# Software Engineering

# Software Testing

# Objectives

- To explain the different types of testing techniques used to discover program faults
- To introduce guidelines for interface testing
- To understand the principles of CASE tool support for testing

# What is Defect testing?

Testing is**:**

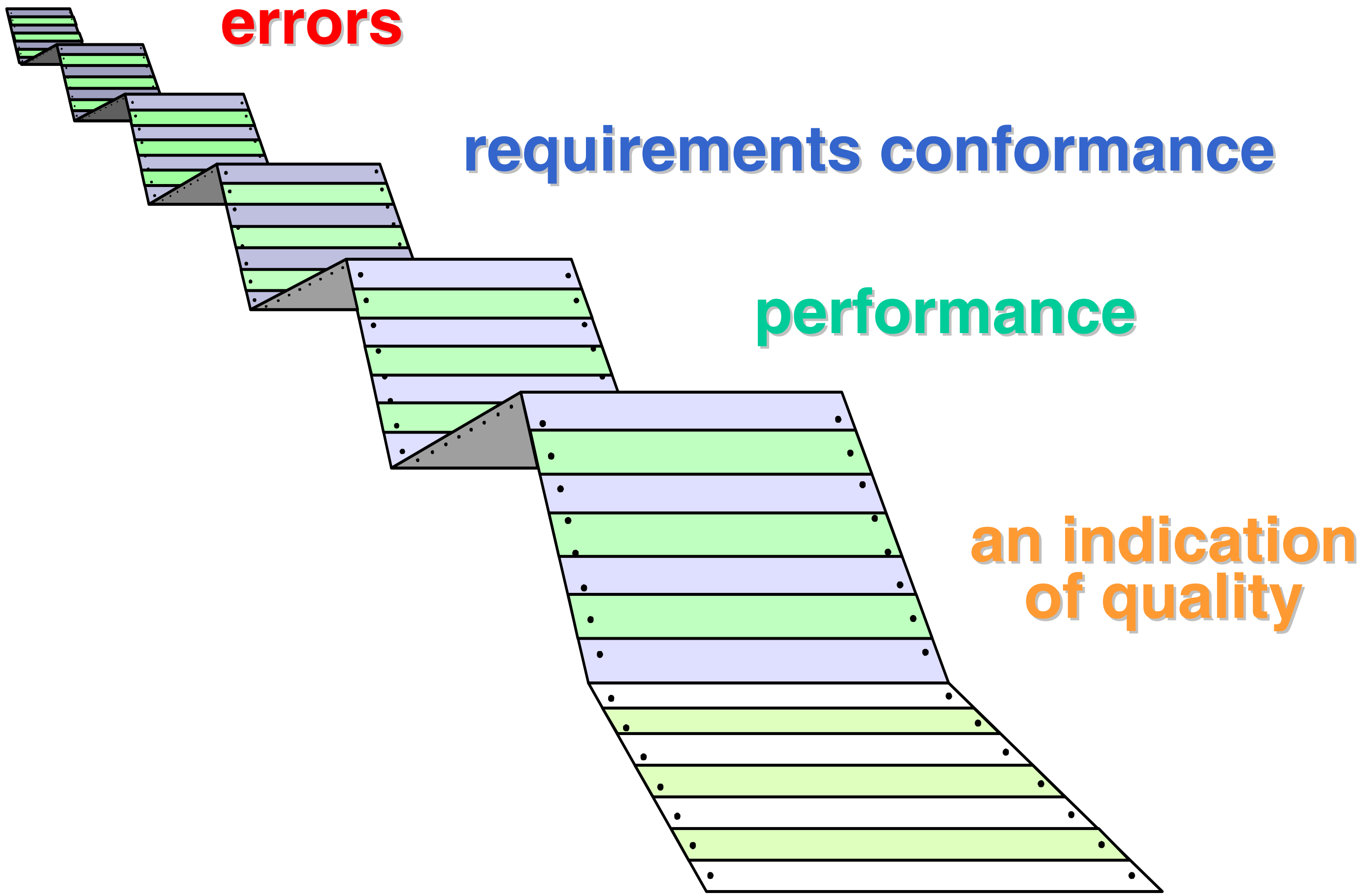
- the process of **exercising a program**
- with the specific intent of **finding errors**
- **prior to delivery** to the end user.

# Types of testing

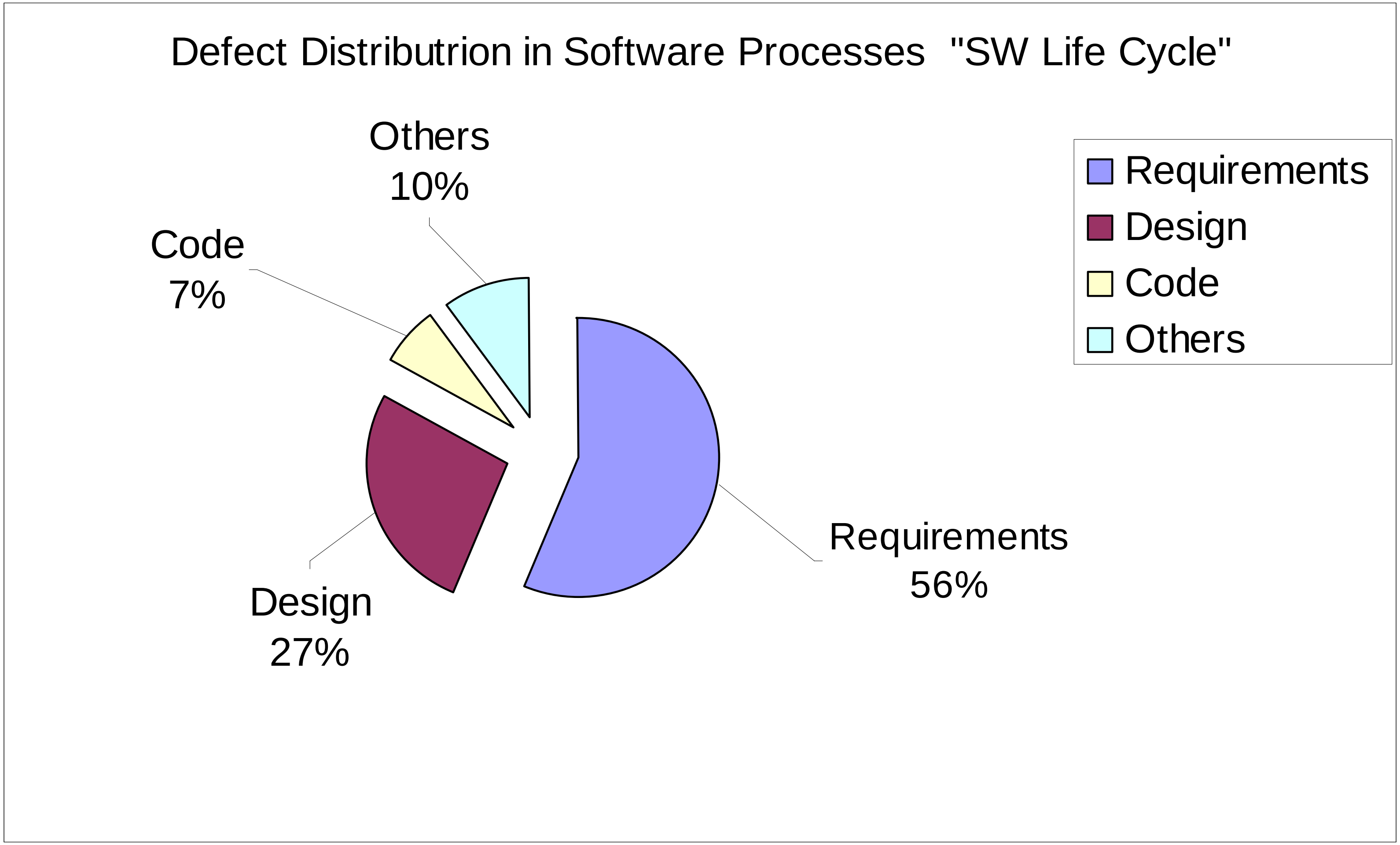
- Defect testing
  - Exhaustive Testing
  - Black-box testing
  - Equivalence partitioning
  - White-box  'Structural' testing
  - Path testing
- Integration testing
- Interface testing
- Stress testing
- Object-oriented (OO) testing
- **XP Automated testing**
- Regression testing
- Acceptance testing
- Monkey testing

