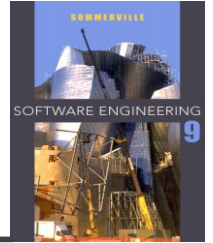


## Chapter 8 – Software Testing

# Program testing

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- ✧ Testing is intended **to show** that a **program does what it is intended to do** and to **discover program defects** before it is put into use.
- ✧ When you test software, you execute a program **using artificial data**.
- ✧ You **check the results** of the test run for **errors, anomalies** or information about the program's **non-functional attributes**.
- ✧ Can reveal the **presence of errors NOT their absence**.
- ✧ Testing is part of a more general **verification and validation** process.

# Program testing goals

---

- ✧ To demonstrate to the developer and the customer that the software **meets its requirements**.
  - This means that there should be **at least one test for every requirement in the requirements document**. Also, it means that there should be tests for **all of the system features**, plus **combinations of these features**, that will be incorporated in the product release.
- ✧ To **discover situations** in which the behavior of the **software is incorrect, undesirable or does not conform** to its specification.
  - Defect testing is concerned with rooting out undesirable system behavior such as **system crashes, unwanted interactions with other systems, incorrect computations and data corruption**.

# Validation and defect testing

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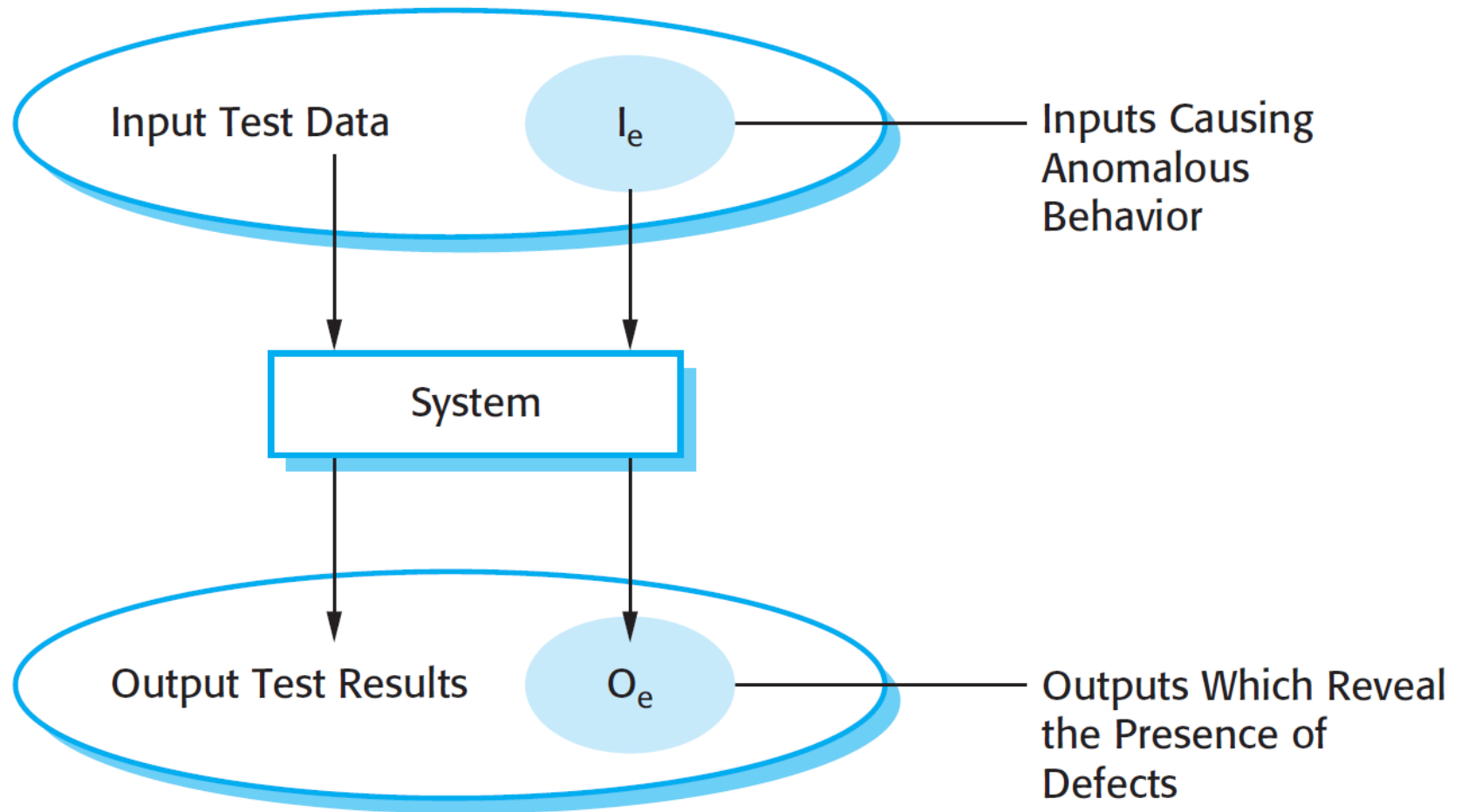
## ✧ The first goal leads to **validation testing**

- You expect the system to perform correctly using a given set of test cases that reflect the system's expected use.

## ✧ The second goal leads to **defect testing**

- The test cases **are designed to expose defects**. The test cases in defect testing **can be deliberately obscure** and need not reflect how the system is normally used.

