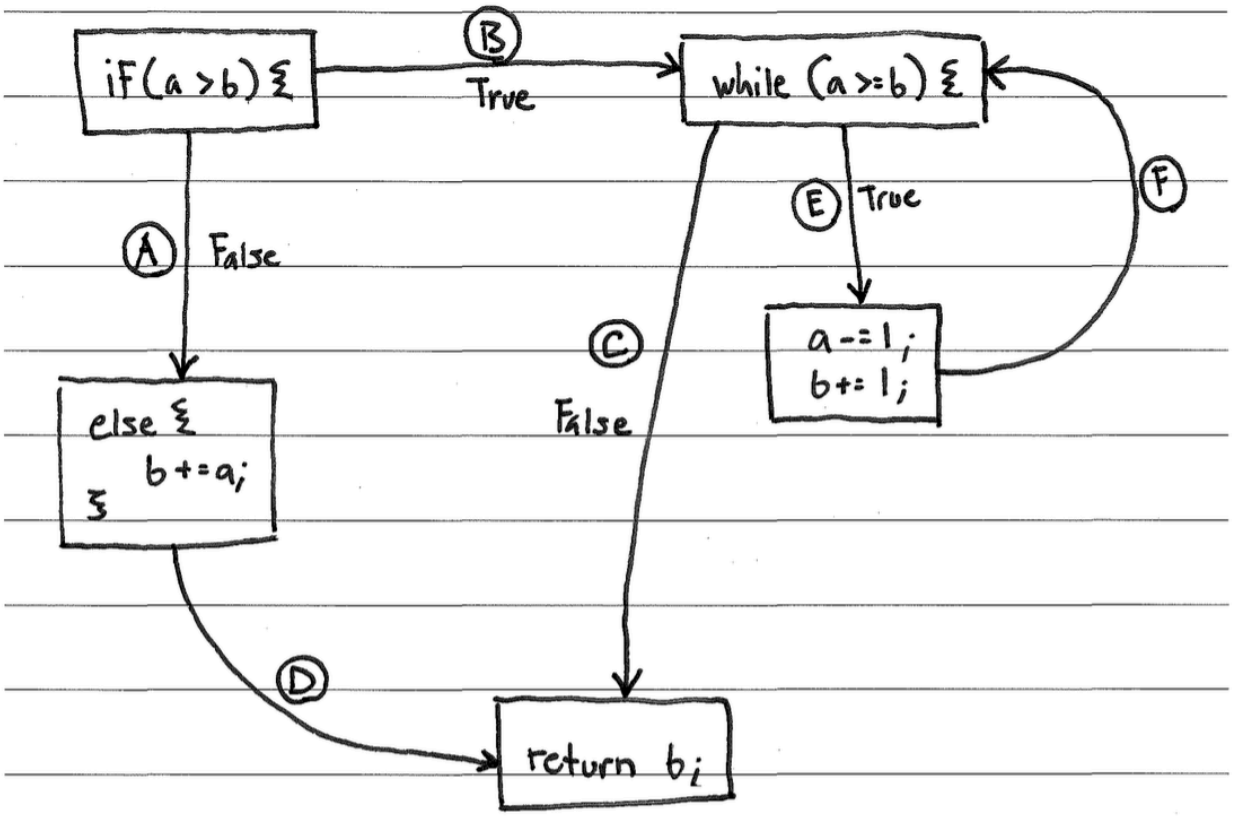
Problem: Draw a control flow diagram for this function. Label each edge with an uppercase letter.

```
int funWithNumbers(int a, int b) {
    if (a > b) {
        while (a >= b) {
            a -= 1;
            b += 1;
        }
    } else {
        b += a;
    }
    return b;
}
```

Solution:


iF(a >b) {
B
True
while (a >=b) {
A
False
E
True
F
a -= 1;
b += 1;
C
False
else {
b += a;
}
D
return b;

Problem: Fill in the table below with a test suite that provides *path coverage* of the code from the previous question. Cover no more than 2 iterations of the loop. In the covers column, list the relevant labeled items in your CFG that each test case covers. If there is some part of the coverage that is impossible to cover, then list it in the covers column, and put "N/A" in the associated x and y cells. Some cells in the table may be left blank.

