# The testing process

- Component testing
  - Testing of individual program components
  - Usually the responsibility of the component developer (except sometimes for critical systems)
  - Tests are derived from the developer's experience
- Integration testing
  - Testing of groups of components integrated to create a system or sub-system
  - The responsibility of an independent testing team
  - Tests are based on a system specification

Testing phases

Component testing	→	Integration testing

Software developer | Independent testing team
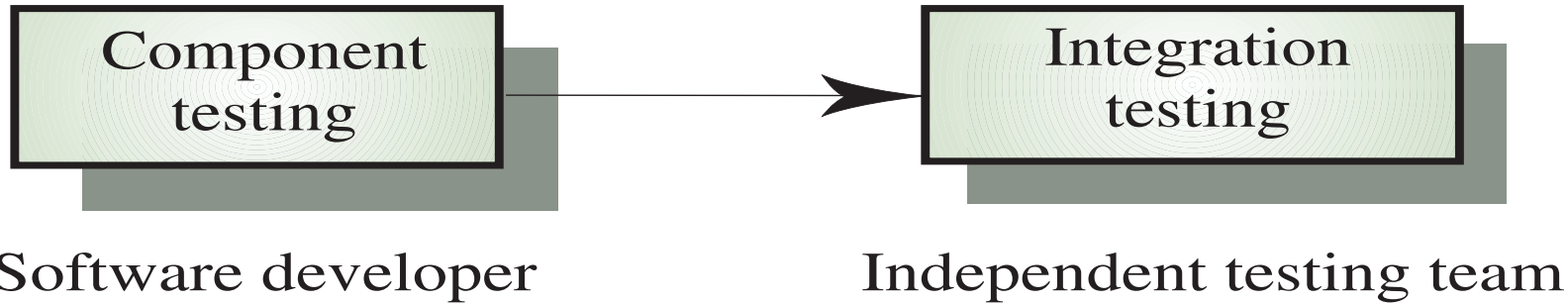
Testing Priorities:

- Only exhaustive testing can show a program is free from defects. However, exhaustive testing is impossible
- Tests should exercise a system's capabilities rather than its components
- Testing old capabilities is more important than testing new capabilities
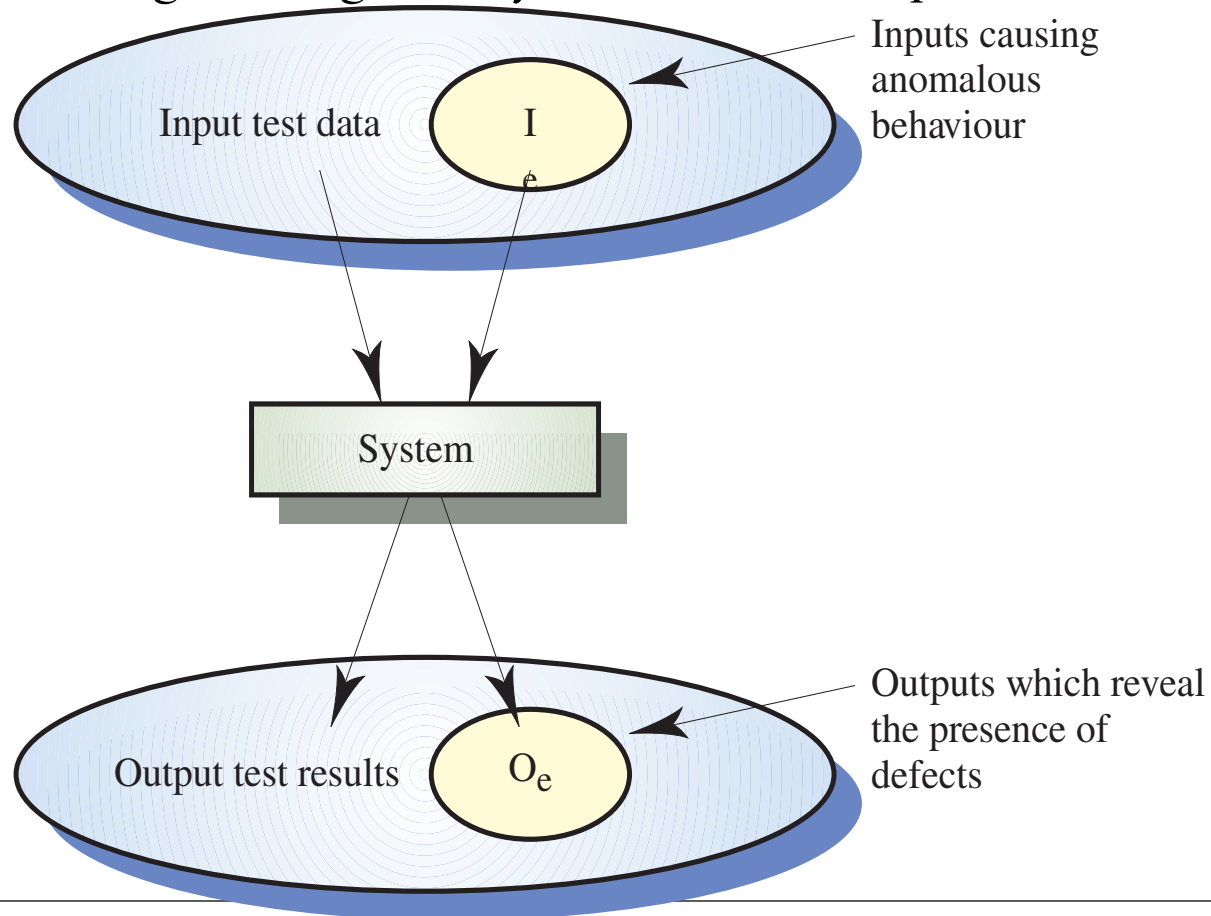- Testing typical situations is more important than boundary value cases