# An input-output model of program testing

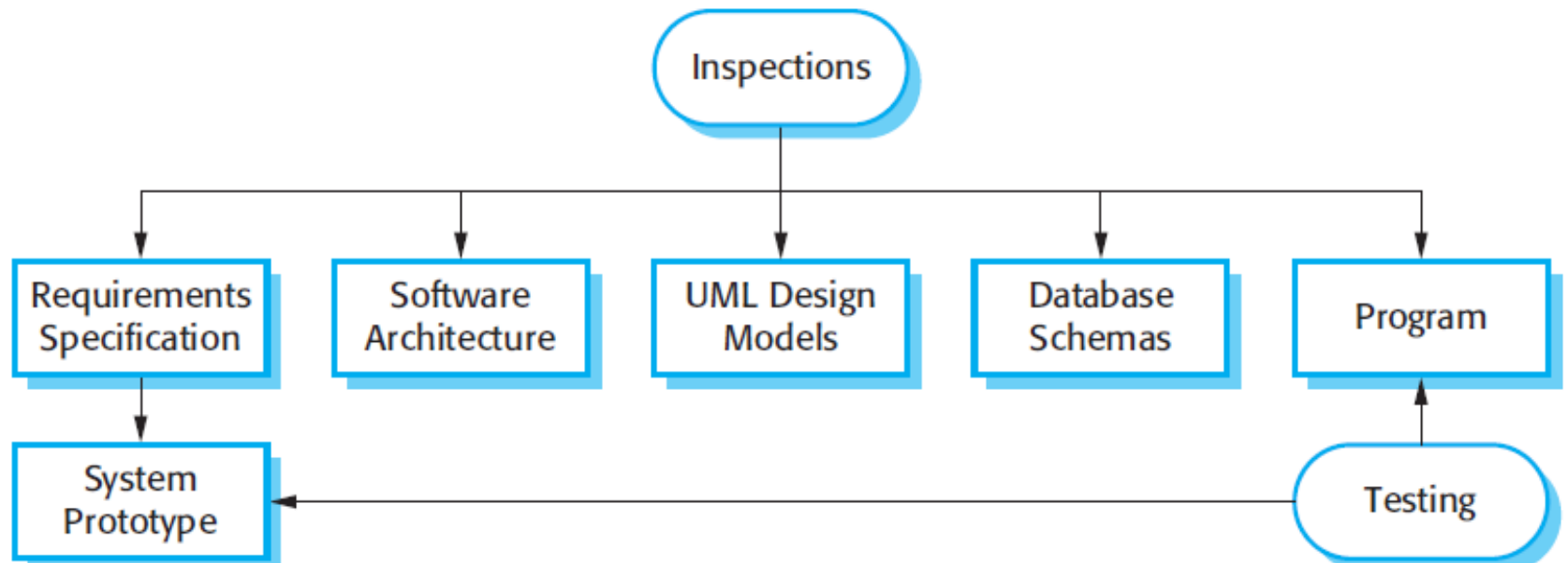
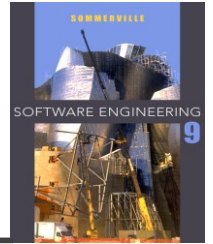


# Inspections and testing

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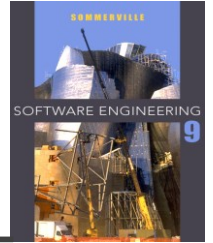
- ✧ **Software inspections** Concerned with **analysis of the static system representation** to discover problems (static verification)
  - May be supplement by tool-based document and code analysis.
  - See Chapter 15.
- ✧ **Software testing** Concerned with exercising and observing product behaviour (dynamic verification)
  - The system is **executed with test data** and its operational behaviour is observed.

# Inspections and testing



# Software inspections

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- ✧ These involve people **examining the source representation** with the aim of discovering anomalies and defects.
- ✧ Inspections **not require execution** of a system so may be used before implementation.
- ✧ They may be **applied to any representation** of the system (requirements, design, configuration data, test data, etc.).
- ✧ They have been shown to be an **effective technique for discovering program errors**.



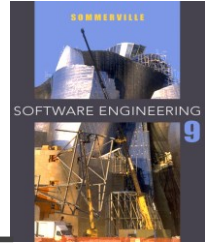
# Advantages of inspections

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- ✧ During testing, **errors can mask (hide) other errors**.  
Because inspection is a static process, you don't have to be concerned with interactions between errors.
- ✧ **Incomplete versions** of a system **can be inspected** without additional costs. If a program is incomplete, then you need to develop specialized test harnesses to test the parts that are available.
- ✧ As well as searching for program defects, an inspection can also consider **broader quality attributes** of a program, such as compliance with standards, portability and maintainability.

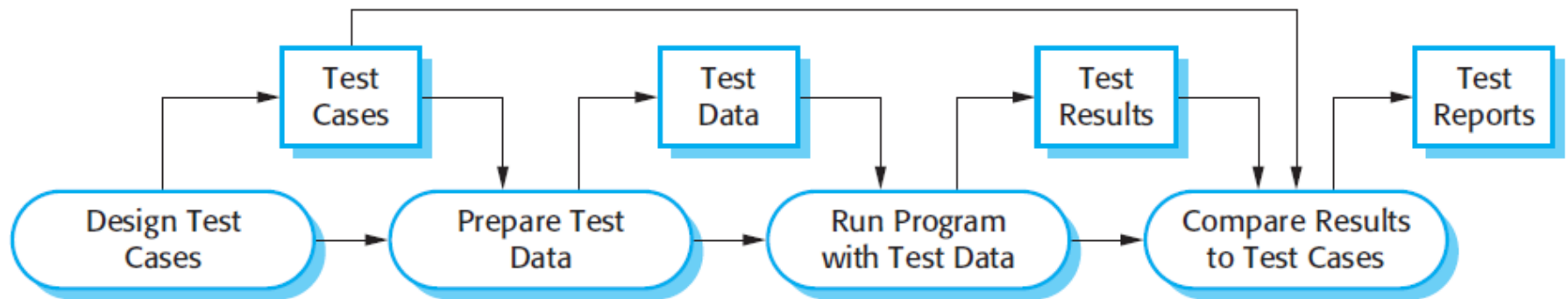
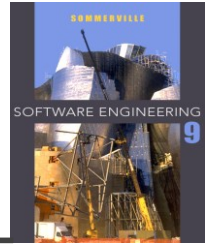
# Inspections and testing

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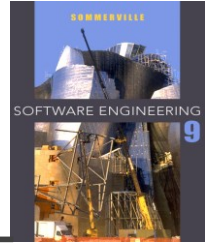
- ✧ **Inspections and testing are complementary** and not opposing verification techniques.
- ✧ Both should be used during the Verification & Validation process.
- ✧ Inspections may not be appropriate to check non-functional characteristics such as performance, usability, etc.