Input		**Covers**
x	**y**	

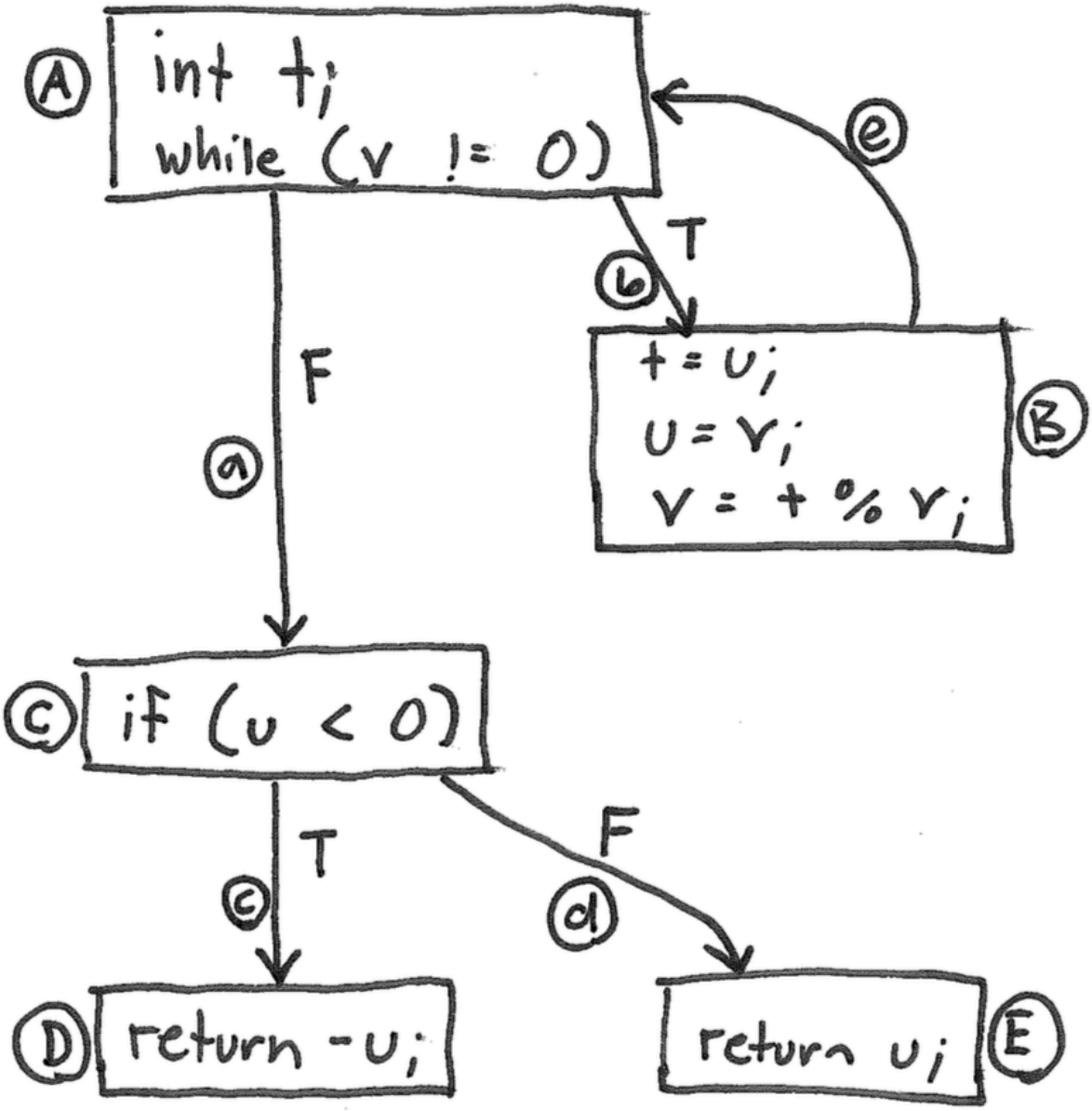
Solution:

Input		Covers
x	y	
1	2	AD
N/A	N/A	BC
1	0	BEFC
4	2	BEFEFC

Problem: Draw a control flow diagram for this function. Label each node in the graph with a capital letter, and label each edge with a lowercase letter.

```
int blammo(int u, int v) {
  int t;
  while (v != 0) {
    t = u;
    u = v;
    v = t % v; // Recall that % computes remainder of t/v
  }
  if (u < 0) { return -u; }
  return u;
}
```

Solution:


A
int t;
while (v != 0)
e
T
b
t = u;
u = v;
v = t % v;
B
F
a
c
if (u < 0)
T
F
c
d
D
return -u;
return u;
E

Problems:

1. Fill in the table below with a test suite that provides statement coverage of the "blammo" code. In the covers column, list the relevant labeled items in your CFG that each test case covers. Some cells in the table may be left blank.

Input		Covers
u	v	

2. Fill in the table below with a test suite that provides path coverage of the "blammo" code. Cover no more than 1 iteration of the loop. In the covers column, list the relevant labeled items in your CFG that each test case covers. Some cells in the table may be left blank.

Input		Covers
u	v	

Solutions:

1.

Input		Covers
u	v	
2	2	A, B, C, E
-1	0	A, C, D

2.