- Testing workbenches

# What Testing Shows



# Statistics:
# Defect Distribution in SW Life Cycle



# Testing & Verification & Validation

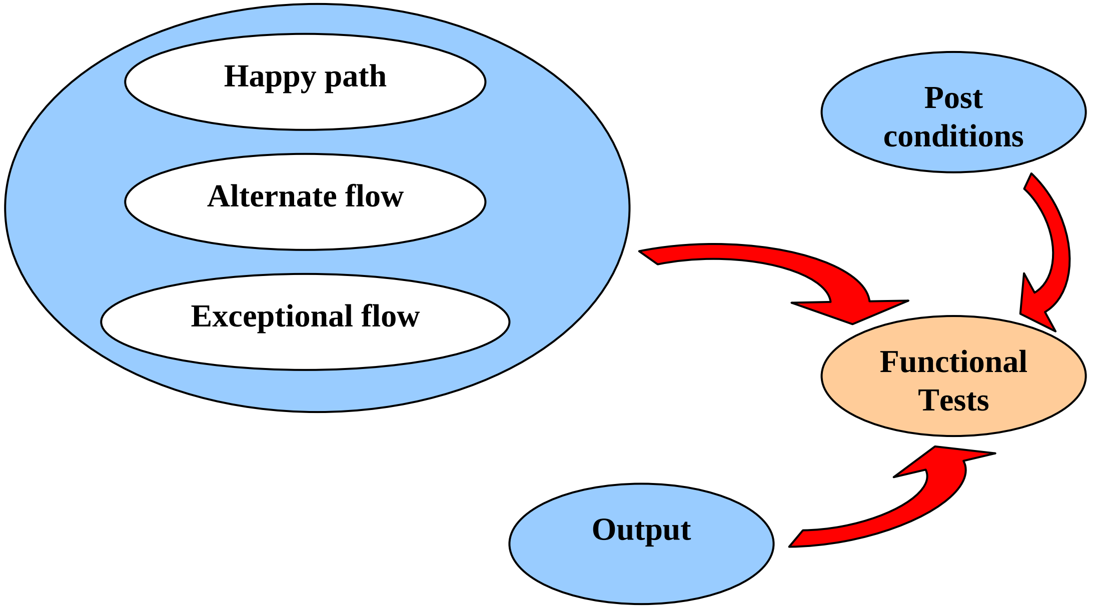
- Testing = Verification + Validation

- **Verification**: Static Testing (no run)

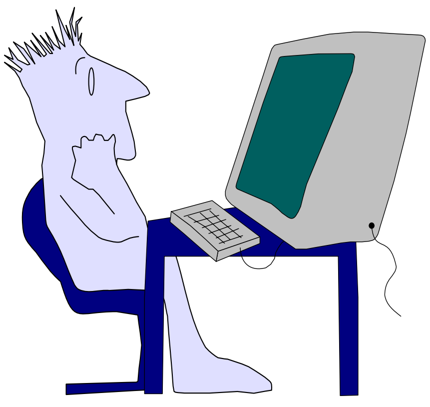
- **Validation**: Dynamic Testing (Run code)

# Use Cases & Functional Test Cases

- Write functional test case early



# Who Tests the Software



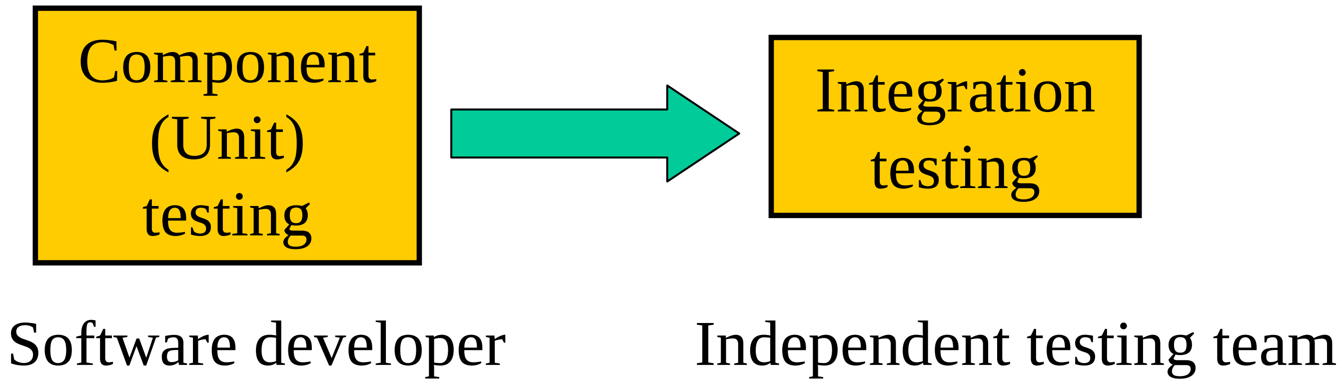
***Developer***

- understands the system
- has the source code
- **white-box 'Unit' testing**
- will test **"gently"**
- driven by **delivery 'schedule' constraint**

***Independent tester***

- must learn about the system
- has no source code
- **black-box 'Acceptance' testing**
- will attempt to **break** the sys (ME!!)
- driven by **quality constraint**

# Testing phases

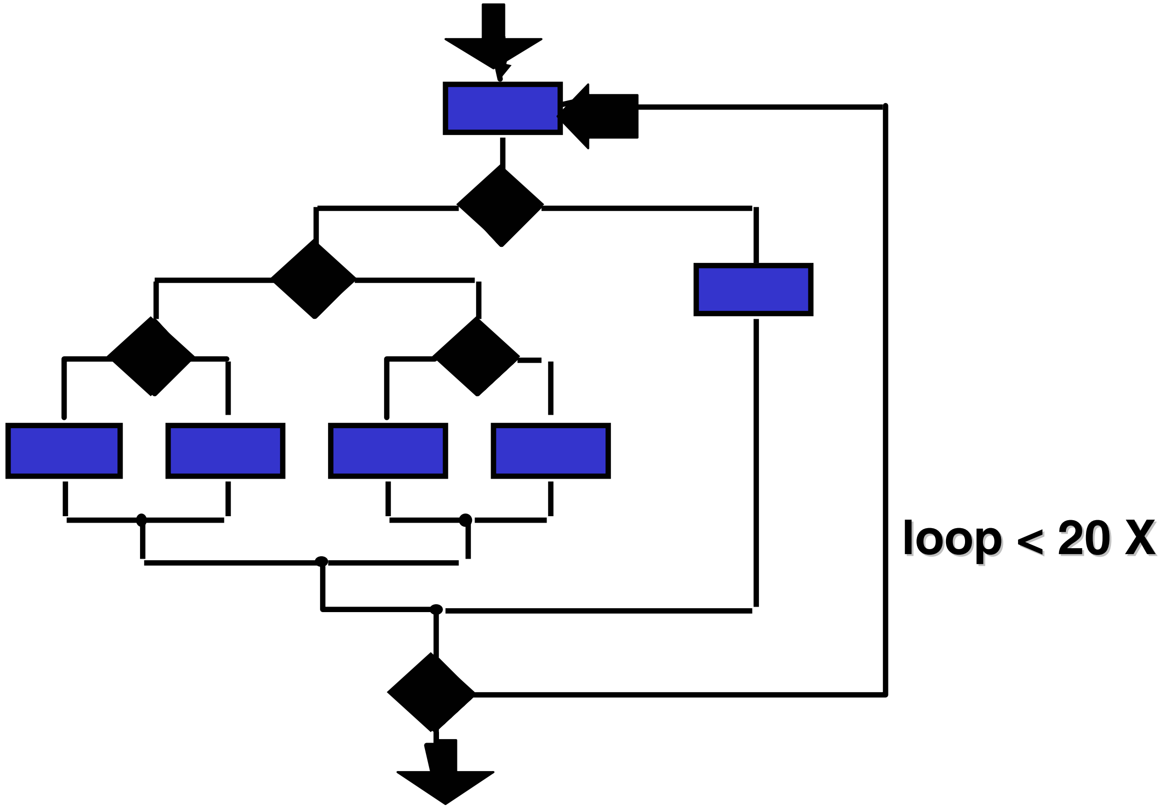


# The testing process

- Component (Unit) testing: needs source code (White-box)
  - Testing of individual program components
  - Usually the responsibility of the component developer
  - Tests are derived from the developer's experience