# A model of the software testing process



# Stages of testing (typical commercial software)

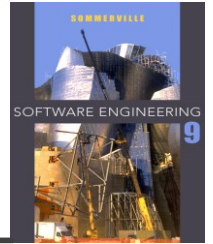
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- ✧ **Development testing**, where the system is tested during development to discover bugs and defects. (mostly done by the development team)
- ✧ **Release testing**, where a separate testing team tests a complete version of the system before it is released to users. (checking to meet requirements)
- ✧ **User testing**, where users or potential users of a system test the system in their own environment. (Acceptance testing is one type of user testing)

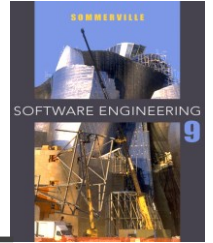
# Development testing

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- ✧ Development testing **includes all testing activities that are carried out by the team developing** the system.
  - **Unit testing**, where individual program units or object classes are tested. Unit testing should focus on testing the **functionality of objects or methods**.
  - **Component testing**, where several individual units are integrated to create composite components. Component testing should focus on testing **component interfaces**.
  - **System testing**, where some or all of the components in a system are integrated and the system is tested as a whole. System testing should focus on testing **component interactions**.

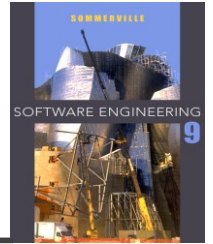
# Unit testing



- ✧ Unit testing is the process of **testing individual part of code in isolation**. It is a defect testing process.
- ✧ Units may be:
  - Individual functions or methods
  - Object classes with several attributes and methods
- ✧ Complete test **coverage of a class** involves
  - Testing **all operations** associated with an object
  - **Setting and interrogating** all object attributes
  - Exercising the object in **all possible states**.
- ✧ Inheritance makes it more difficult to design object class tests as the **information to be tested is not localised**.

# Automated testing

---



- ✧ Whenever possible, unit testing **should be automated** so that tests are run and checked without manual intervention.
- ✧ In automated unit testing, you make use of a **test automation framework** (such as JUnit) to write and run your program tests.
- ✧ Unit **testing frameworks** may provide generic test classes that you extend to create specific test cases. They can then **run all of the tests** that you have implemented and **report**, often through some GUI, on the success of otherwise of the tests.

# Automated test components

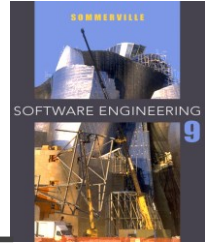
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- ✧ A **setup part**, where you initialize the system with the test case, namely the inputs and expected outputs.
- ✧ A **call part**, where you call the object or method to be tested.
- ✧ An **assertion part**, where you compare the result of the call with the expected result. If the assertion evaluates to true, the test has been successful if false, then it has failed.



# Sample test in JUnit

---



```
public class MyTests {  
  
    @Test  
    public void multiplicationOfZeroIntegersShouldReturnZero() {  
        Calculator calc = new Calculator(); // Class that is being tested  
  
        // assert statements  
        assertEquals(0, calc.multiply(10, 0), "10 x 0 must be 0");  
        assertEquals(0, calc.multiply(0, 10), "0 x 10 must be 0");  
        assertEquals(0, calc.multiply(0, 0), "0 x 0 must be 0");  
    }  
}
```

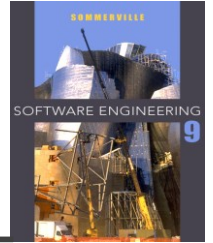
# Unit test effectiveness

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- ✧ The test cases should show that, when used as expected, the component that you are testing **does what it is supposed to do**.
- ✧ If there are **defects in the component**, these should be revealed by test cases.
- ✧ This leads to 2 types of unit test case:
  - The first of these should **reflect normal operation** of a program and should show that the **component works as expected**.
  - The other kind of test case should be based on testing experience of where common problems arise. It should use **abnormal inputs** to check that these are **properly processed** and do not crash the component.

# Testing strategies

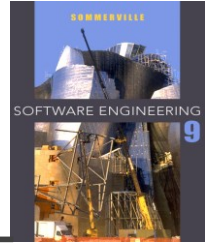
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- ✧ **Partition testing**, where you identify groups of inputs that have common characteristics and should be processed in the same way.
  - You should choose tests from within each of these groups.
- ✧ **Guideline-based testing**, where you use testing guidelines to choose test cases.
  - These guidelines reflect **previous experience of the kinds of errors that programmers often make** when developing components.