Test data and test cases

- *Test data* Inputs which have been devised to test the system

- *Test cases* Inputs to test the system and the predicted outputs from these inputs if the system operates according to its specification
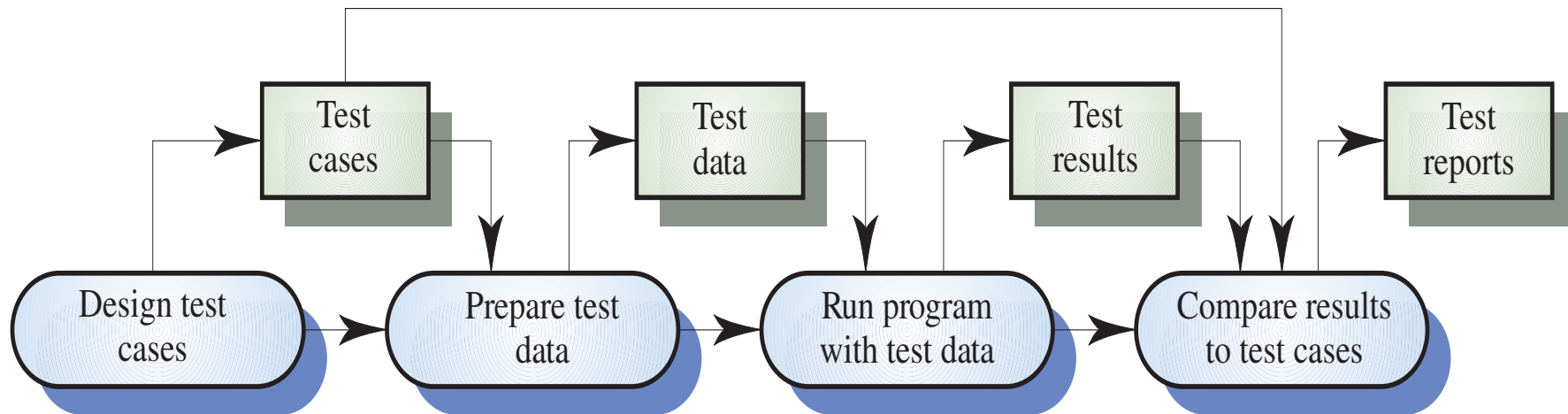
Black-box testing

- An approach to testing where the program is considered as a 'black-box'

- The program test cases are based on the system specification

- Test planning can begin early in the software process

Input test data

I$_e$ — Inputs causing anomalous behaviour

System

Output test results

O$_e$ — Outputs which reveal the presence of defects

Equivalence partitioning

- Input data and output results often fall into different classes where all members of a class are related
- Each of these classes is an equivalence partition where the program behaves in an equivalent way for each class member
- Test cases should be chosen from each partition