- Integration testing (Acceptance testing, Black-box 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 (Acceptance testing)

# Exhaustive Testing

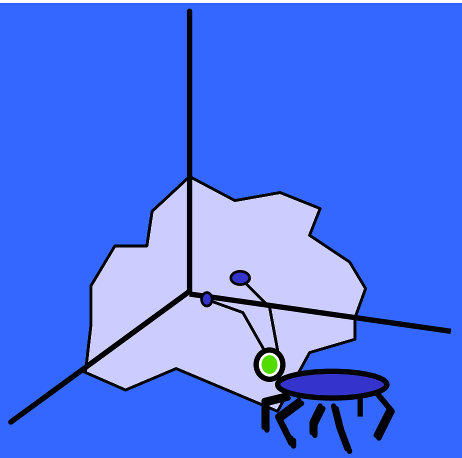



**If there are $10^{14}$ possible paths and we execute one test per millisecond, it would take 3,170 years to test this program!!**

# Test Case Design

"Bugs lurk in corners and congregate at boundaries ..."

*Boris Beizer*

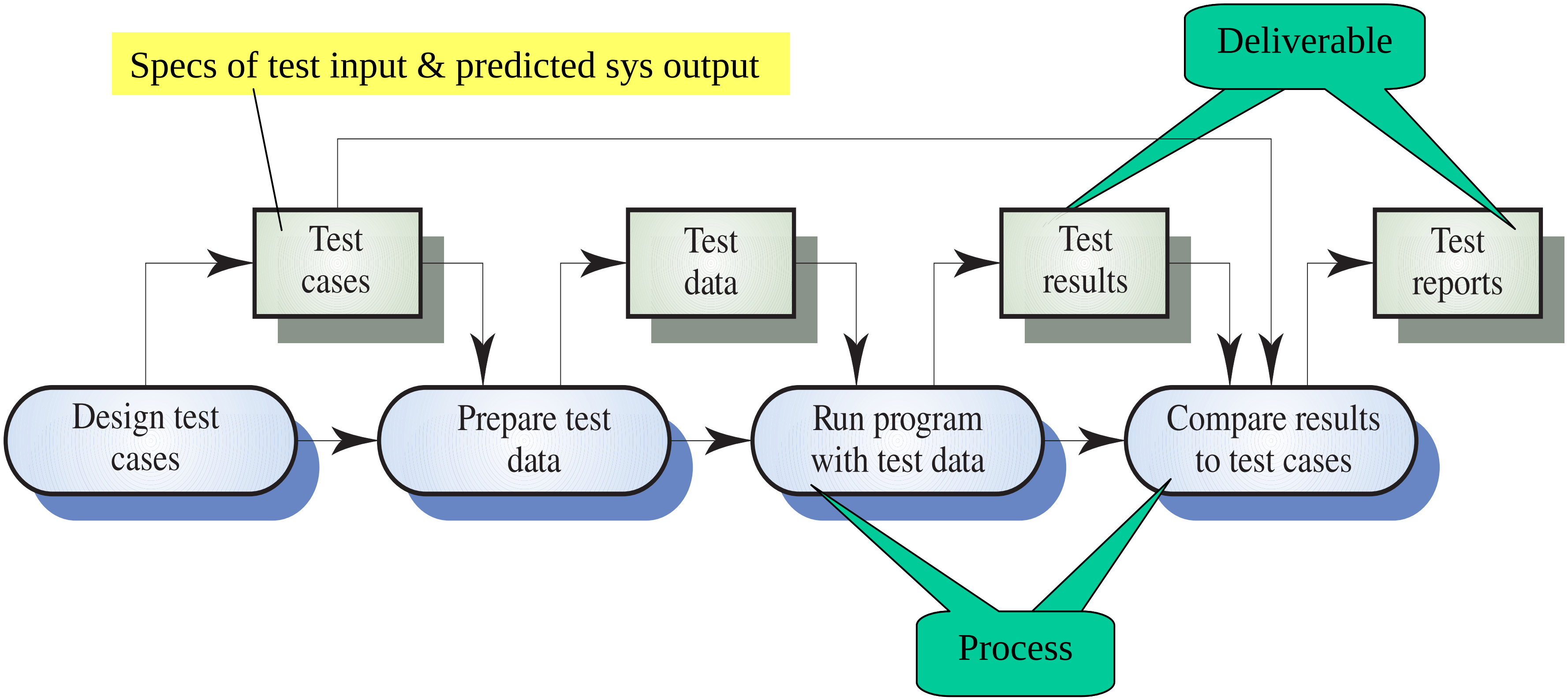


| | |
|---|---|
| *OBJECTIVE* | to uncover errors |
| *CRITERIA* | in a complete manner |
| *CONSTRAINT* | with a minimum of effort and time |

# Test data and test cases

- *Test data*
  - Inputs to test the system
- *Test case 'Test scenario' includes:*
  - Inputs to test the system
  - and the predicted outputs