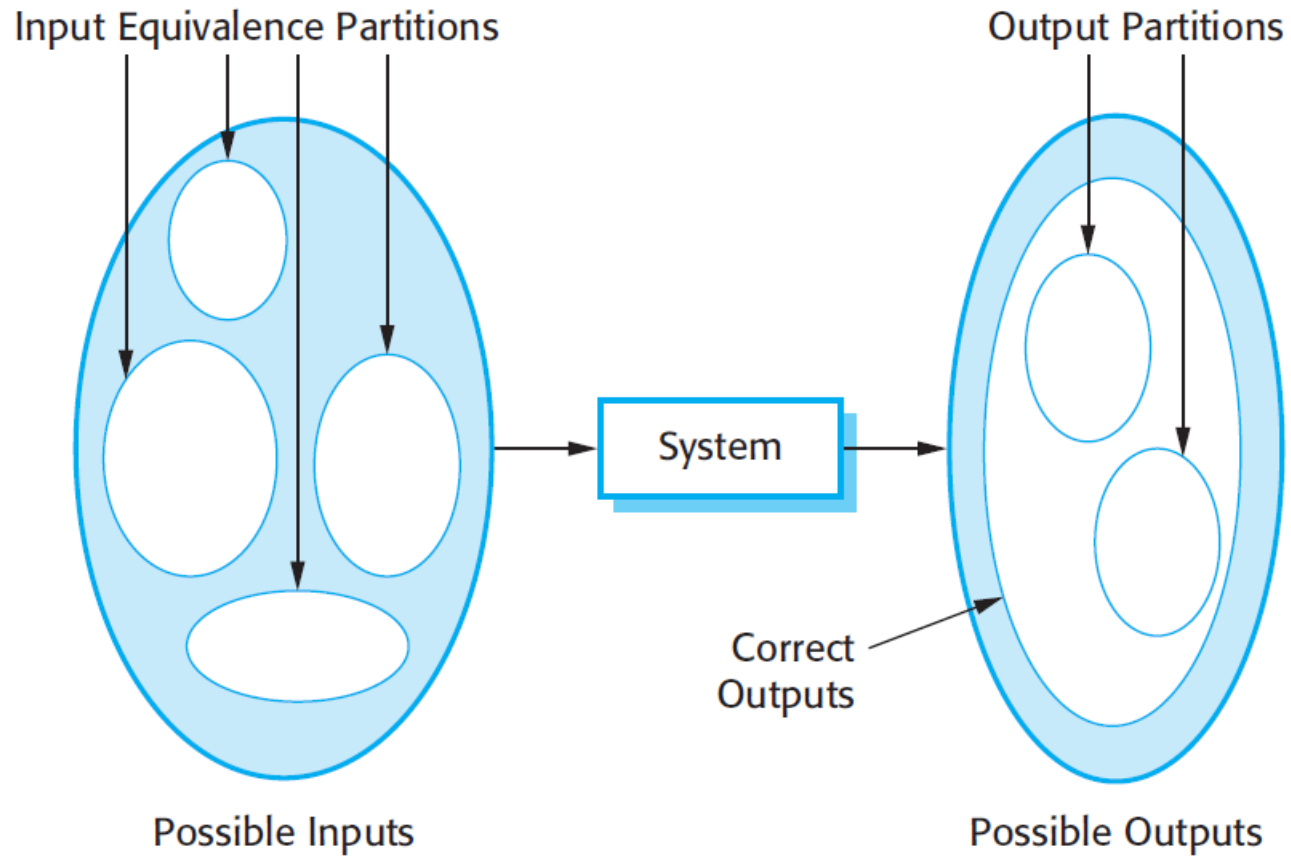
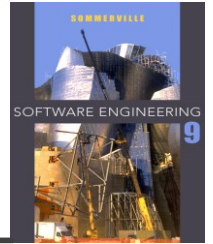
# Partition testing

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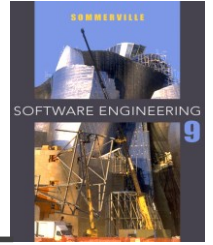
- ✧ **Input data** results often fall into **different classes** where all members of a class are related and result in similar output.
- ✧ Each of these classes is an **equivalence partition** or domain where the program **behaves in an equivalent way** for each class member.
- ✧ Test cases should be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

# Equivalence partitioning



# Equivalence partitions

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## ✧ Exercise:

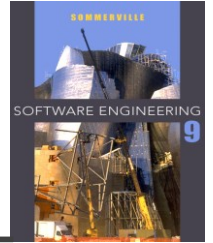
- identify equivalence partitions for a program that takes int value representing a month and returns the name of the month.
- identify equivalence partitions for a program that takes int value representing a month and returns the name of the season the month belongs to.
- Height categorizer!

# Boundary testing

```
public char gradeRank(double studentGrade) {  
    char grade;  
    if (studentGrade >= 90) {  
        grade = 'A';  
    } else if (studentGrade >= 80) {  
        grade = 'B';  
    } else if (studentGrade >= 70) {  
        grade = 'B';  
    } else if (studentGrade >= 60) {  
        grade = 'D';  
    } else {  
        grade = 'F';  
    }  
    return grade;  
}
```

# Testing guidelines (sequences, arrays, lists)

---



- ✧ 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. (partition boundaries)
- ✧ Test with sequences of zero length.