Invalid inputs · Valid inputs
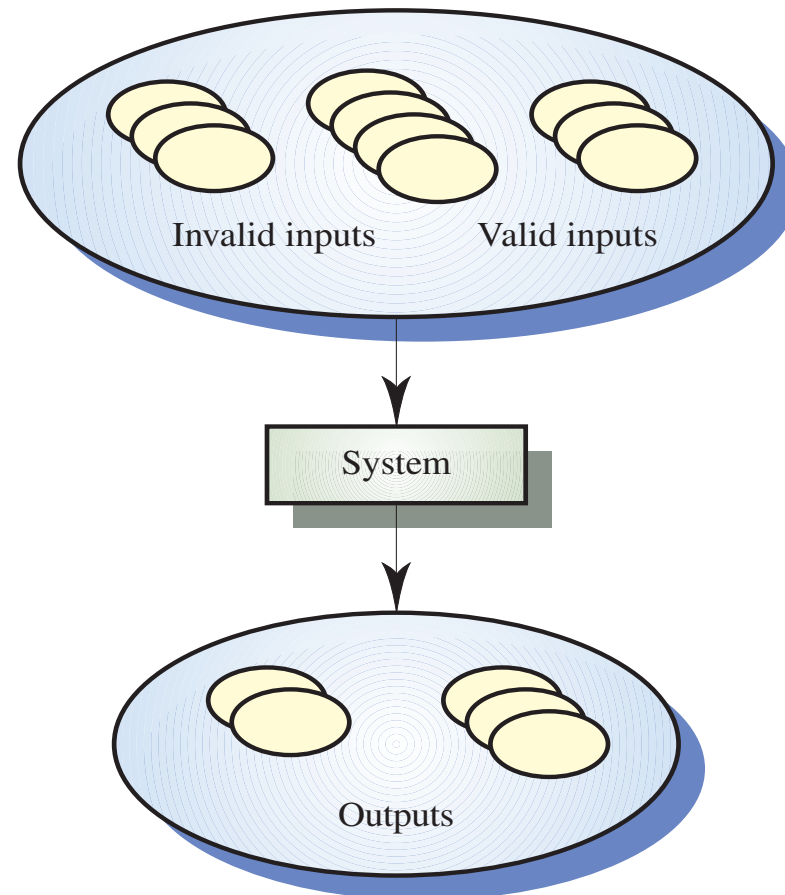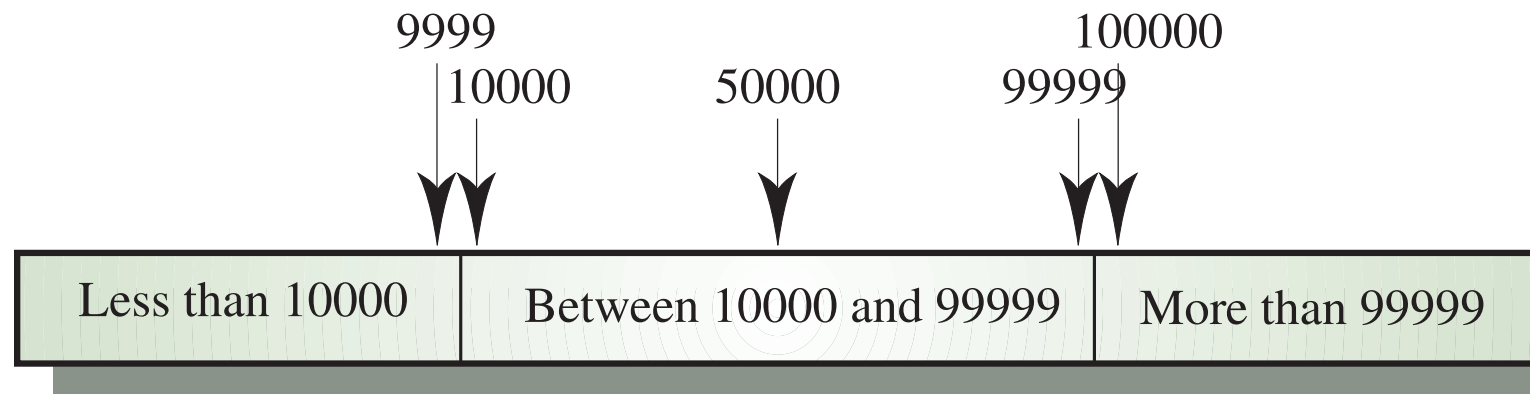
System

