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Software Testing

Foundations of Software Engineering

FSE v2022.1

Aleksandr Mikhalev, Fall 2022

Lecture Outline

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§1. Why software testing [10 min]

1.1. Verification and validation

1.2. Incompleteness of testing

§2. Levels of software testing [10 min]

2.1. Unit testing, component testing, and system testing

2.2. Integration testing and regression testing

2.3. User acceptance testing

§3. The software testing process [5 min]

3.1. Automated testing

§1. Why software testing?

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§1. Why software testing?

Bugs in software updates

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Bugs in software updates

Bugs at runtime (financial services)

§1. Why software testing?

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Bugs in software updates

Bugs at runtime (financial services)

Bugs at runtime (critical software)

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Bugs in software updates

Bugs at runtime (financial services)

Bugs at runtime (critical software)

Verification and Validation

§1. Why software testing?

1.1. Verification and validation

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§1. Why software testing?

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1.1. Verification and validation

- **Goal:** make sure that software is meeting the user's needs.

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1.1. Verification and validation

- **Goal:** make sure that software is meeting the user's needs.

- **Verification:** “Are we building the software *right?*”
  - Conformity to software requirements specification

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1.1. Verification and validation

- **Goal:** make sure that software is meeting the user's needs.

- **Verification:** “Are we building the software *right?*”
  - Conformity to software requirements specification

- **Validation:** “Are we building *the right product?*”
  - Conformity to real user requirements

§1. Why software testing?

1.1. Verification and validation

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1.1. Verification and validation

- Understand and validate software requirements

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1.1. Verification and validation

- Understand and validate software requirements
- Verification and validation for:

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1.1. Verification and validation

- Understand and validate software requirements
- Verification and validation for:
  - Inspections

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- Understand and validate software requirements
- Verification and validation for:
  - Inspections
  - Design discussions

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1.1. Verification and validation

- Understand and validate software requirements
- Verification and validation for:
  - Inspections
  - Design discussions
  - Static analysis

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1.1. Verification and validation

- Understand and validate software requirements
- Verification and validation for:
  - Inspections
  - Design discussions
  - Static analysis
  - Testing

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1.1. Verification and validation

- Understand and validate software requirements
- Verification and validation for:
  - Inspections
  - Design discussions
  - Static analysis
  - Testing
  - Runtime verification

§1. Why software testing?

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1.1. Verification and validation

- Understand and validate software requirements
- Verification and validation for:
  - Inspections
  - Design discussions
  - Static analysis
  - Testing
  - Runtime verification

- Study a piece of code to see whether it meets the requirements and works correctly under all circumstances
- Check the whole system
- Accurately assess some system behaviors
- Necessary to “accept” the system by customers
- Document expected system behavior

Incompleteness of software testing

§1. Why software testing?

1.2. Incompleteness of testing

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1.2. Incompleteness of testing

- **Diminishing returns:** finding each next bug is more and more difficult

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- **Diminishing returns:** finding each next bug is more and more difficult
- **Deadlines:** fix high-profile bugs, let others remain

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- **Frequency of updates:** fix security issues immediately, serious flaws monthly, minor flaws two times a year, and nice-to-have new features yearly

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- **Usefulness:** “Any sufficiently advanced bug is indistinguishable from a feature.”

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- **Usefulness:** “Any sufficiently advanced bug is indistinguishable from a feature.”
- **Obsolescence:** don’t fix bugs for features that are expected to go away
- **Not a bug:** train users to avoid misunderstanding

§1. Why software testing?