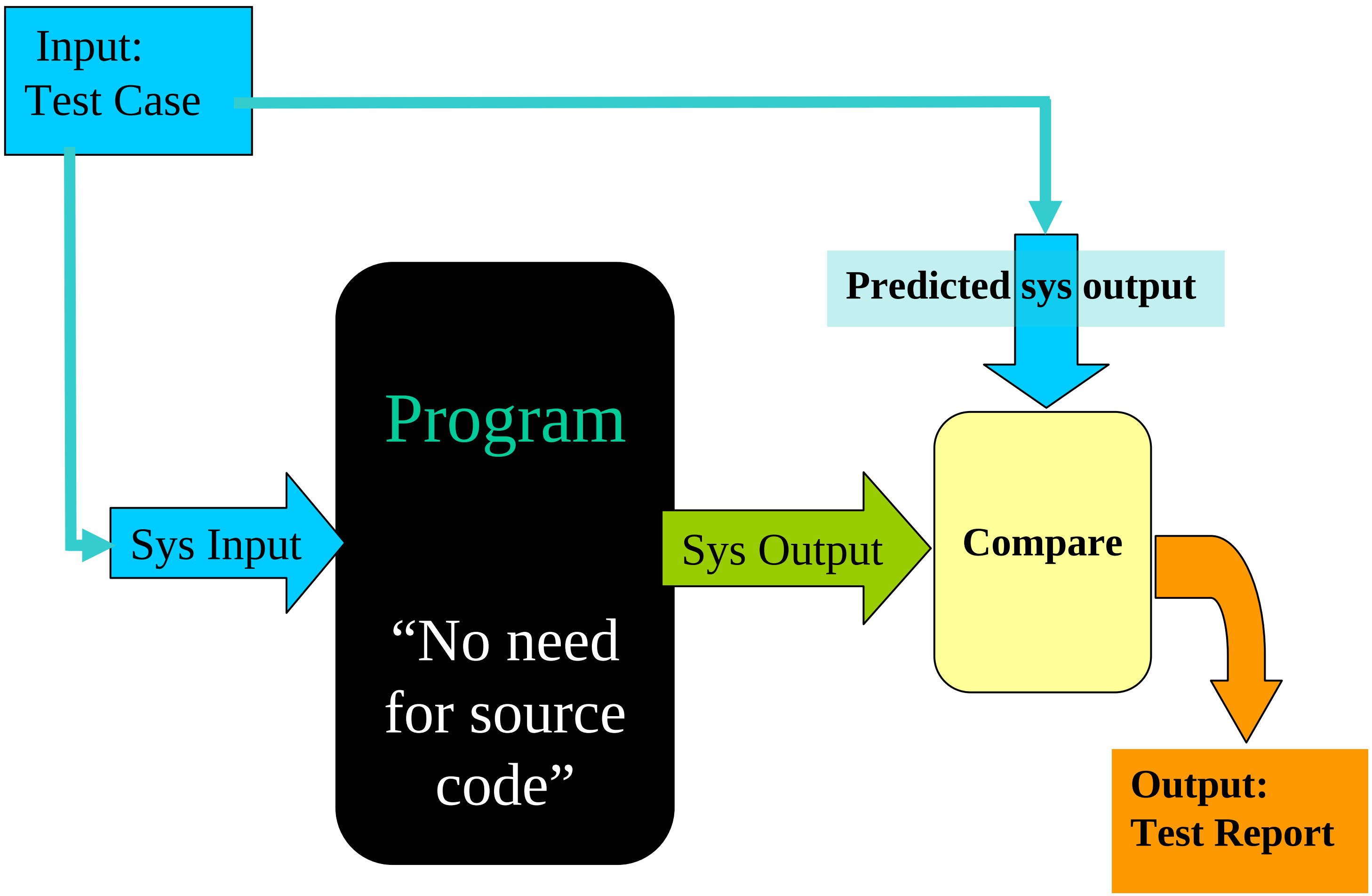
# The defect testing process



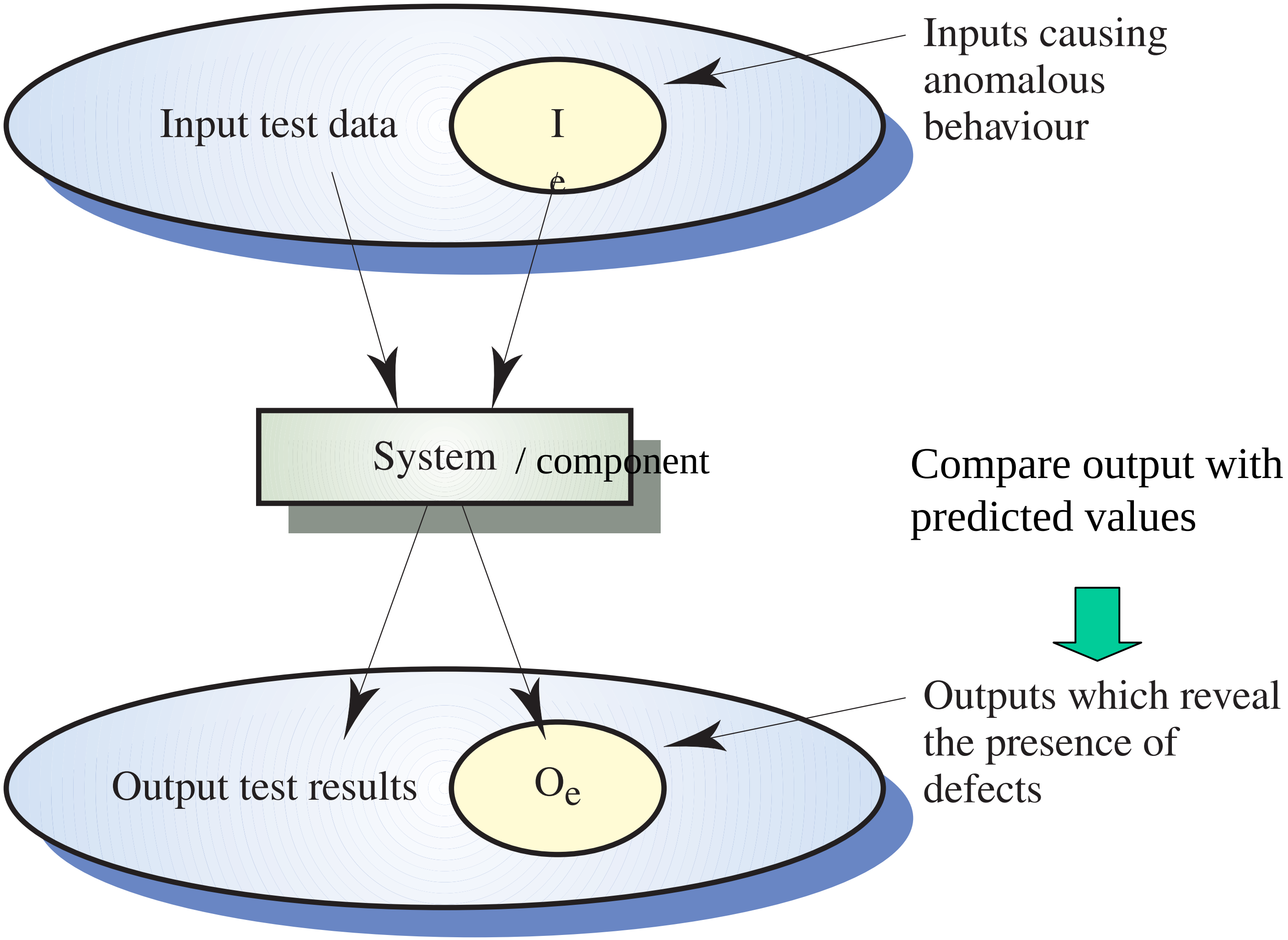
# Black-box testing

- Program is considered as a ‘black-box’
- No need to know or access source code
- Functionality testing
- No implementation testing (implementation testing needs source code)
- Test cases are based on the system specification
- Test planning can begin early in the software process

# Black-box Testing
# "Functionality testing"



# Black-box Testing



# Equivalence partitioning

- Objective:

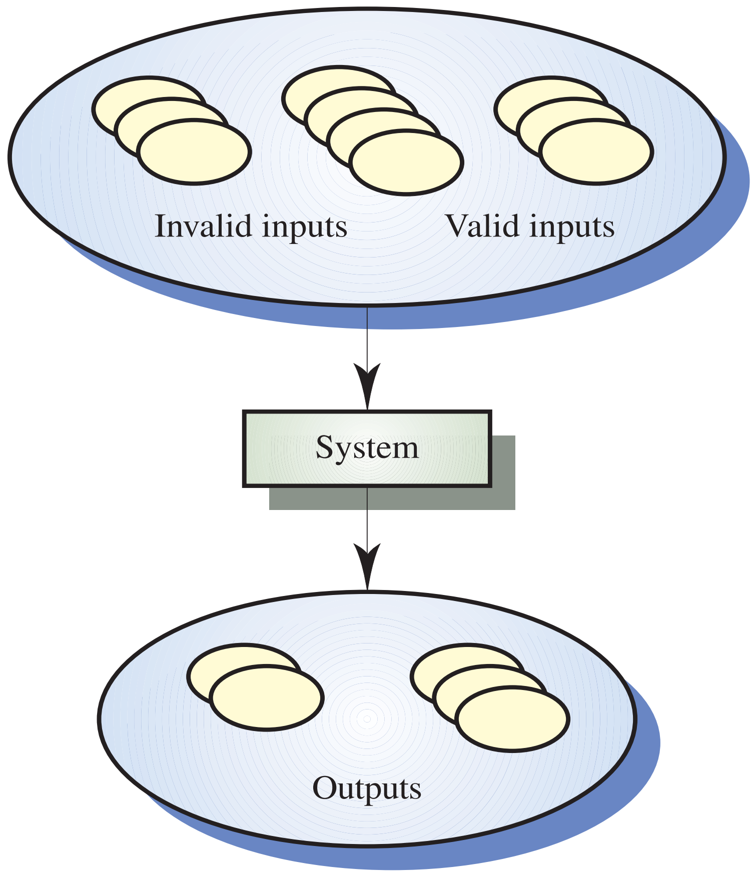
Reduce the number of test cases

# Equivalence partitioning - cont.

- A way to derive test cases
- Is a black-box testing method
- Input data with common characteristics (positive numbers, negative numbers, strings without blanks, etc)
- Each of these classes is an equivalence partition
- Program behaves in an equivalent way for each member of an Equivalence partition
- Divides the input domain into classes of data form which test cases can be derived