Outputs

Equivalence partitioning

- Partition system inputs and outputs into 'equivalence sets'
  - If input is a 5-digit integer between 10.000 and 99.999, equivalence partitions are <10.000, 10.000-99. 999 and > 99.999
- Choose test cases at the boundary of these sets
  - 00000, 09999, 10000, 99999, 10001

Equivalence partitions
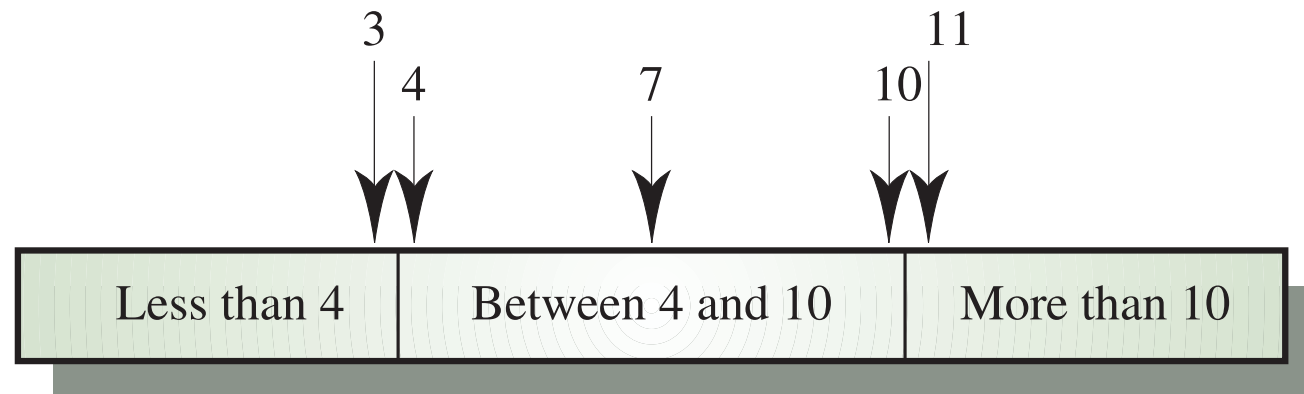
Number of input values

Input values

Search routine specification

procedure Search (Key : ELEM ; T: ELEM_ARRAY;
    Found : **in out** BOOLEAN; L: **in out** ELEM_INDEX) ;

Pre-condition
    -- the array has at least one element
    T'FIRST <= T'LAST
Post-condition
    -- the element is found and is referenced by L
    (Found and T (L) = Key)
or
    -- the element is not in the array
    (**not** Found **and**
    not (**exists** i, T'FIRST >= i <= T'LAST, T (i) = Key))

Search routine - input partitions

- Inputs which conform to the pre-conditions
- Inputs where a pre-condition does not hold
- Inputs where the key element is a member of the array
- Inputs where the key element is not a member of the array
- **<u>Testing guidelines (sequences)</u>**
- Test software with sequences which have only a single value
- Use sequences of different sizes in different tests
- Derive tests so that the first, middle and last elements of the sequence are accessed
- Test with sequences of zero length

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Search routine - input partitions

Array	Element
Single value	In sequence
Single value	Not in sequence
More than 1 value	First element in sequence
More than 1 value	Last element in sequence
More than 1 value	Middle element in sequence
More than 1 value	Not in sequence

Input sequence (T)	Key (Key)	Output (Found, L)
17	17	true, 1
17	0	false, ??
17, 29, 21, 23	17	true, 1
41, 18, 9, 31, 30, 16, 45	45	true, 7
17, 18, 21, 23, 29, 41, 38	23	true, 4
21, 23, 29, 33, 38	25	false, ??