## General testing guidelines (examples)

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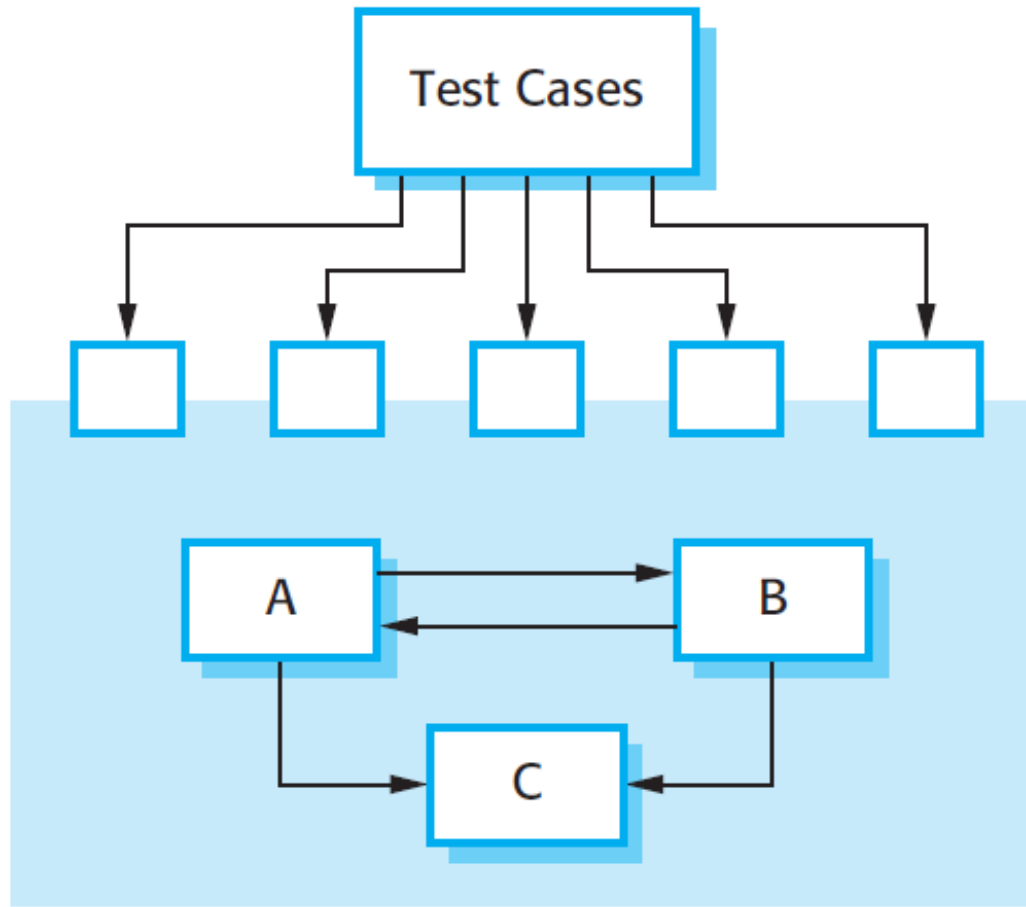
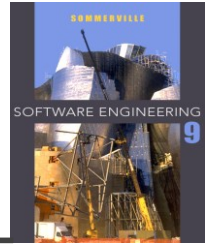
- ✧ Choose inputs that force the system to **generate all error messages**
- ✧ Design inputs that cause input **buffers to overflow**
- ✧ Repeat the same input or series of **inputs numerous times**
- ✧ Force computation results to be **too large or too small**

# Component testing

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- ✧ Software components are often **composite components** that are made up of **several interacting objects**.
- ✧ You **access the functionality** of these objects through the defined component **interface**.
- ✧ Testing composite components should therefore **focus on showing that the component interface** behaves according to its specification. (black box testing)
  - You can assume that unit tests on the individual objects within the component have been completed.

# Interface testing



# Interface errors

---

## ✧ Interface misuse

- A calling component calls another component and makes an error in its use of its interface e.g. parameters in the wrong order.

## ✧ Interface misunderstanding

- A calling component embeds assumptions about the behaviour of the called component which are incorrect.

## ✧ Timing errors

- The called and the calling component operate at different speeds and out-of-date information is accessed.

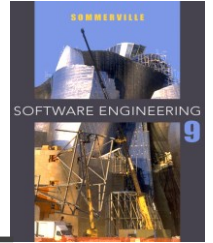
# Interface testing guidelines

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- ✧ Design tests so that parameters to a called procedure are at the **extreme ends of their ranges**.
- ✧ Always test **pointer** parameters with **null** pointers.
- ✧ Design tests which cause the **component to fail**.
- ✧ Use **stress testing** in message passing systems.
- ✧ **Vary the order** in which components are activated.

# System testing

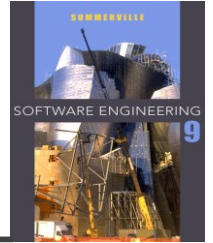
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- ✧ System testing during development involves integrating components to create a **version of the system** and then **testing the integrated system**.
- ✧ The focus in system testing is testing the **interactions between components**.
- ✧ System testing checks that **components are compatible**, interact correctly and transfer the right data at the right time across their interfaces.

# System and component testing

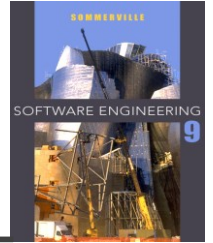
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- ✧ During system testing, **reusable components that have been separately developed and off-the-shelf systems** may be integrated with newly developed components. The complete system is then tested.
- ✧ Components **developed by different team members** or sub-teams may be integrated at this stage. System testing is a collective rather than an individual process.
  - In some companies, system testing **may involve a separate testing team** with no involvement from designers and programmers.

# Use-case testing

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- ✧ The use-cases developed to identify system interactions can be used as a **basis for system testing**.
- ✧ Each use case usually involves **several system components** so testing the use case **forces these interactions** to occur.
- ✧ The **sequence diagrams** associated with the use case documents the components and interactions that are being tested.