1.2. Incompleteness of testing

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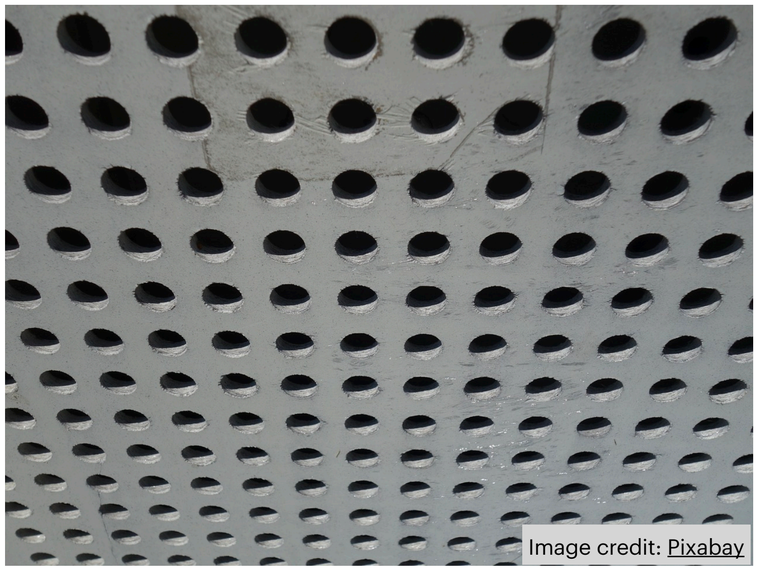
1.2. Incompleteness of testing

- Only sample a set of possible behaviors from the system's state space



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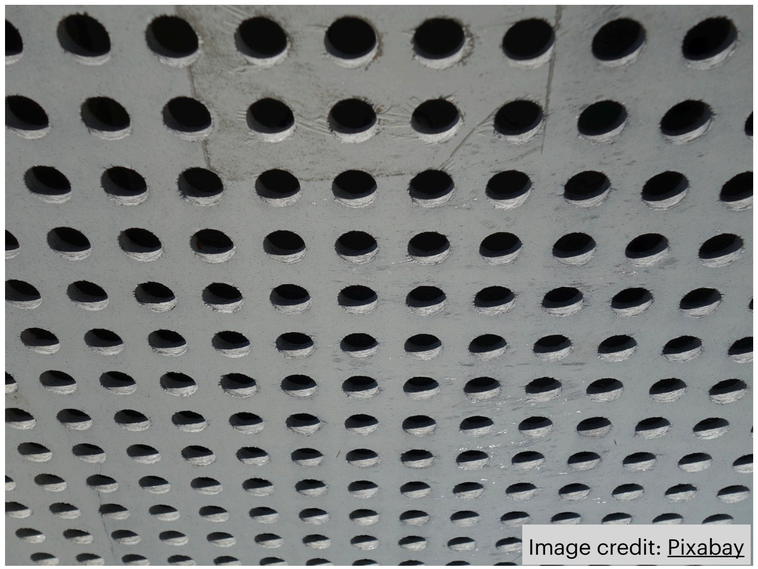

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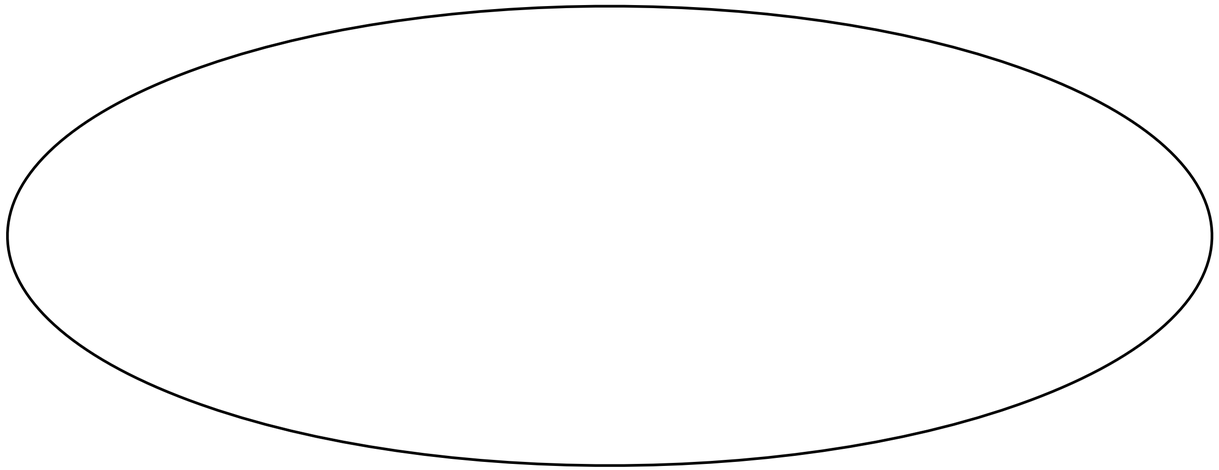