Structural testing

- Sometime called white-box testing

- Derivation of test cases according to program structure. Knowledge of the program is used to identify additional test cases

- Objective is to exercise all program statements (not all path combinations)

```
Test data

       Tests          Derives

       Component          Test
         code            outputs
```
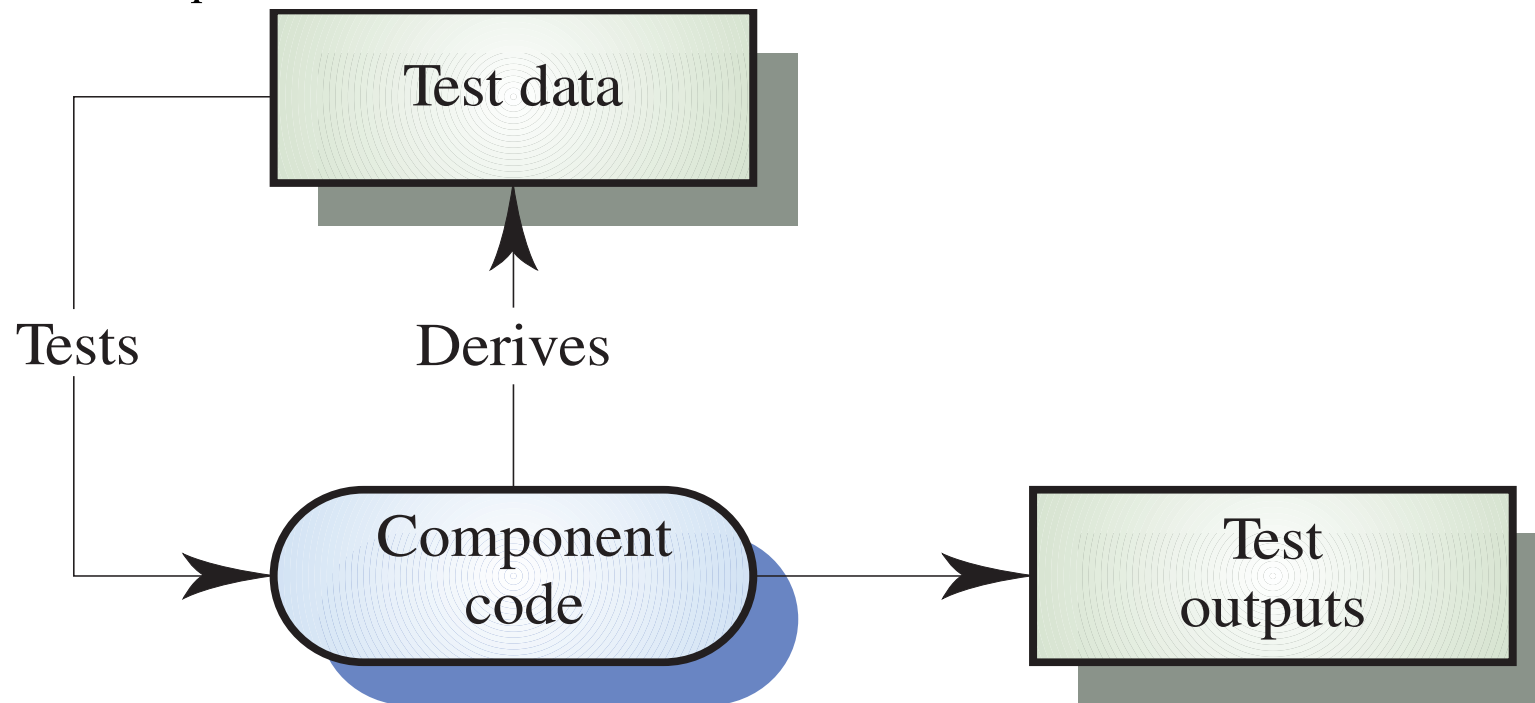
```java
class BinSearch {

// This is an encapsulation of a binary search function that takes an array of
// ordered objects and a key and returns an object with 2 attributes namely
// index - the value of the array index
// found - a boolean indicating whether or not the key is in the array
// An object is returned because it is not possible in Java to pass basic types by
// reference to a function and so return two values
// the key is -1 if the element is not found

        public static void search ( int key, int [] elemArray, Result r )
        {
                int bottom = 0 ;
                int top = elemArray.length - 1 ;
                int mid ;
                r.found = false ; r.index = -1 ;
                while ( bottom <= top )
                {
                        mid = (top + bottom) / 2 ;
                        if (elemArray [mid] == key)
                        {
                                r.index = mid ;
                                r.found = true ;
                                return ;
                        } // if part
                        else
                        {
                                if (elemArray [mid] < key)
                                        bottom = mid + 1 ;
                                else
                                        top = mid - 1 ;

                        }
                } //while loop
        } // search
} //BinSearch
```