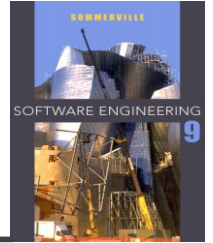


# Test-driven development

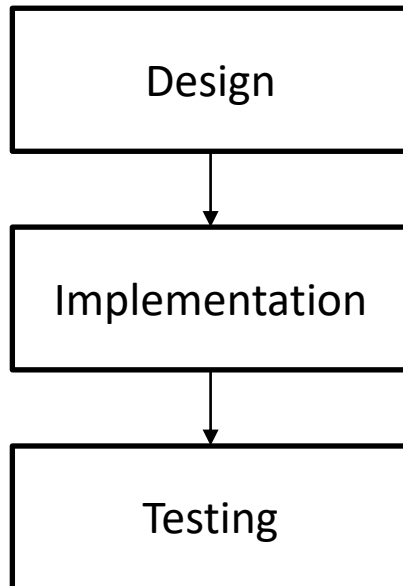
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- ✧ Test-driven development (TDD) is an approach to program development in which you **inter-leave testing and code development**.
- ✧ Tests are written **before code** and ‘passing’ the tests is the critical driver of development.
- ✧ You **develop code incrementally**, along **with a test** for that increment. You don’t move on to the next increment until the code that you have developed passes its test.
- ✧ TDD was introduced as **part of agile** methods such as Extreme Programming. However, it can also be used in plan-driven development processes.

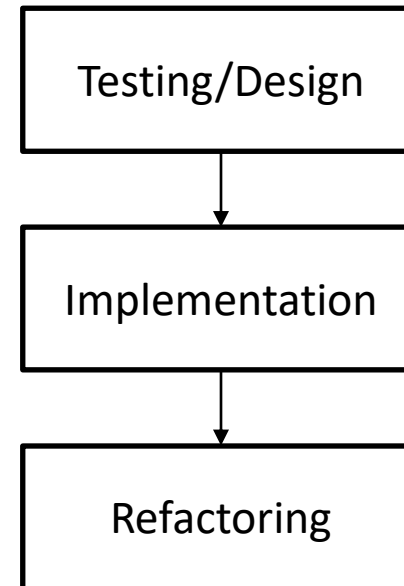
# Test-driven development



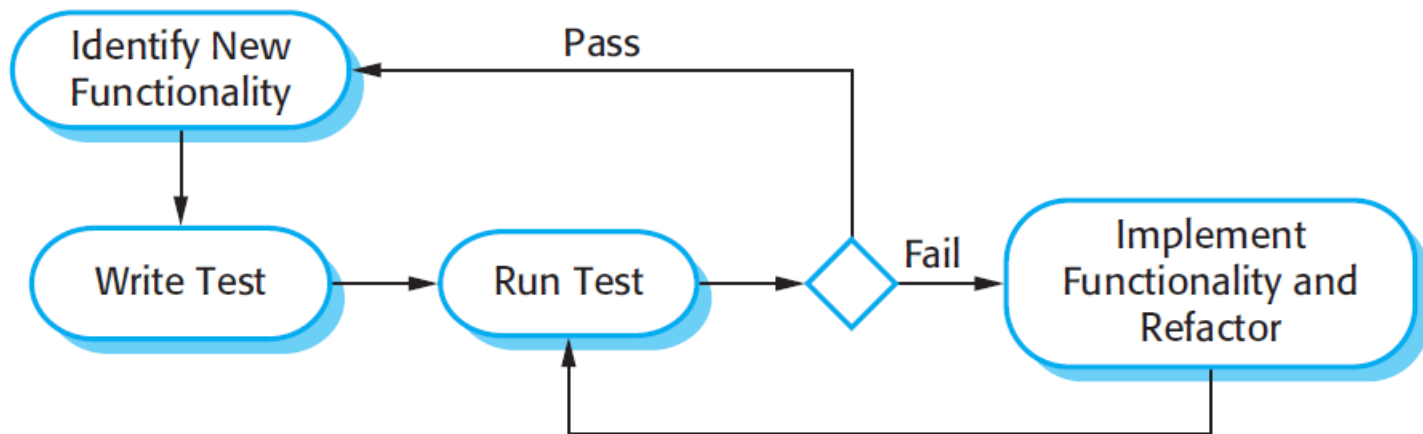
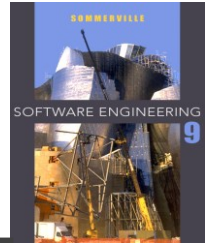
Traditional Approach