Input		Covers
u	v	
-1	0	a, c
0	0	a, d
-2	-2	b, e, a, c
2	2	b, e, a, d

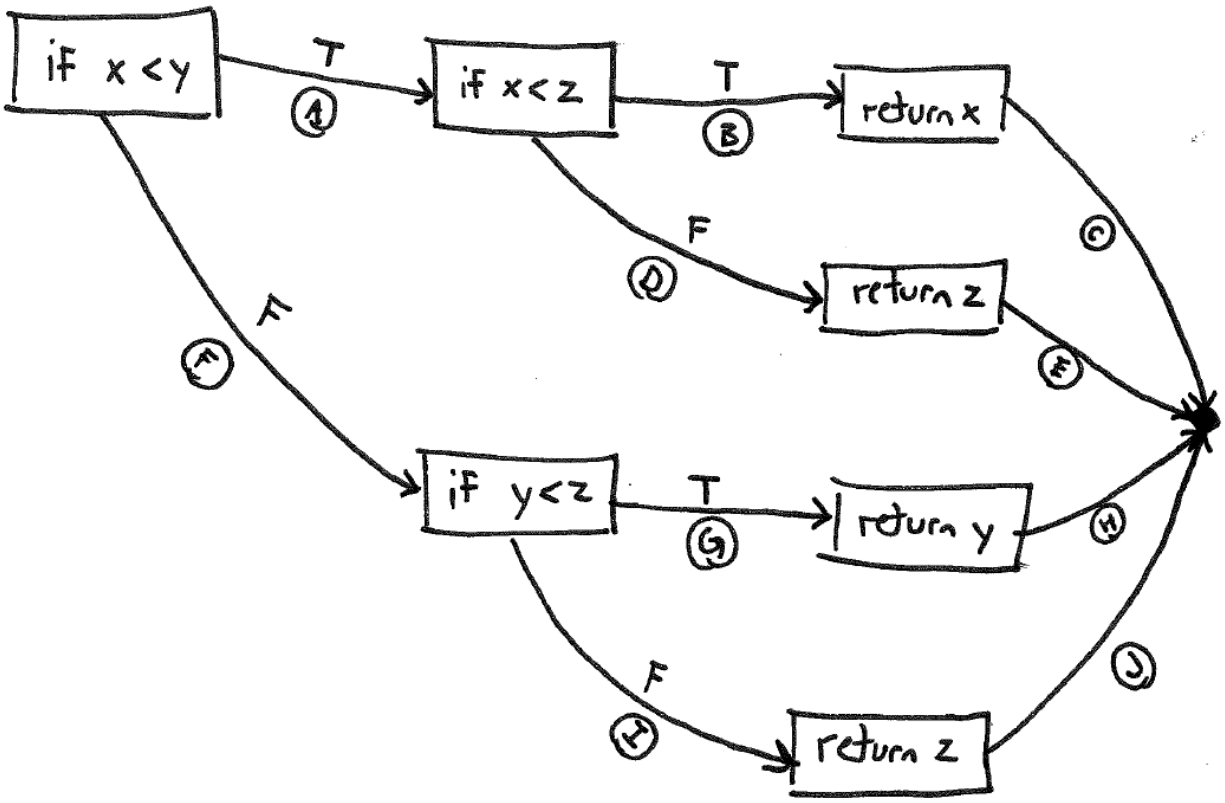
Paths:

a, c
a, d
b, e, a, c
b, e, a, d

Problem: Draw a control-flow graph for the following function. Label each edge in the graph with an uppercase letter.

```
def min_of_three(x, y, z)
  if x < y then
    if x < z then
      return x
    else
      return z
    end
  else
    if y < z then
      return y
    else
      return z
    end
  end
end
```

Solution:


if x<y
T
1
if x<z
T
B
return x
C
F
D
return z
E
F
if y<z
T
G
return y
H
F
I
return z
J

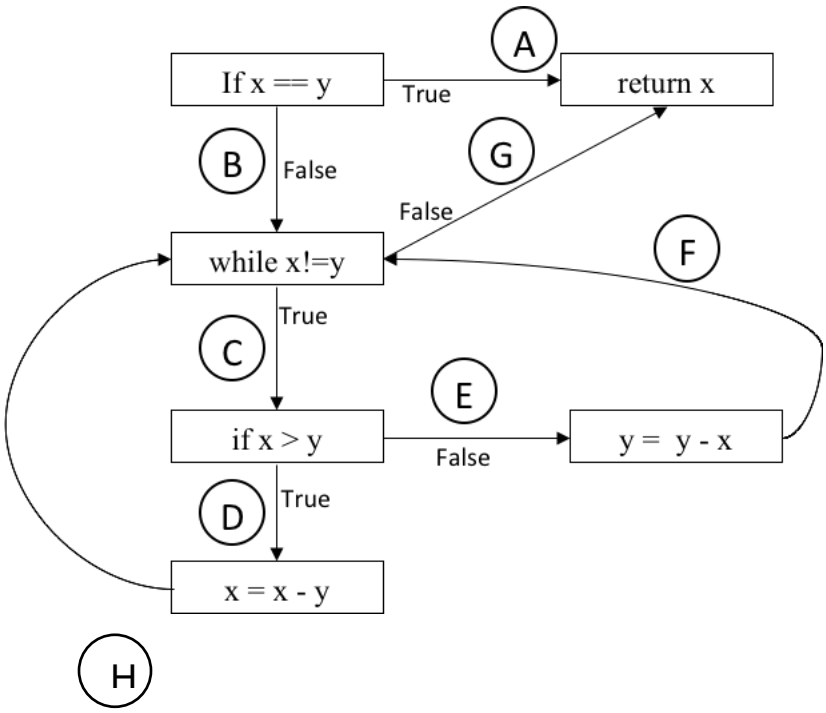
Problem: Fill in the table below with a test suite that provides path coverage of the `min_of_three` function from the previous question. In the covers column, list the relevant labeled edges in your CFG that each test case covers. Some cells in the table may be left blank.