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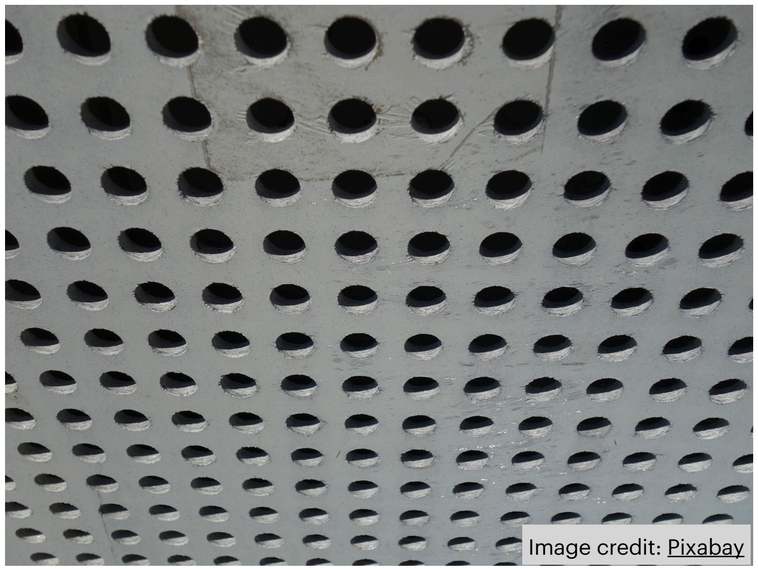
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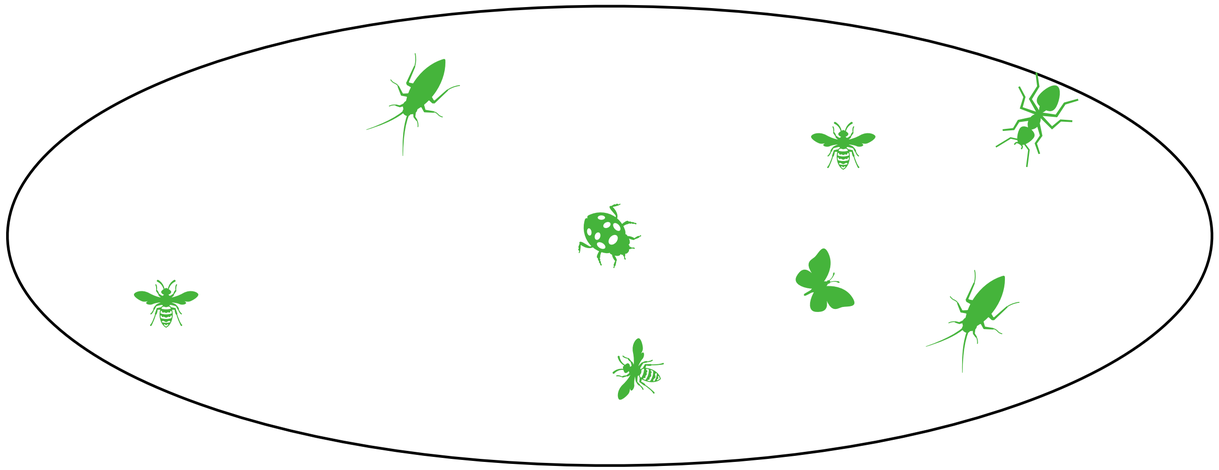