TDD Approach



# Test-driven development

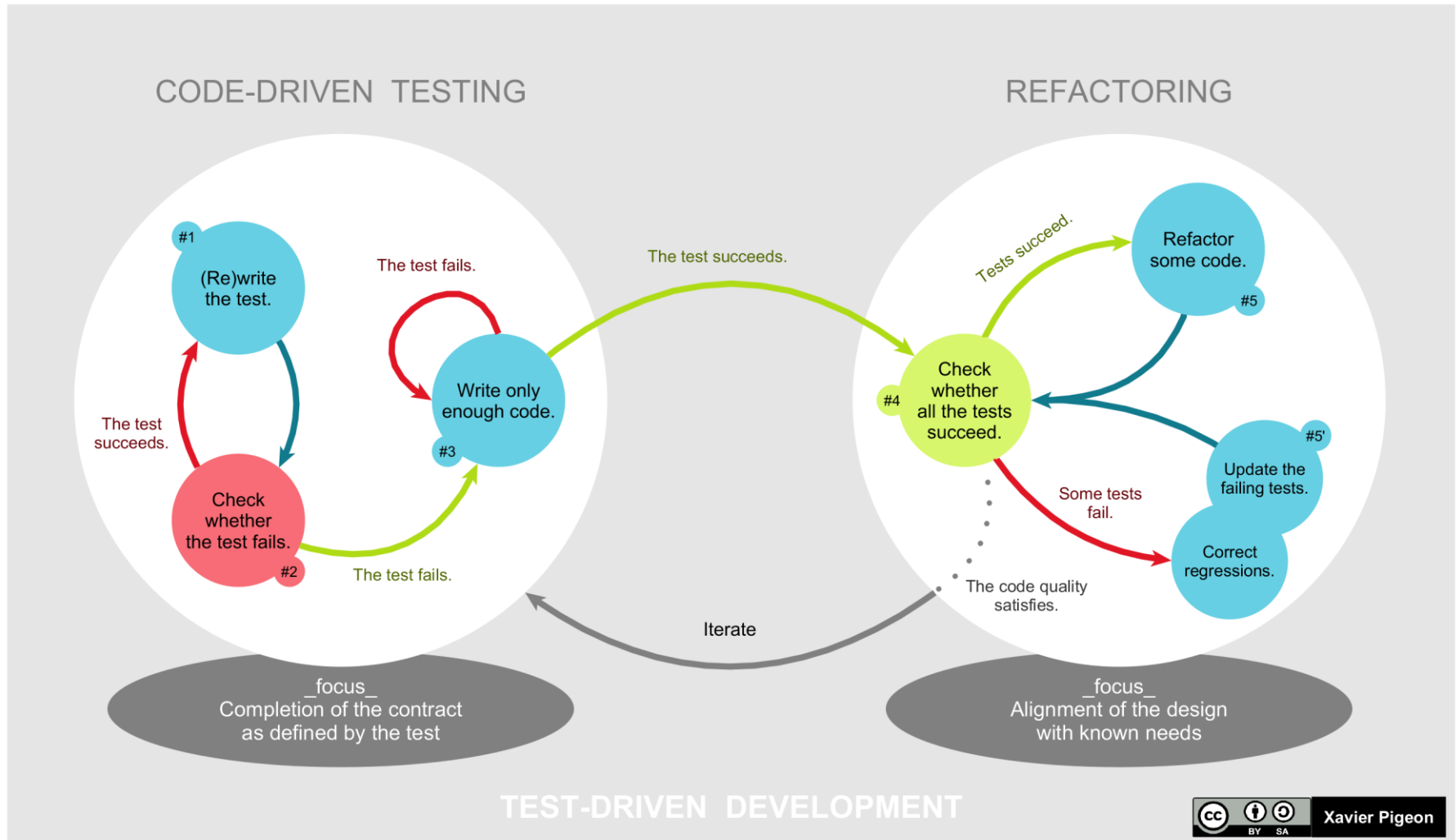
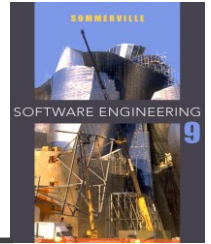


## TDD process activities

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- ✧ Start by **identifying the increment of functionality** that is required. This should normally be small and implementable in a few lines of code.
- ✧ Write a **test for this functionality** and implement this as an automated test.
- ✧ Run the test, along with all other tests that have been implemented. **Initially, you have not implemented the functionality so the new test will fail.**
- ✧ Implement the functionality and re-run the test.
- ✧ Once all tests run successfully, you move on to implementing the next chunk of functionality.

# Test-driven development



# Benefits of test-driven development

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## ✧ Code coverage

- Every code segment that you write has **at least one associated test** so all code written has at least one test.

## ✧ Regression testing

- A regression test suite is developed incrementally as a program is developed.

## ✧ Simplified debugging

- When a test fails, it should be obvious where the problem lies. The newly written code needs to be checked and modified.

## ✧ System documentation

- The tests themselves are a form of documentation that describe what the code should be doing.

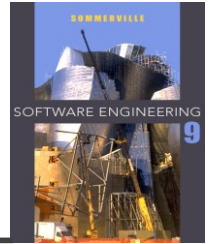
# Regression testing

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- ✧ Regression testing is testing the system to check that changes **have not 'broken' previously working code.**
- ✧ In a manual testing process, regression testing is expensive but, with automated testing, it is simple and straightforward. All tests are **rerun every time a change is made** to the program.
- ✧ Tests must run 'successfully' before the change is committed.

# Release testing

---



- ✧ Release testing is the process of testing a particular release of a system that is **intended for use outside of the development team**.
- ✧ The primary goal of the release testing process is to **convince the supplier** of the system that it is **good enough for use**.
  - Release testing, therefore, has to show that the system **delivers its specified functionality, performance and dependability**, and that it **does not fail during normal use**.
- ✧ Release testing is usually a black-box testing process where tests are only **derived from the system specification**.



# Release testing and system testing

---

- ✧ Release testing is a form of system testing.
- ✧ Important differences:
  - A **separate team** that has not been involved in the system development, should be responsible for release testing.
  - System testing by the **development team should focus on discovering bugs** in the system (**defect testing**). The objective of release testing is to check that the **system meets its requirements** and is good enough for external use (**validation testing**).

# Requirements based testing

---

- ✧ Requirements-based testing involves **examining each requirement** and developing a test or tests for it.
- ✧ Mentcare requirements:
  - If a patient is known to be allergic to any particular medication, then prescription of that medication shall result in a warning message being issued to the system user.
  - If a prescriber chooses to ignore an allergy warning, they shall provide a reason why this has been ignored.

# Requirements tests

---

- ✧ Set up a patient record with no known allergies. Prescribe medication for allergies that are known to exist. Check that a warning message is not issued by the system.
- ✧ Set up a patient record with a known allergy. Prescribe the medication that the patient is allergic to, and check that the warning is issued by the system.
- ✧ Set up a patient record in which allergies to two or more drugs are recorded. Prescribe both of these drugs separately and check that the correct warning for each drug is issued.
- ✧ Prescribe two drugs that the patient is allergic to. Check that two warnings are correctly issued.
- ✧ Prescribe a drug that issues a warning and overrule that warning. Check that the system requires the user to provide information explaining why the warning was overruled.

## A usage scenario for the Mentcare

Kate is a nurse who specializes in mental health care. One of her responsibilities is to visit patients at home to check that their treatment is effective and that they are not suffering from medication side -effects.