Input			Expected Output	Covers
x	y	z		

Solution:

Input			Expected Output	Covers
x	y	z		
1	2	2	1	A, B, C
2	3	1	1	A, D, E
2	1	2	1	F, G, H
3	2	1	1	F, I, J

Consider the following control-flow graph for a `gcd` function in answering the questions below.



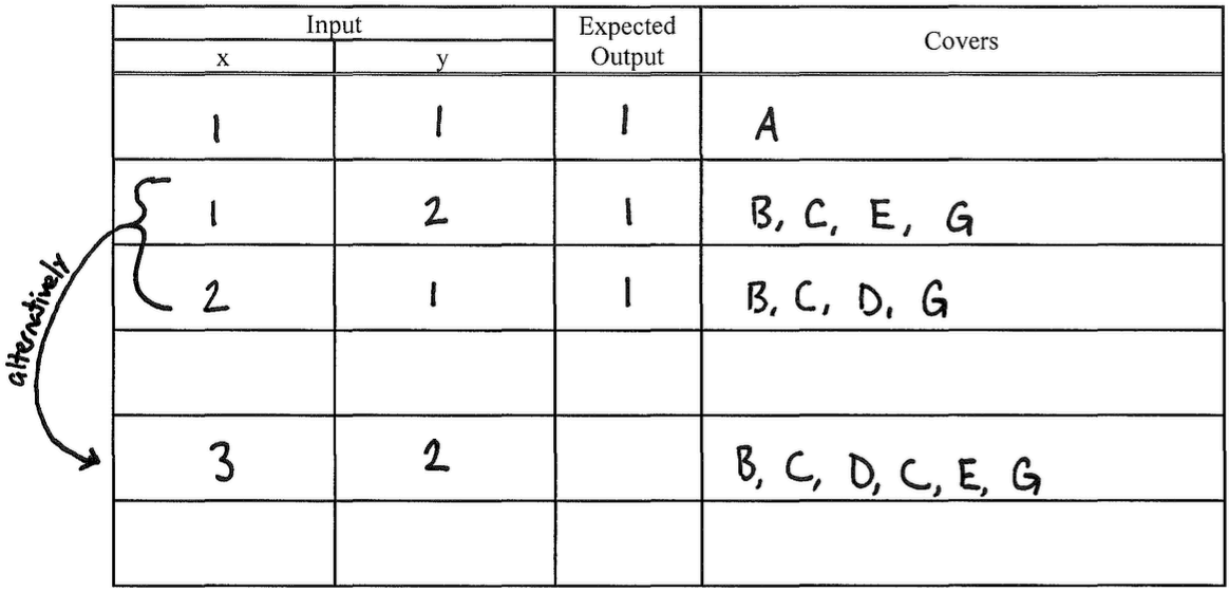
Problem: Fill in the table below with a test suite that provides condition coverage of the `gcd` function (see control-flow graph above). In the Covers column, list the relevant labeled edges in the CFG that each test case covers. Some cells in the table may be left blank.

Input		Expected Output	Covers
x	y		

Problem: Fill in the table below with a test suite that provides path coverage of the `gcd` function (see control-flow graph above). In the Covers column, list the relevant labeled edges in the CFG that each test case covers. Some cells in the table may be left blank. You need only cover executions that involve 1 iteration of the loop.

Input		Expected Output	Covers
x	y		

Solution: Condition Coverage



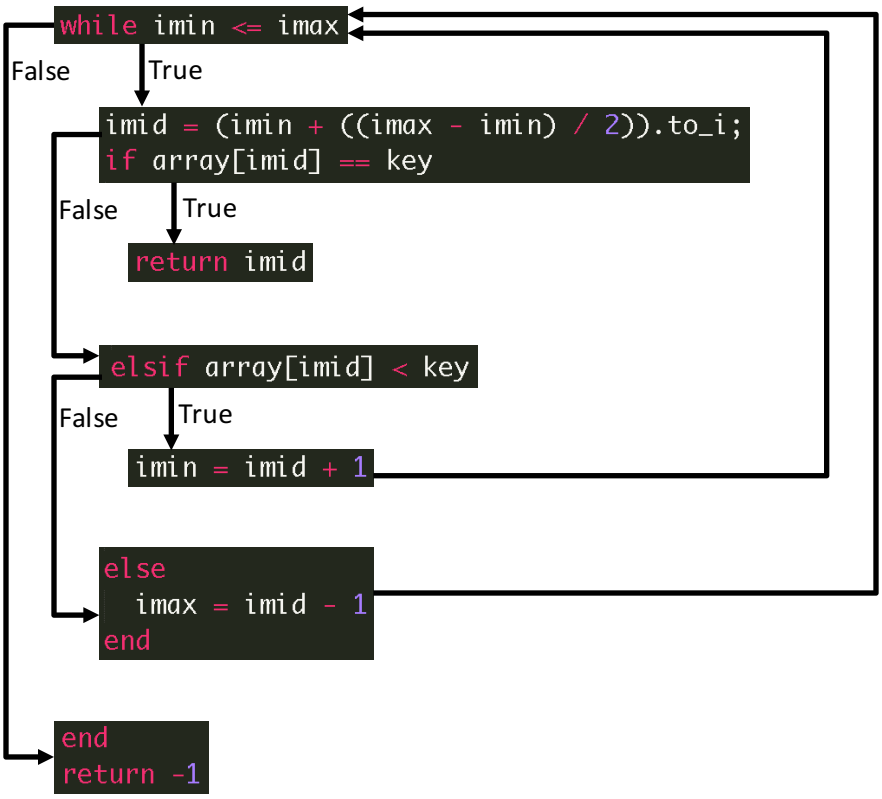
Input		Expected Output	Covers
x	y		
1	1	1	A
1	2	1	B, C, E, G
2	1	1	B, C, D, G
3	2		B, C, D, C, E, G