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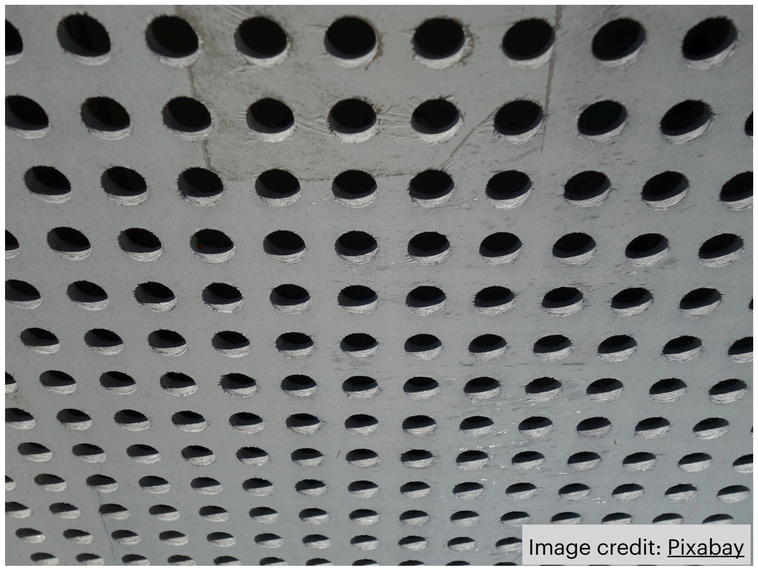
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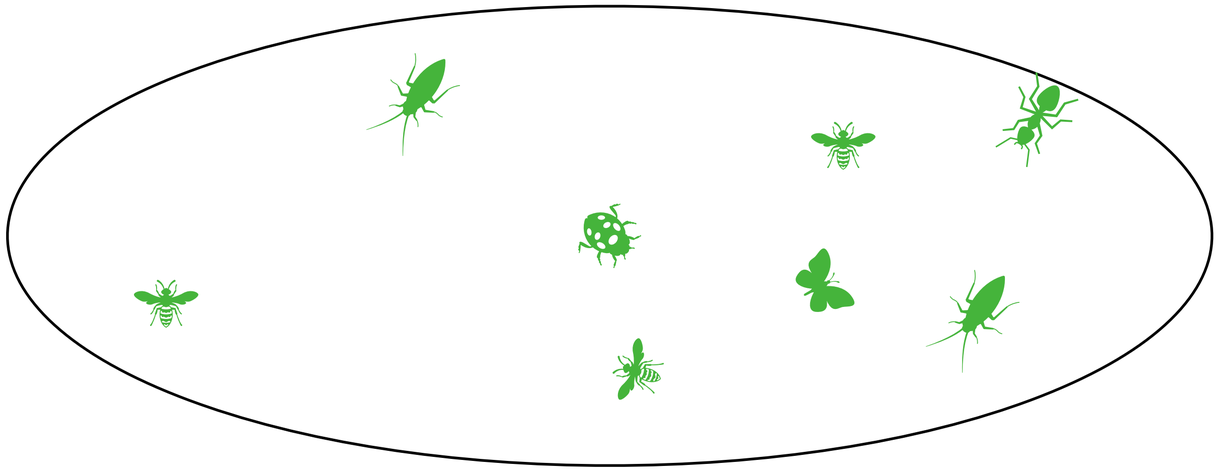
- State space is discrete and discontinuous:



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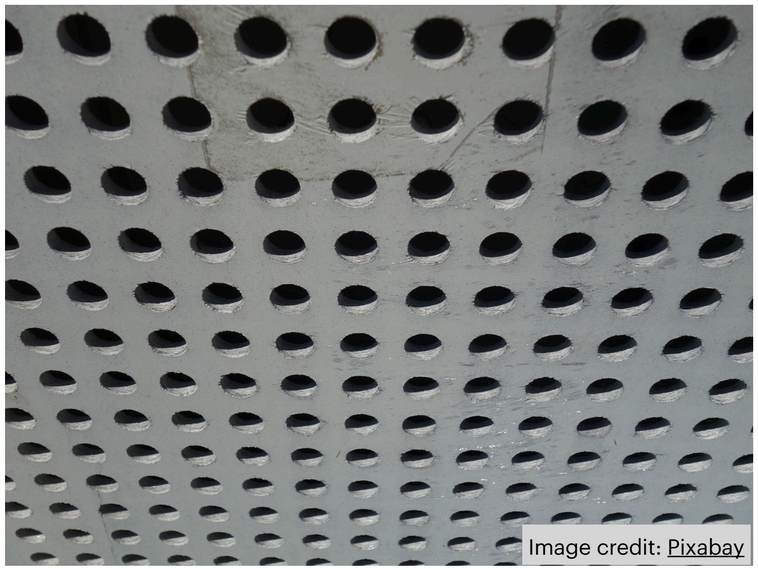
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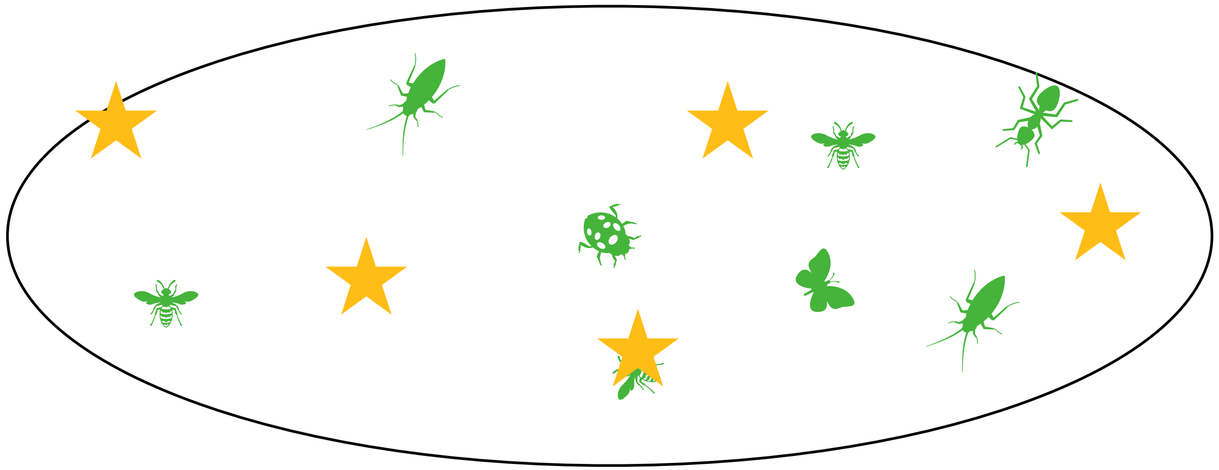