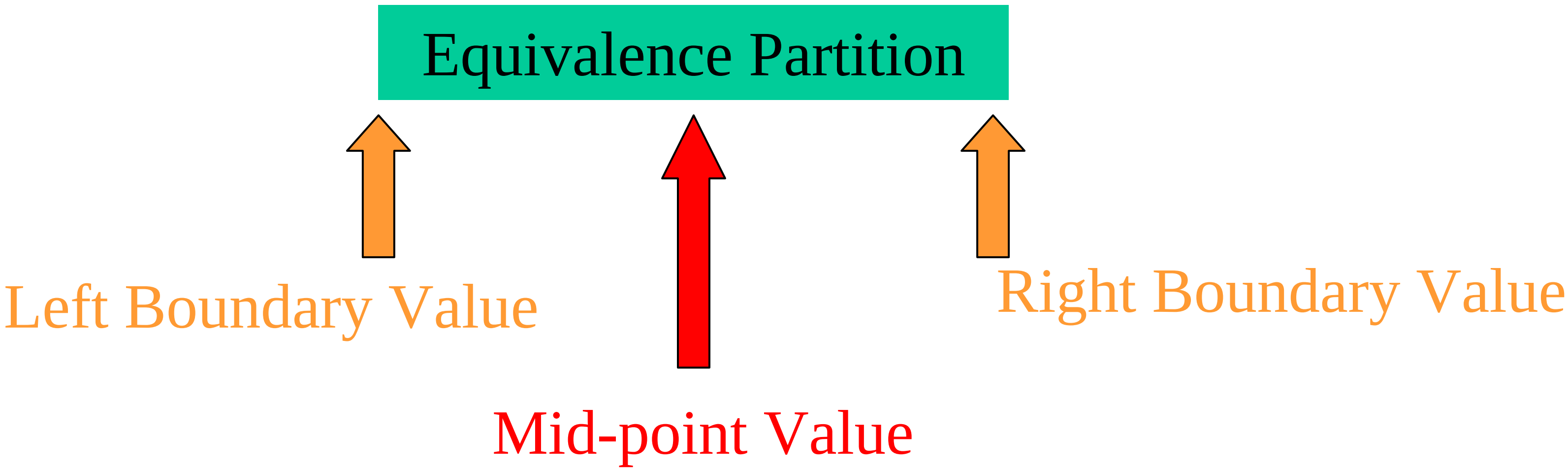
# Equivalence partitioning – cont.

**Input**



# Equivalence partitioning - cont.

- Guide lines for test case selection for partitions
  - At the **boundaries** of the partition
  - Close to **mid-poin**t of the partition

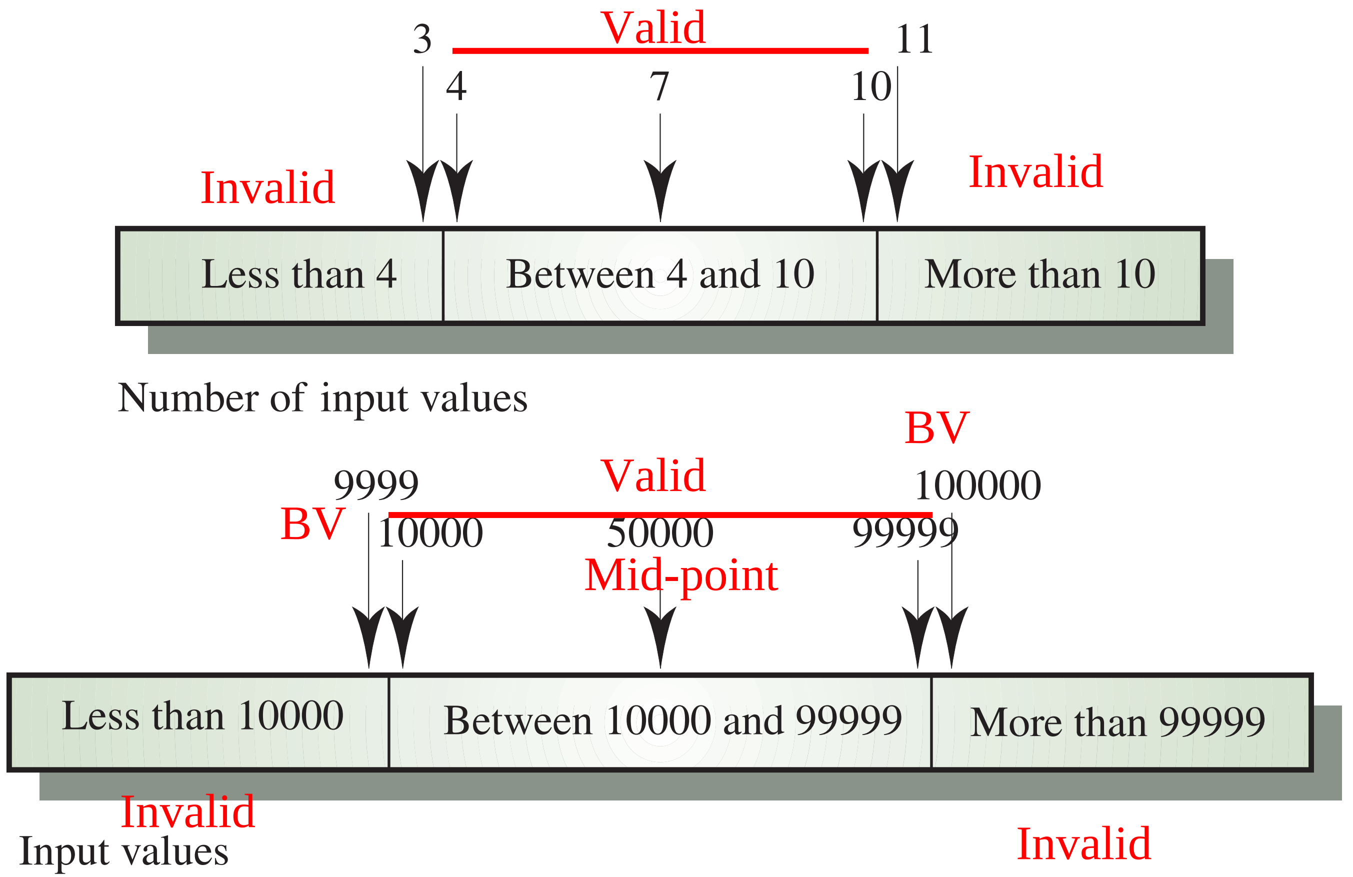


# Equivalence partitioning - Example 1

- Program specs states:
  - Accepts 4 to 10 inputs
  - Each input is 5-digit integer greater > = than 10,000

- Partition system inputs and outputs into 'equivalence sets'

# Equivalence partitioning - cont. Example



# Equivalence partitioning - cont. Example 1

- If input is a 5-digit integer between 10,000 and 99,999, equivalence partitions are ( fig 20.5 Sommerville)
  - <10,000,
  - 10,000 - 99, 999
  - and > 99, 999