Solution: Path Coverage

Input		Expected Output	Covers
x	y		
1	1	1	A
2	1	1	B, C, D, H, G
1	2	1	B, C, E, F, G
			B, G ← not possible

Consider this binary-search function and its associated control-flow graph.

```
def binary_search(array, key, imin, imax)
  while imin <= imax
      imid = (imin + ((imax - imin) / 2)).to_i;
      if array[imid] == key
        return imid
      elsif array[imid] < key
        imin = imid + 1
      else
        imax = imid - 1
      end
  end
  return -1
end
```



Problems:

Consider the following test cases for the `binary_search` function.

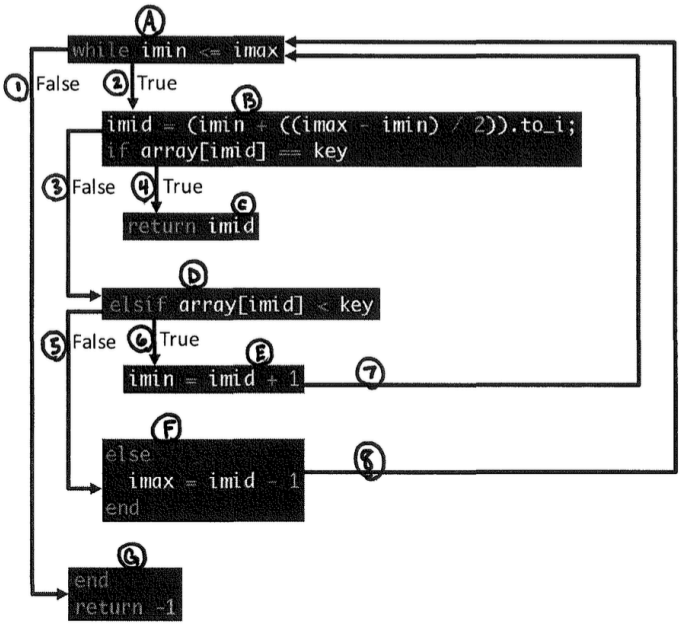
	array	key	imin	imax
a.	`[1]`	0	0	0
b.	`[1]`	1	0	0
c.	`[1]`	1	1	0
d.	`[1, 2, 3]`	1	0	2
e.	`[1, 2, 3]`	2	0	2
f.	`[1, 2, 3]`	3	0	2
g.	`[1, 2, 3]`	1	2	0
h.	`[1, 2, 3]`	2	2	0
i.	`[1, 2, 3]`	3	2	0

1. Select tests from the above to create a test suite that provides statement coverage of the `binary_search` function. Your suite should contain the minimum number of tests to provide the coverage.

2. Select tests from the above to create a test suite that provides condition coverage of the `binary_search` function. Your suite should contain the minimum number of tests to provide the coverage.

3. Select tests from the above to create a test suite that provides path coverage of the `binary_search` function. Cover only paths that contain one loop iteration or fewer (i.e., no path should enter the loop more than once). Your suite should contain the minimum number of tests to provide the coverage.

Solutions:



	array	key	imin	imax	Statements Covered	Edges Covered
a.	[1]	0	0	0	ABDFAG	23581
b.	[1]	1	0	0	ABC	24
c.	[1]	2	0	0	ABDEAG	23671
d.	[1, 2, 3]	1	0	2	ABDFABC	235824
e.	[1, 2, 3]	2	0	2	ABC	24
f.	[1, 2, 3]	3	0	2	ABDEABC	236724
g.	[1, 2, 3]	1	2	0	AG	1
h.	[1, 2, 3]	2	2	0	AG	1
i.	[1, 2, 3]	3	2	0	AG	1

1. a, F or c, d
(Need to cover statements A, B, C, D, E, F, G)

2. a, F or c, d
(Need to cover edges 1, 2, 3, 4, 5, 6)

3. (g|h|i), (b|e), c, a

Any 1 of these — Any 1 of these

Possible paths	Tests that cover
1	g, h, i
24	b, e
23671	c
23581	a

Problems:

Consider the following test cases for the `binary_search` function.