Binary search (Java)

Binary search - equiv. partitions

- Pre-conditions satisfied, key element in array
- Pre-conditions satisfied, key element not in array
- Pre-conditions unsatisfied, key element in array
- Pre-conditions unsatisfied, key element not in array
- Input array has a single value
- Input array has an even number of values
- Input array has an odd number of values

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Binary search equiv. partitions

Equivalence class boundaries

Elements < Mid | Elements > Mid

Mid-point
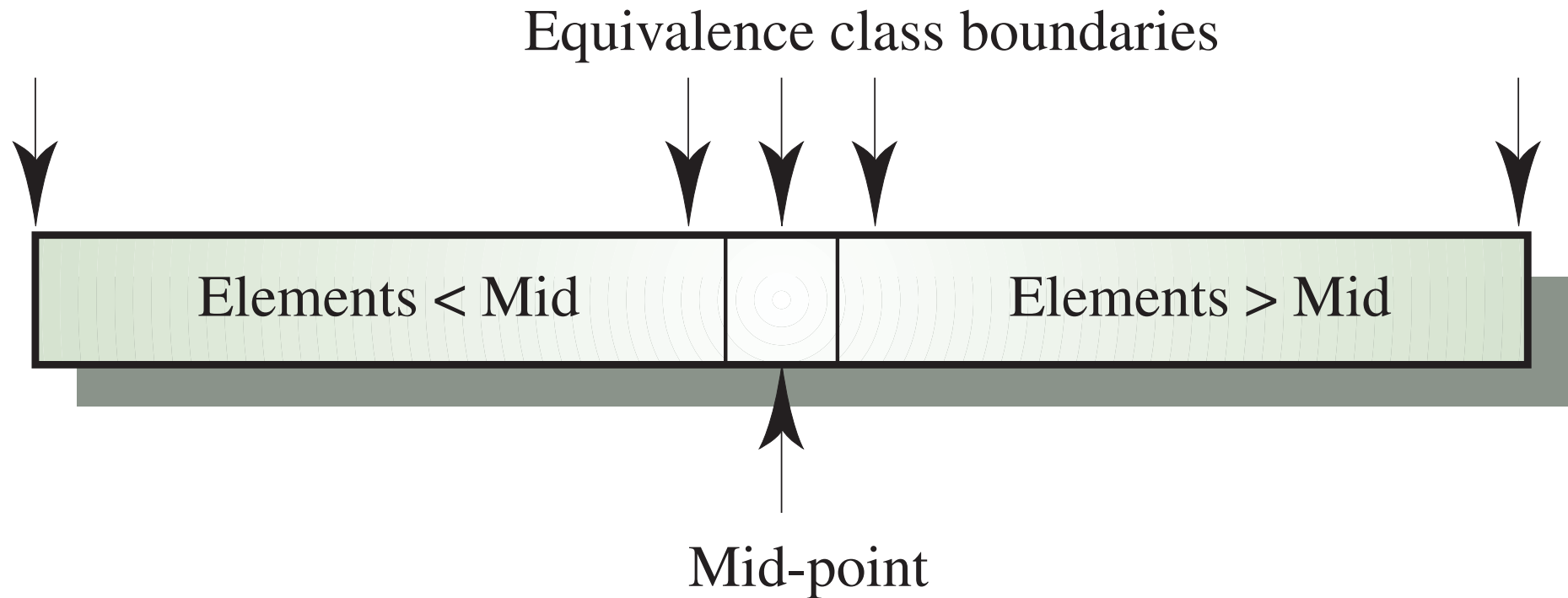
Path testing

- The objective of path testing is to ensure that the set of test cases is such that each path through the program is executed at least once

- The starting point for path testing is a program flow graph that shows nodes representing program decisions and arcs representing the flow of control

- Statements with conditions are therefore nodes in the flow graph

Program flow graphs and Cyclomatic complexity

- Describes the program control flow. Each branch is shown as a separate path and loops are shown by arrows looping back to the loop condition node

- Used as a basis for computing the cyclomatic complexity

- Cyclomatic complexity = Number of edges - Number of nodes +2

- The number of tests to test all control statements equals the cyclomatic complexity

- Cyclomatic complexity equals number of conditions in a program

- Useful if used with care. Does not imply adequacy of testing.