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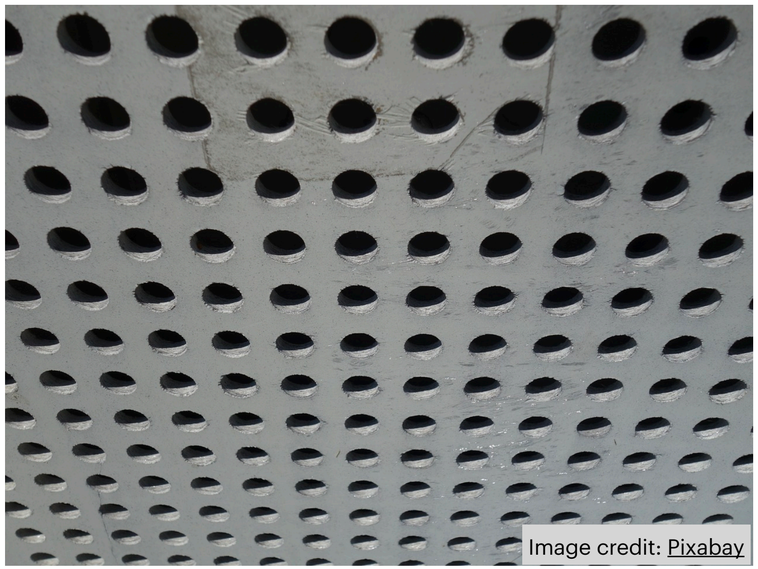
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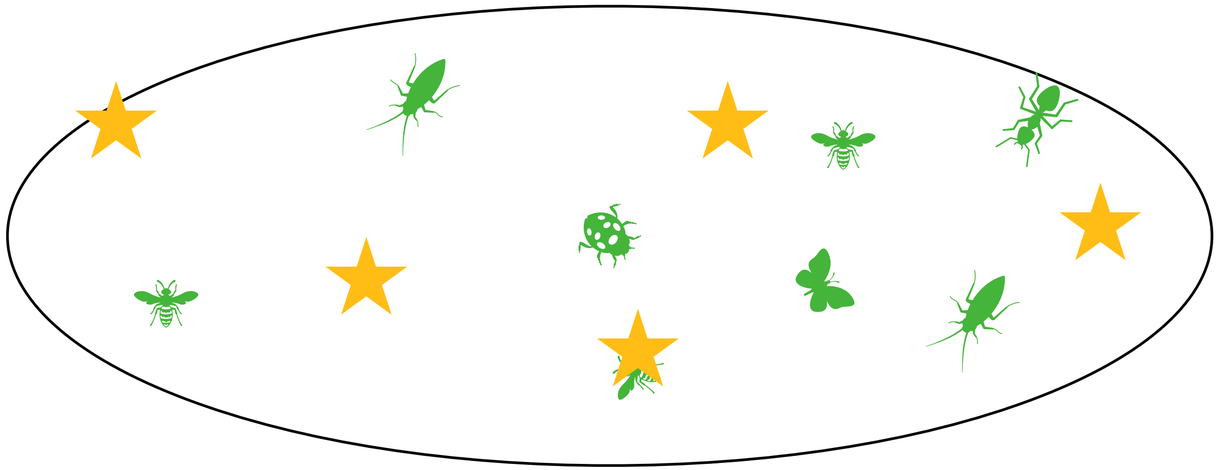
- State space is discrete and discontinuous:
  - No basis for extrapolating from seen cases to unseen ones



“Testing can only show the presence of errors, not their absence”