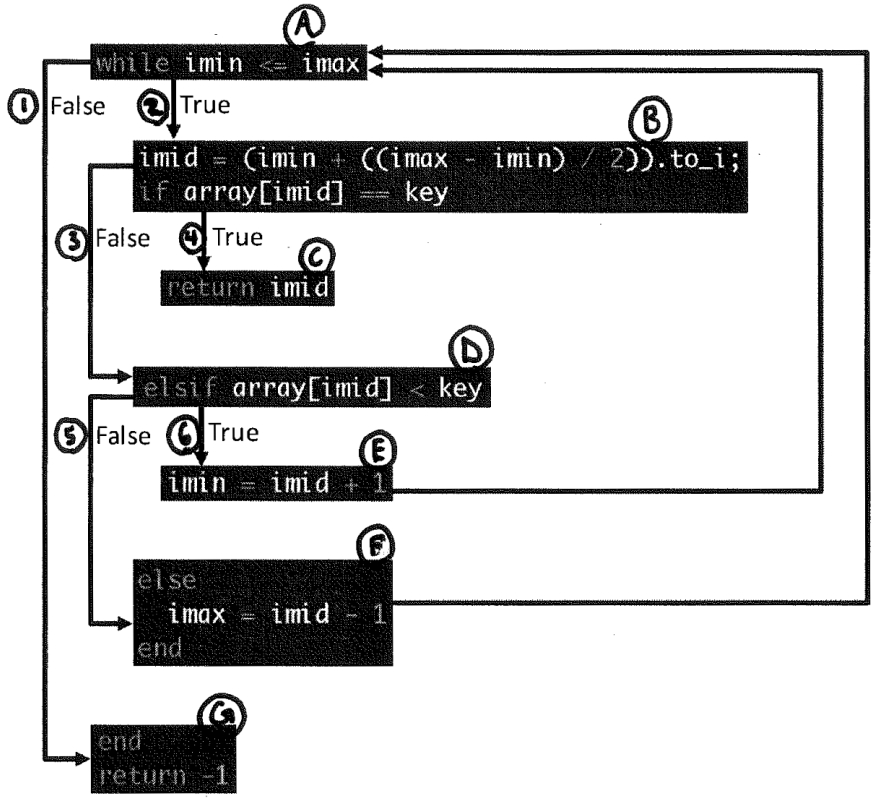
	array	key	imin	imax
a.	[0]	0	0	0
b.	[0]	1	0	0
c.	[0]	1	1	0
d.	[0]	-1	0	0

1. Select tests from the above to create a test suite that provides statement coverage of the `binary_search` function. Your suite should contain the minimum number of tests to provide the coverage.

2. Select tests from the above to create a test suite that provides condition coverage of the `binary_search` function. Your suite should contain the minimum number of tests to provide the coverage.

3. Select tests from the above to create a test suite that provides path coverage of the `binary_search` function. Cover only paths that contain one loop iteration or fewer (i.e., no path should enter the loop more than once). Your suite should contain the minimum number of tests to provide the coverage.

Solutions:



	array	key	imin	imax	Statements Covered	Conditions Covered
a.	[0]	0	0	0	A B C	2 4
b.	[0]	1	0	0	A B D E G	2 3 6 1
c.	[0]	1	1	0	A G	1
d.	[0]	-1	0	0	A B D F G	2 3 5 1

Path	Covered by
A G	c
A B C	a
A B D E A G	b
A B D F A G	d

1. a, b, d
2. a, b, d
3. a, b, c, d

Consider this figure in answer the following questions.