On a day for home visits, Kate logs into the Mentcare and uses it to print her schedule of home visits for that day, along with summary information about the patients to be visited. She requests that the records for these patients be downloaded to her laptop. She is prompted for her key phrase to encrypt the records on the laptop.

One of the patients that she visits is Jim, who is being treated with medication for depression. Jim feels that the medication is helping him but believes that it has the side -effect of keeping him awake at night. Kate looks up Jim's record and is prompted for her key phrase to decrypt the record. She checks the drug prescribed and queries its side effects. Sleeplessness is a known side effect so she notes the problem in Jim's record and suggests that he visits the clinic to have his medication changed. He agrees so Kate enters a prompt to call him when she gets back to the clinic to make an appointment with a physician. She ends the consultation and the system re-encrypts Jim's record.

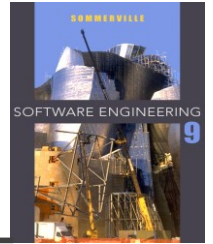
After, finishing her consultations, Kate returns to the clinic and uploads the records of patients visited to the database. The system generates a call list for Kate of those patients who she has to contact for follow-up information and make clinic appointments.

## Features tested by scenario

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- ✧ Authentication by logging on to the system.
- ✧ Downloading and uploading of specified patient records to a laptop.
- ✧ Home visit scheduling.
- ✧ Encryption and decryption of patient records on a mobile device.
- ✧ Record retrieval and modification.
- ✧ Links with the drugs database that maintains side-effect information.
- ✧ The system for call prompting.

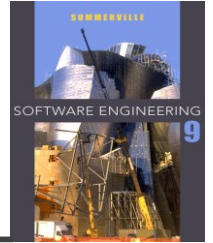
# Performance testing



- ✧ Part of **release testing** may involve testing the **emergent properties of a system**, such as performance and reliability.
- ✧ Tests should **reflect the profile of use of the system**.
- ✧ Performance tests usually involve planning a series of tests where the **load is steadily increased** until the system performance becomes unacceptable.
- ✧ Stress testing is a form of performance testing where the system is **deliberately overloaded** to test its failure behavior.

# User testing

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- ✧ User or customer testing is a stage in the testing process in which **users or customers provide input and advice** on system testing.
- ✧ User testing is essential, even when comprehensive system and release testing have been carried out.
  - The reason for this is that **influences from the user's working environment** have a major effect on the reliability, performance, usability and robustness of a system. These **cannot be replicated in a testing environment**.

# Types of user testing

---

## ✧ Alpha testing

- Users of the software **work with the development team** to test the software **at the developer's site**.

## ✧ Beta testing

- A release of the software is **made available to users** to allow them to experiment and to **raise problems that they discover** with the system developers.

## ✧ Acceptance testing

- Customers test a system to decide **whether or not it is ready to be accepted from the system developers** and deployed in the customer environment. Primarily for custom systems.

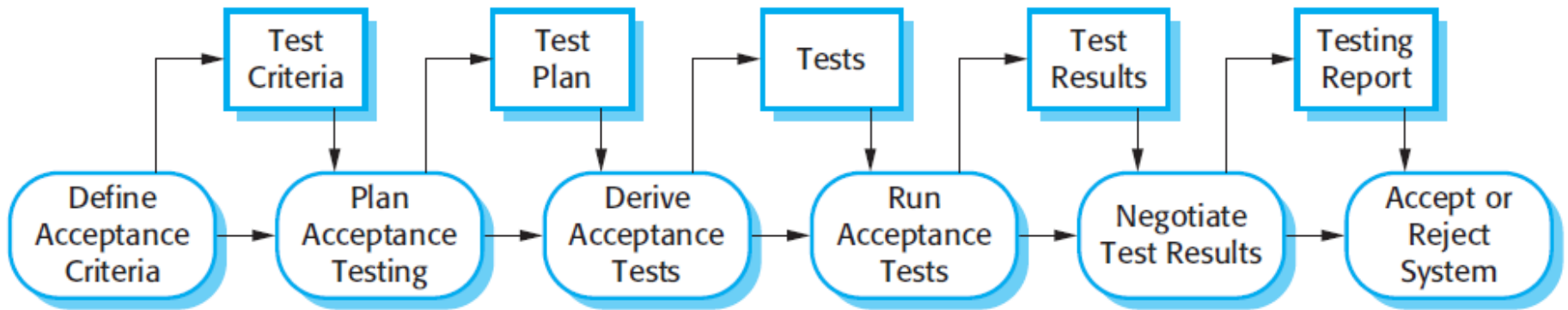


# Stages in the acceptance testing process

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- ✧ Define acceptance criteria
- ✧ Plan acceptance testing
- ✧ Derive acceptance tests
- ✧ Run acceptance tests
- ✧ Negotiate test results
- ✧ Reject/accept system

# The acceptance testing process



# Agile methods and acceptance testing

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- ✧ In agile methods, the **user/customer is part of the development team** and is **responsible for making decisions on the acceptability** of the system.
- ✧ Tests are defined by **the user/customer and are integrated with other tests** in that they are run automatically when changes are made.
- ✧ There is no separate acceptance testing process.
- ✧ Main problem here is whether or not the embedded user is 'typical' and **can represent the interests of all system stakeholders**.

# Key points

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- ✧ When testing software, you should **try to 'break'** the software by using experience and guidelines to choose types of test case that have been effective in **discovering defects** in other systems.
- ✧ Wherever possible, you should **write automated tests**. The tests are embedded in a program that can be run every time a change is made to a system.
- ✧ Test-driven development is an **approach to development** where **tests are written before the code** to be tested.
- ✧ Scenario testing involves inventing a typical usage scenario and using this to derive test cases.
- ✧ Acceptance testing is a user testing process where the aim is to decide if the **software is good enough to be deployed** and used in its operational environment.