”, line 15, in main
next(f) # 5th element – raises StopIteration Exception
StopIteration
```

The below code explains another scenario, where a programmer can raise StopIteration and exit from the generator.

`raise StopIteration`

```
def stopIteration():
    num = 5
    for i in range(1, num):
        if i == 3:
            raise StopIteration
        yield i


def main():
    f = stopIteration()

    # 1 is generated
    print(next(f))

    # 2 is generated
    print(next(f))

    # StopIteration raises and
    # code exits
    print(next(f))
    print(next(f))


if __name__ == "__main__":
    main()
```

**Output**

```
1
2
Traceback (most recent call last):
File “C:\Users\Sonu George\Documents\GeeksforGeeks\Python
Pro\Generators\stopIteration.py”, line 5, in stopIteration
raise StopIteration
StopIteration

The above exception was the direct cause of the following exception:

Traceback (most recent call last):
File “C:\Users\Sonu George\Documents\GeeksforGeeks\Python
Pro\Generators\stopIteration.py”, line 19, in
main()
File “C:\Users\Sonu George\Documents\GeeksforGeeks\Python
Pro\Generators\stopIteration.py”, line 13, in main
print(next(f)) # StopIteration raises and code exits
RuntimeError: generator raised StopIteration
```

**send**

So far, we have seen how generator yield values to the invoking code where the communication is unidirectional. As of now, the generator hasn't received any data from the caller.
In this section, we will discuss **the `send` method that allows the caller to communicate with the generator.**

```python
def factorial():
    num = 1
    while True:
        factorial = 1

        for i in range(1, num + 1):

            # determines the factorial
            factorial = factorial * i

        # produce the factorial to the caller
        response = yield factorial

        # if the response has value
        if response:

            # assigns the response to
            # num variable
            num = int(response)
        else:

            # num variable is incremented
            # by 1
            num = num + 1

def main():
    fact = factorial()
    print(next(fact))
    print(next(fact))
    print(next(fact))
    print(fact.send(5))   # send
    print(next(fact))

if __name__ == '__main__':
    main()
```

## Output

```
1
2
6
120
720
```

The generator yields the first three values (1, 2 and 6) based on the request by the caller (using the next method) and the fourth value (120) is produced based on the data (5) provided by the caller (using send method).
Let's consider the 3rd data (6) yielded by the generator. Factorial of 3 = 3*2*1, which is yielded by the generator and the execution halts.

```
factorial = factorial * i
```

At this point, the caller uses the `send` method and provide the data '5`. Hence generator executes from where it is left off i.e. saves the data sent by the caller to the `response` variable (`response = yield factorial`). **Since the `response` contains a value, the code enters the `if` condition and assigns the response to the `num` variable.**

```
if response:
    num = int(response)
```

Now the flow passes to the `while` loop and determines the factorial and is yielded to the caller. Again, the generator halts the execution until the next request.

If we look into the output, we can see that the order got interrupted after the caller uses the `send` method. More precisely, within the first 3 requests the output as follows:
Factorial of 1 = 1
Factorial of 2 = 2
Factorial of 3 = 6

But when the user sends the value 5 the output becomes 120 and the `num` maintains the value 5. On the next request (using `next`) we expect num to get incremented based on last `next` request (i.e. 3+1 = 4) rather than the `send` method. But in this case, the `num` increments to 6 (based on last value using `send`) and produces the output 720.

The below code shows a different approach in handling values sent by the caller.

```
def factorial():
    num = 0
    value = None
    response = None
    while True:
        factorial = 1
        if response:
            value = int(response)
        else:
            num = num + 1
            value = num

        for i in range(1, value + 1):
            factorial = factorial * i
        response = yield factorial


def main():
    fact = factorial()
    print(next(fact))
    print(next(fact))
    print(next(fact))
    print(fact.send(5))    # send
    print(next(fact))

if __name__ == '__main__':
    main()
```

## Output

```
1
2
6
120
24
```