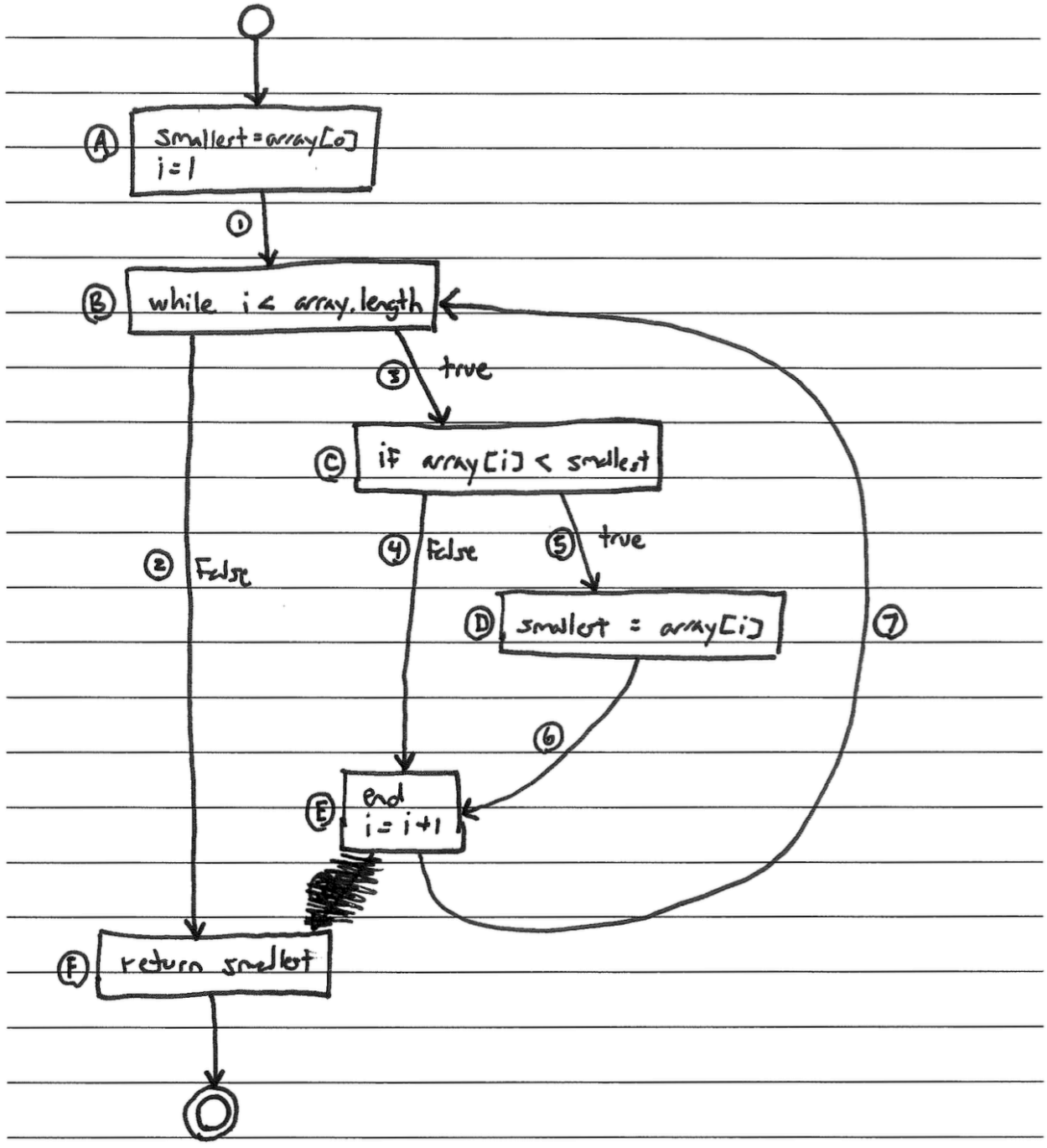
```
def find_smallest(array)
  smallest = array[0]
  i = 1
  while i < array.length
    if array[i] < smallest
        smallest = array[i]
    end
    i = i + 1
  end
  return smallest
end
```

Figure 1. Function that finds the smallest value in an array.

Problem:

Draw a control-flow graph (CFG) for the function in Figure 1. In addition to the usual CFG features, label the nodes with capital letters (A, B, C, etc.), and label the edges with numbers (1, 2, 3, etc.). Don't forget to include entry and exit points.

Solution:


A
smallest = array[0]
i = 1
1
B
while i < array.length
3
true
C
if array[i] < smallest
2
False
4
False
5
true
D
smallest = array[i]
7
6
E
end
i = i+1
F
return smallest

Problems:

Use the CFG you created for the function in Figure 1 to answer the following questions.

1. Fill in the table below with a test suite that provides statement coverage. In the Covers column, list the letter labels (A, B, C, etc.) of the nodes covered by each test case.

Input array	Expected Output	Covers

2. Fill in the table below with a test suite that provides branch coverage. In the Covers column, list the number labels (1, 2, 3, etc.) of the edges covered by each test case (only true/false edges needed).

Input array	Expected Output	Covers

3. Fill in the table below with a test suite that provides path coverage. In the Covers column, list the number labels (1, 2, 3, etc.) of the edges covered by each test case. You need only cover executions that involve at most 1 iteration of each loop (if there are any). Before you fill in the table, list all the paths to be covered.

Paths:

Input array	Expected Output	Covers

Solutions:

Multiple solutions are possible. These are just examples of correct solutions.

1.

Input array	Expected Output	Covers
[1,0]	0	A, B, C, D, E, B, F

2.

Input array	Expected Output	Covers
[1,0,2]	0	3, 5, 3, 4, 2

3.

- 1, 2
- 1, 3, 5, 6, 7, 2
- 1, 3, 4, 7, 2

Input array	Expected Output	Covers
[0]	0	1,2
[1,0]	0	1,3,5,6,7,2
[0,1]	0	1, 3, 4, 7, 2

Consider this figure in answer the following questions.