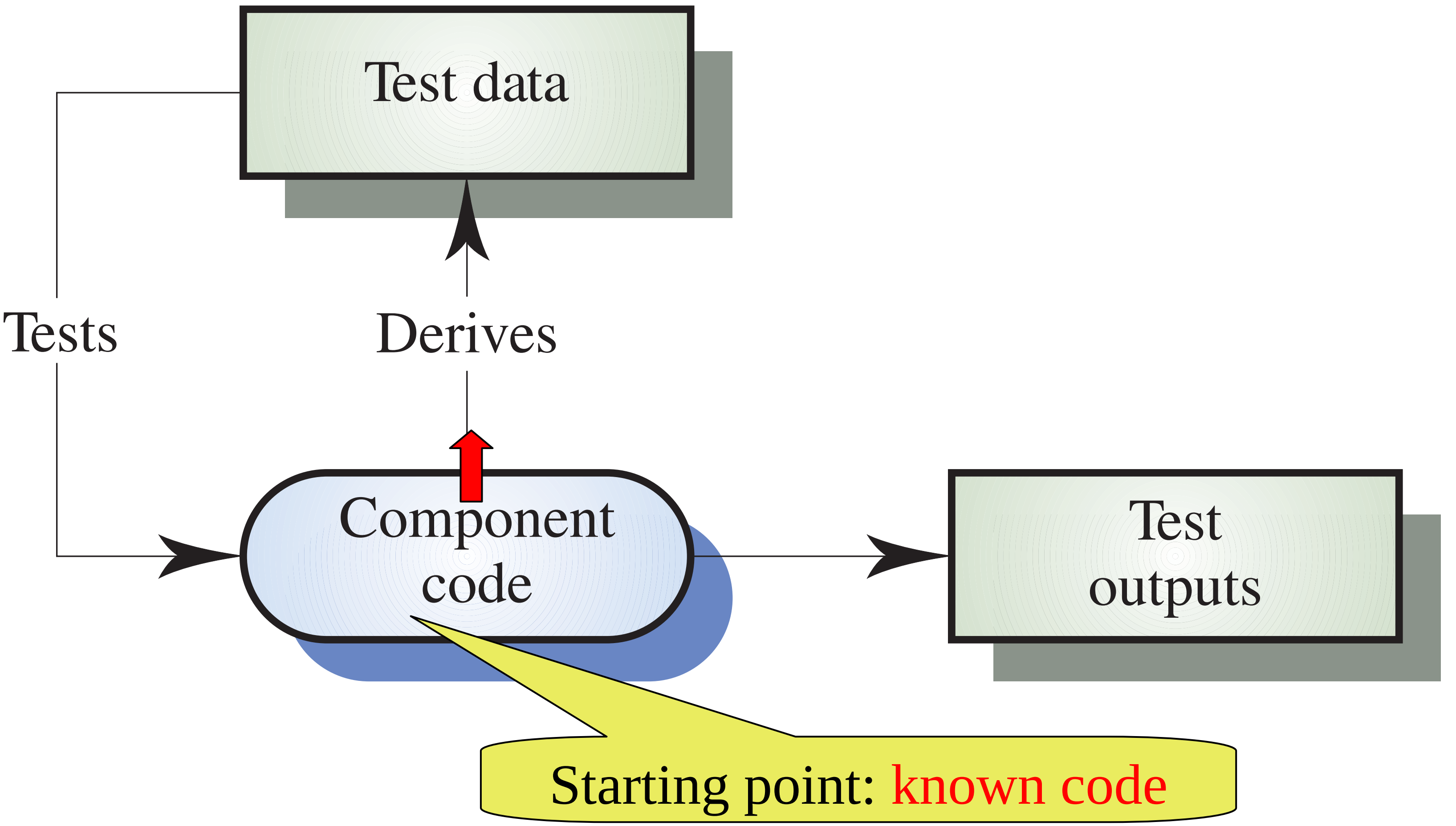
- **Test cases: 6 cases**
  - 00000, (invalid special value that may be checked)
  - 09999, (invalid left boundary value)
  - 10000, (valid left boundary value)
  - 50000, (valid mid value)
  - 99999, (valid right boundary value)
  - 100000, (invalid right boundary value)

Remember: Bugs lurk in corners & congregate at boundaries

# Structural testing 'White-box testing'

- **Synonyms:**
  - **Glass-box, Clear-box, Transparent-box**
- For small program units
- Needs **source code**
- Objective: is to exercise **all program statements**
- (not all path combinations)

# White-box testing



# Path testing

- Each path through the program is executed **at least once**
- For loops & conditions
- Used at unit testing and module testing levels

# Program flow graphs

- **Flow Graph**:
  - nodes representing program decisions
  - arcs representing the flow of control
  - Ignore sequential statements (assignments, procedures calls, I/O)

- Statements with conditions are therefore nodes in the flow graph

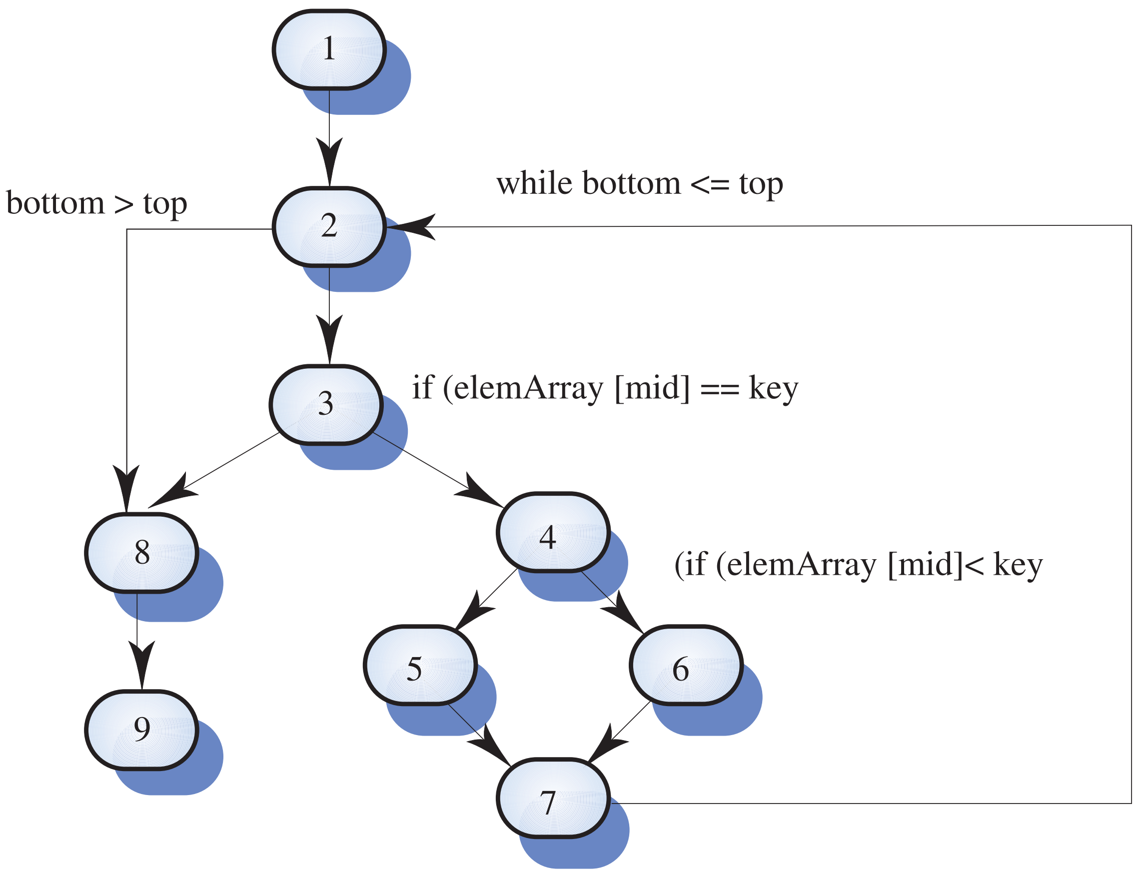
- **Cyclomatic complexity =**

  **Number of edges - Number of nodes + 2**

# Cyclomatic complexity

- Cyclomatic complexity = **number of tests** to test all control statements
- Cyclomatic complexity **=** number of conditions in a program
- Although all paths are executed, all combinations of paths are not executed