- Although all paths are executed, all combinations of paths are not executed

bottom > top

while bottom <= top

if (elemArray [mid] == key

(if (elemArray [mid]< key
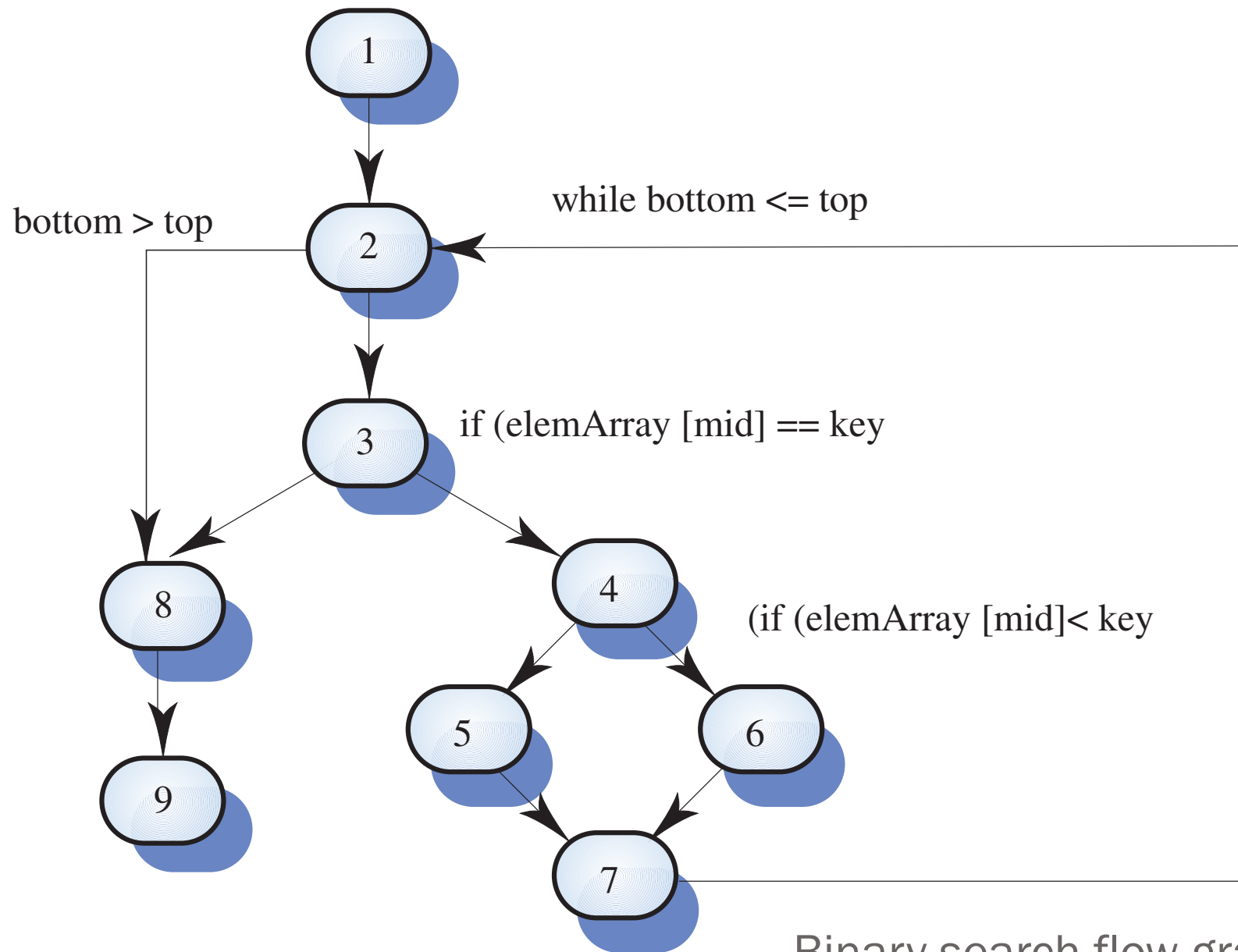
Binary search flow graph

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Independent paths

- 1, 2, 3, 8, 9
- 1, 2, 3, 4, 6, 7, 2
- 1, 2, 3, 4, 5, 7, 2
- 1, 2, 3, 4, 6, 7, 2, 8, 9
- Test cases should be derived so that all of these paths are executed
- A dynamic program analyser may be used to check that paths have been executed