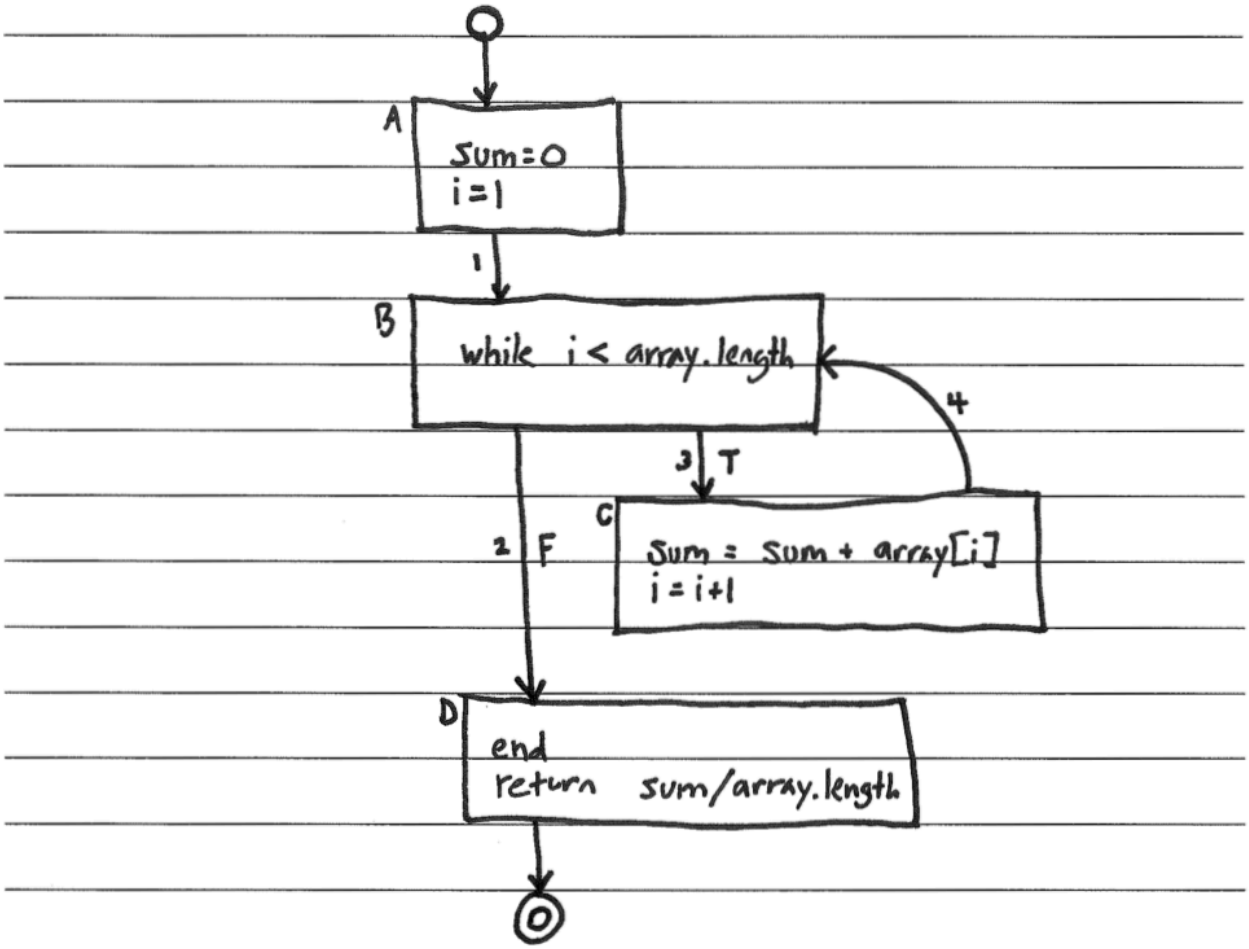
```
def average(array)
  sum = 0
  i = 1
  while i < array.length
    sum = sum + array[i]
    i = i + 1
  end
  return sum/array.length
end
```

Figure 2. Buggy function that computes the average value of an array of numbers.

Problem:

Draw a control-flow graph (CFG) for the function in Figure 2. In addition to the usual CFG features, label the nodes with capital letters (A, B, C, etc.), and label the edges with numbers (1, 2, 3, etc.). Don't forget to include entry and exit points.

Solution:


A
Sum=0
i=1
1
B
while i < array.length
4
3 T
C
2 F
Sum = Sum + array[i]
i = i+1
D
end
return sum/array.length

Problems:

Use the CFG you created for the function in Figure 2 to answer the following questions.

1. Fill in the table below with a test suite that provides statement coverage. In the Covers column, list the letter labels (A, B, C, etc.) of the nodes covered by each test case.

Input array	Expected Output	Covers

2. Fill in the table below with a test suite that provides branch coverage. In the Covers column, list the number labels (1, 2, 3, etc.) of the edges covered by each test case (only true/false edges needed).

Input array	Expected Output	Covers

Solutions:

1.

Input array	Expected Output	Covers
[1,1]	1	A, B, C, D

2.

Input array	Expected Output	Covers
[1,1]	1	3, 2

Problem:

Fill in the table below with a test suite that provides path coverage. In the Covers column, list the number labels (1, 2, 3, etc.) of the edges covered by each test case. You need only cover executions that involve at most 1 iteration of each loop (if there are any). Before you fill in the table, list all the paths to be covered.

Paths:

Input array	Expected Output	Covers

Solution:

Paths:

- 1,2
- 1,3,4,2

Input array	Expected Output	Covers
[1]	1	1,2
[1,1]	1	1,3,4,2

Question:

Which, if any, of your above three test suites would have caught the bug in the function?

Solution:

All of the above test suites would have caught the bug.