# Example: Path testing
# Binary search flow graph



# Independent paths

- **Cyclomatic complexity = 11 - 9 + 2 = 4**

- Thus **4** 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

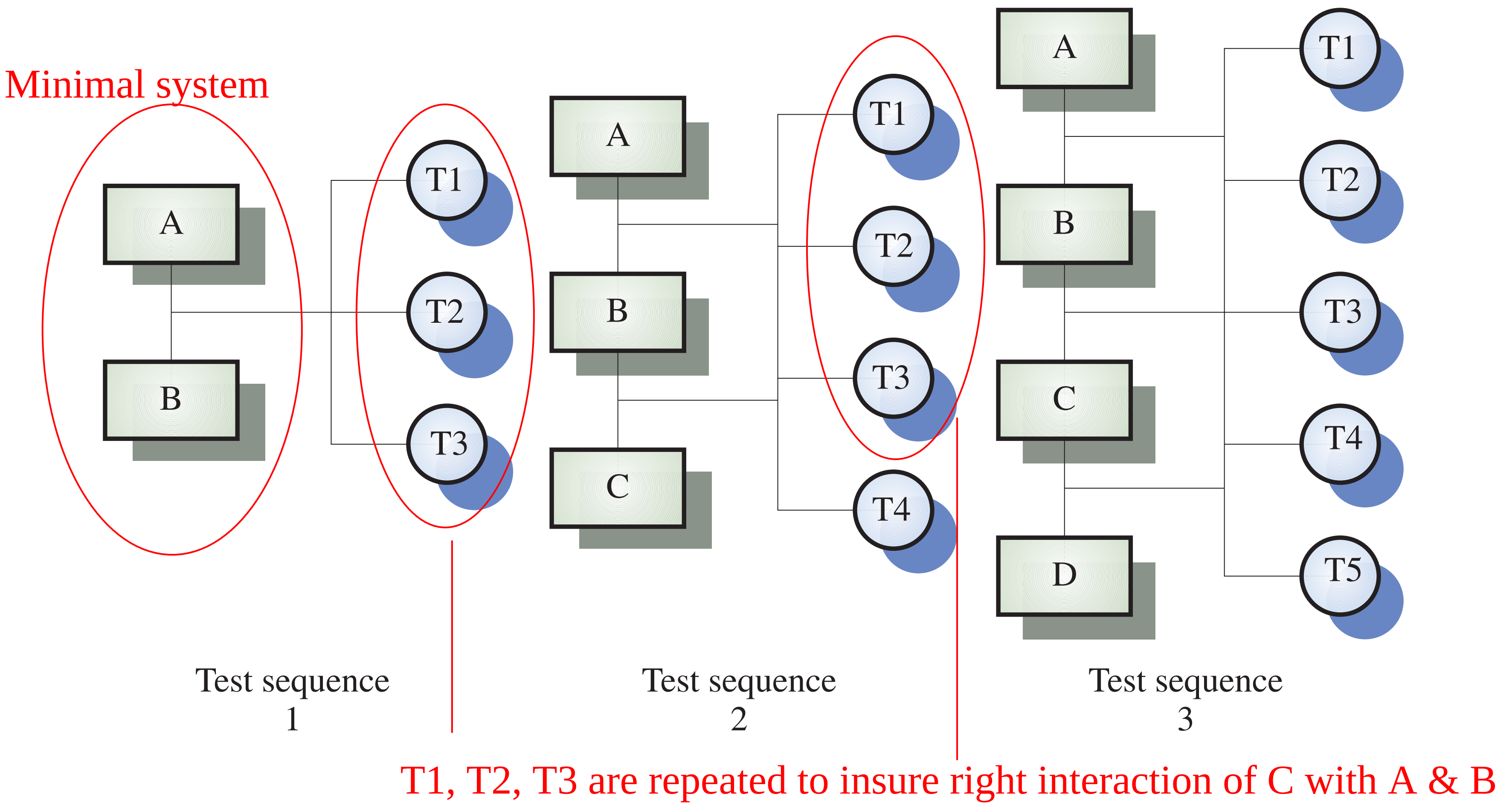
- Test cases should be derived so that all of these paths are executed

# Integration testing **(black-box)**

- Tests complete systems or subsystems composed of integrated components
- Integration testing should be **black-box** testing with tests derived from the **specification**
- Main difficulty is localising errors
- Incremental integration testing reduces this problem

# Incremental integration testing

Recall: XP Continuous Integration of: Stories + (Acceptance & Unit Tests)



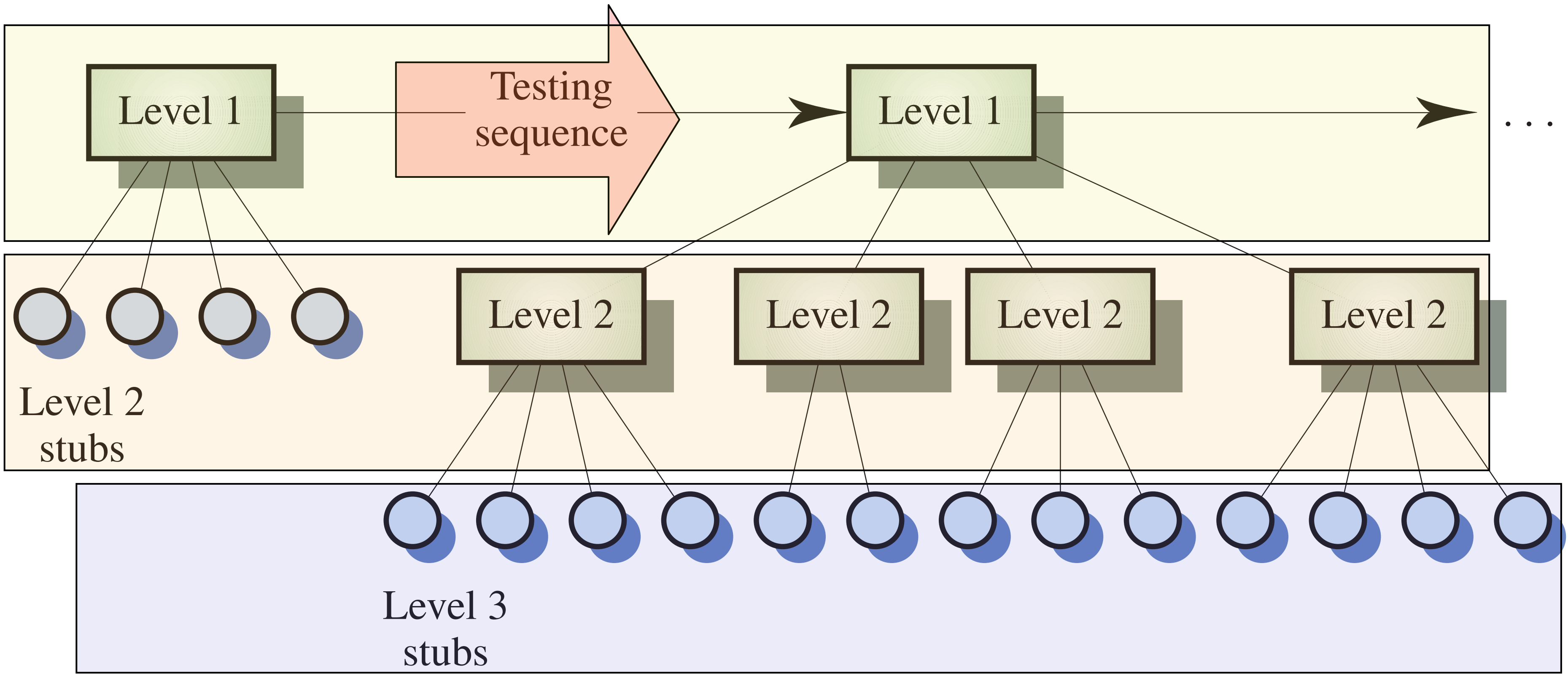
# Approaches to integration testing

- **Top-down integration testing**
  - Start with high-level system and integrate from the top-down replacing individual components by **stubs**
  - **Stubs** have the **same interface** as the components but **very limited functionality**

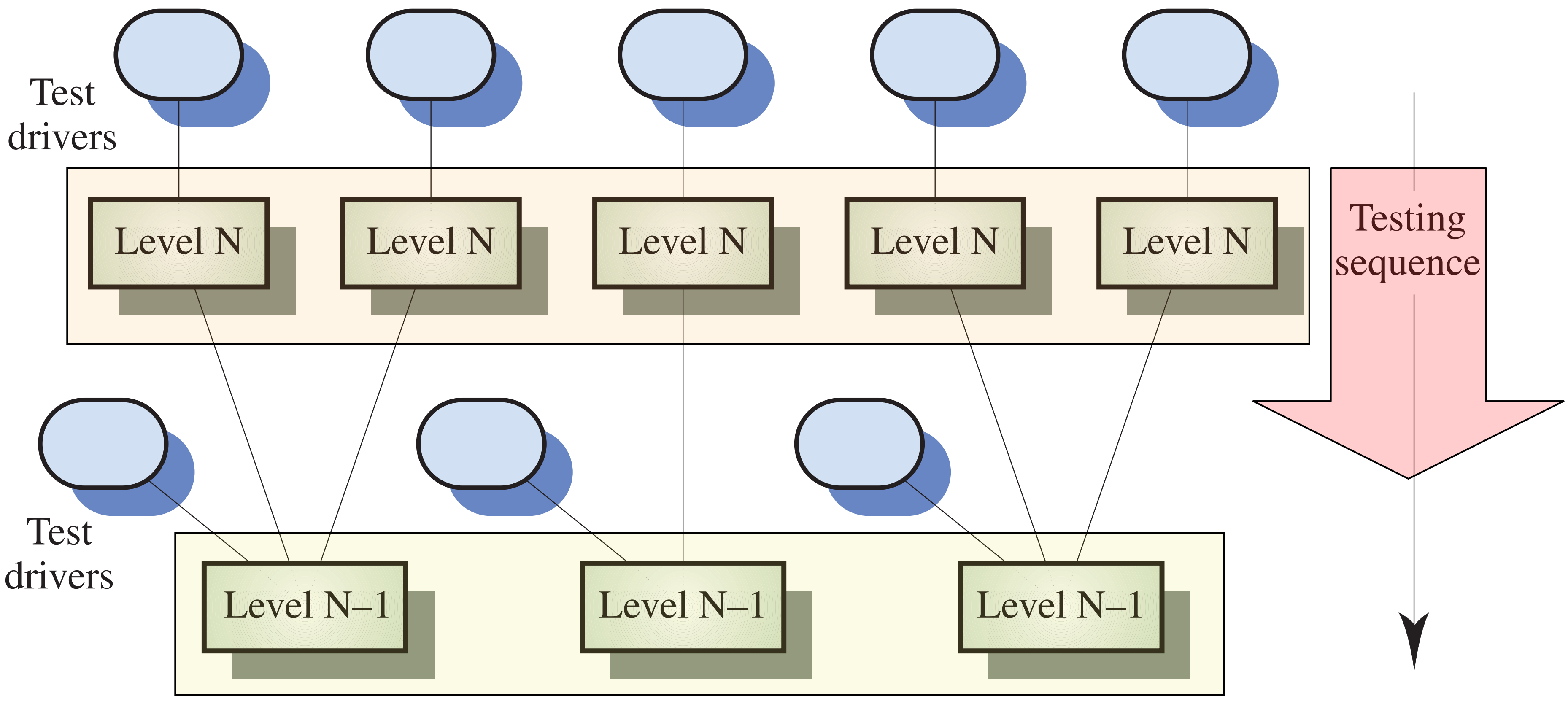
- **Bottom-up integration testing (XP)**
  - Integrate and test low-level components (or stories in XP), with **full functionality**, before developing higher level components, until the complete system is created

- In practice, combination of both

# Top-down integration testing



# Bottom-up integration testing



# Testing approaches

- Architectural validation
  - Top-down integration testing is better at discovering errors in the system architecture
- System demonstration
  - Top-down integration testing allows a limited demonstration at an early stage in the development
- Test implementation
  - Often easier with bottom-up integration testing

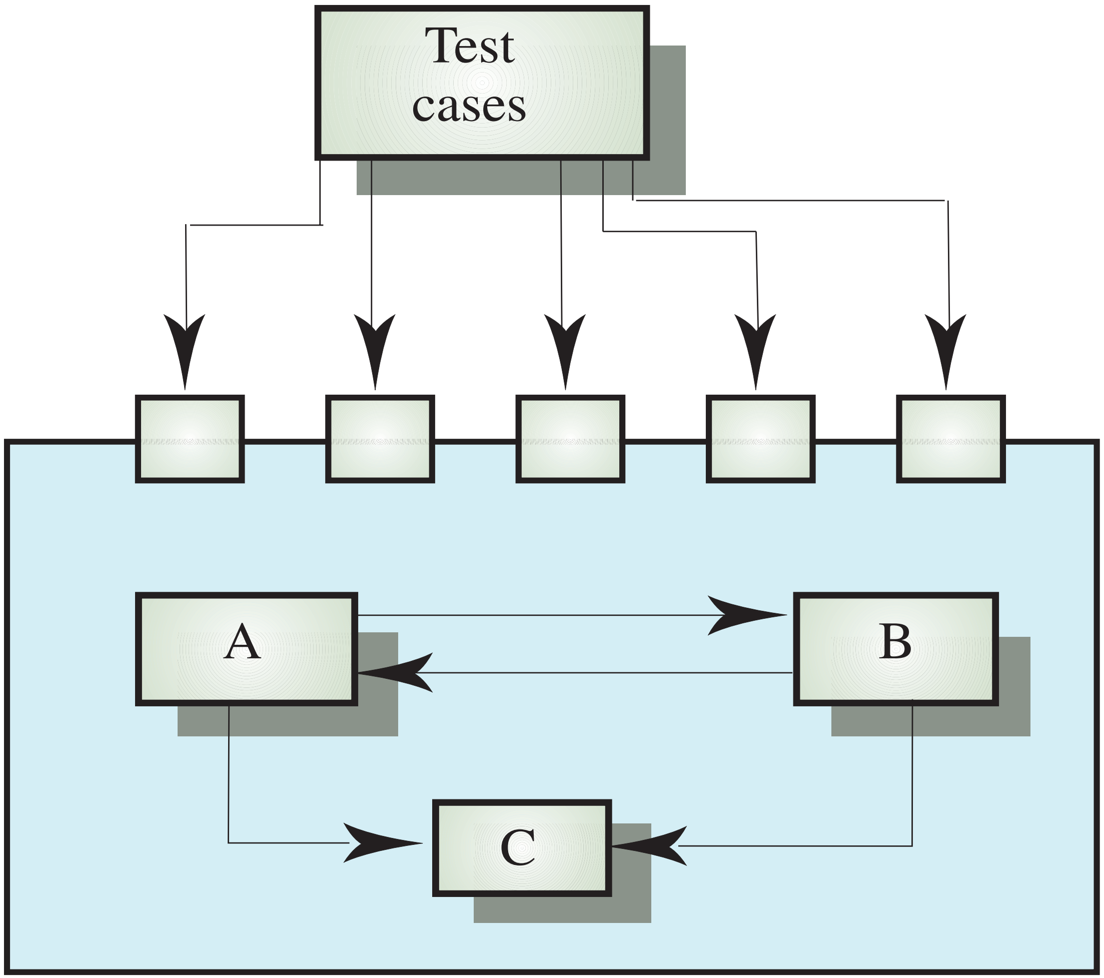
# Interface testing

- Takes place when modules or sub-systems are integrated to create larger systems

- Objectives are to detect faults due to interface errors or invalid assumptions about interfaces

- Particularly important for object-oriented development as objects are defined by their interfaces

# Interface testing



# Interfaces types

- Parameter interfaces
  - Data passed from one procedure to another
- Shared memory interfaces
  - Block of memory is shared between procedures
- Message passing interfaces
  - Sub-systems request services from other sub-systems

# Interface testing guidelines

- Design tests so that parameters to a called procedure are at the extreme ends of their ranges
- Use stress testing in message passing systems

# Stress testing

- Exercises the system beyond its maximum design load.
- Stressing the system often causes defects to come to light
- Stress testing failure behaviour..
  - Systems should **not fail catastrophically**.
  - Stress testing checks for unacceptable loss of service or data
- Particularly relevant to distributed systems which can exhibit severe degradation as a network becomes overloaded

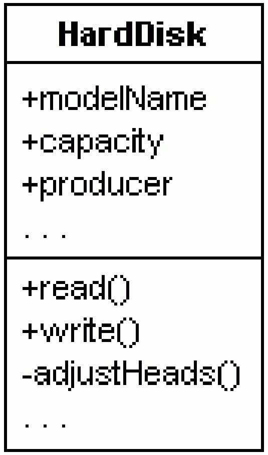
# Object-oriented (OO) testing

- The components to be tested are object classes that are instantiated as objects

# Object-oriented testing: Testing levels

- Testing operations (methods) associated with objects

  Remember: XP Unit Testing by developers on operations




**Testing levels** :

- Testing object classes
- Testing clusters of cooperating objects
- Testing the complete OO system

# Object class testing

- Complete test coverage of a class involves:
  - Testing all operations (methods) associated with an object
  - Setting and interrogating all object attributes
  - (Recall: XP Unit testing for all methods and attributes of a class)

- **Inheritance makes it more difficult** to design object class tests
  - the information to be tested is **not localised**

# Key Testing Issues

- Give high testing priority for parts of a system which are commonly used
  - give less priority for parts which are rarely executed
- Equivalence partitions
  - are sets of test cases where the program should behave in an equivalent way
  - aims at reducing the number of test cases
- Black-box testing is based on the system specification
- Structural testing identifies test cases which cause all paths through the program to be executed

# Key Testing Issues

- Test coverage:
  - measures ensure that all statements have been executed at least once.
- For OO testing:
  - test object classes, test all operations, attributes and states