Edsger Dijkstra, 1972

§2. Levels of software testing

Unit, Component, and System Testing

§2. Levels of software testing

2.1. Unit testing

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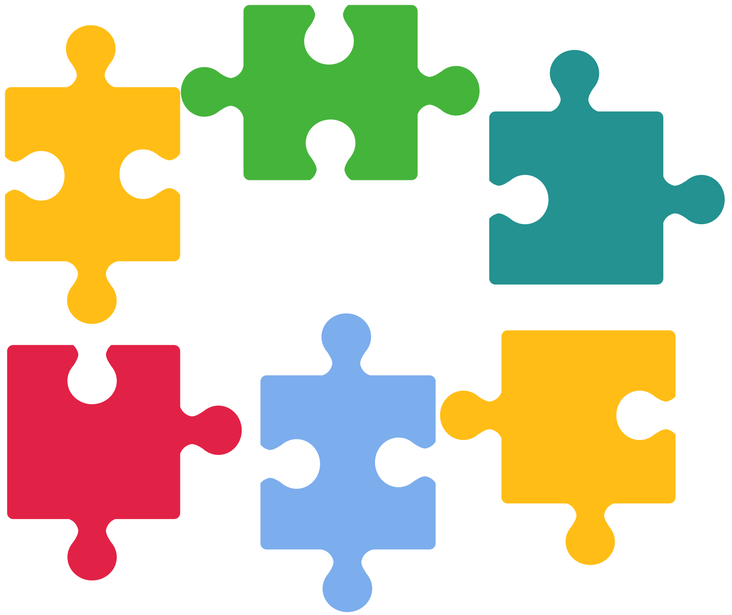
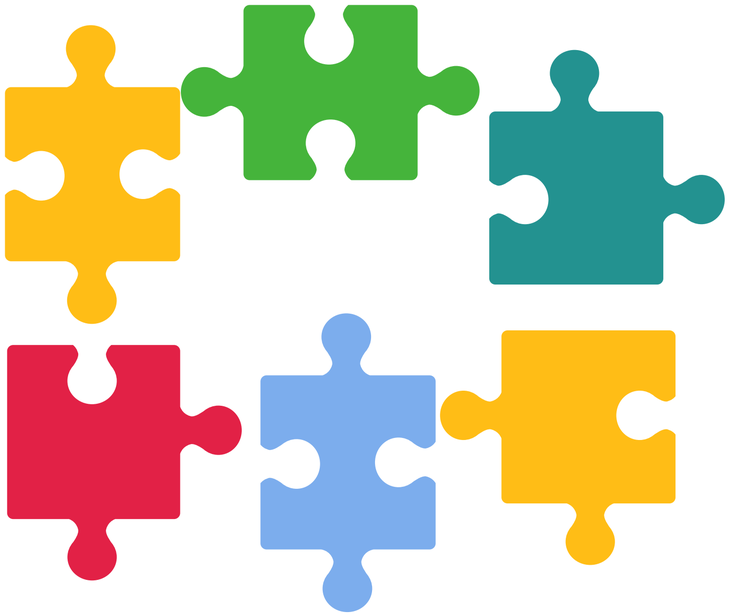


§2. Levels of software testing

2.1. Unit testing

- **Targets:** individual functions or methods



§2. Levels of software testing

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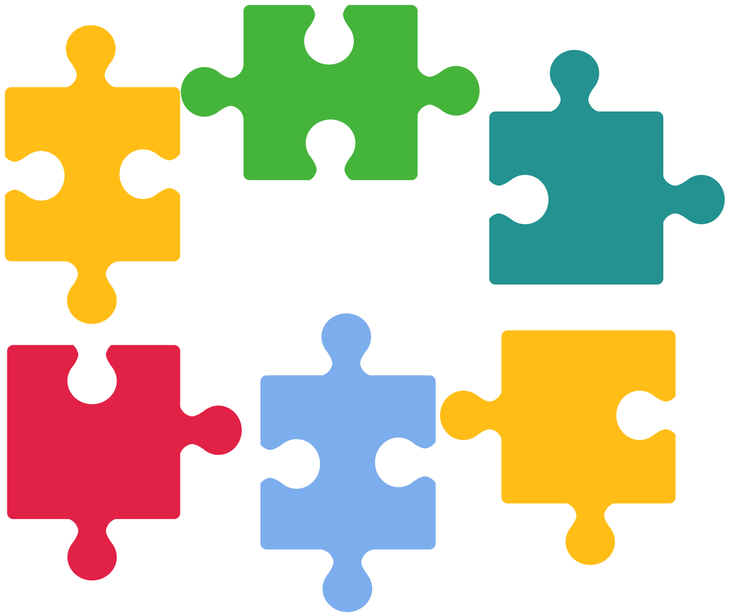

- **Targets:** individual functions or methods
- **How to test:** calls to these routines with different input parameters

§2. Levels of software testing

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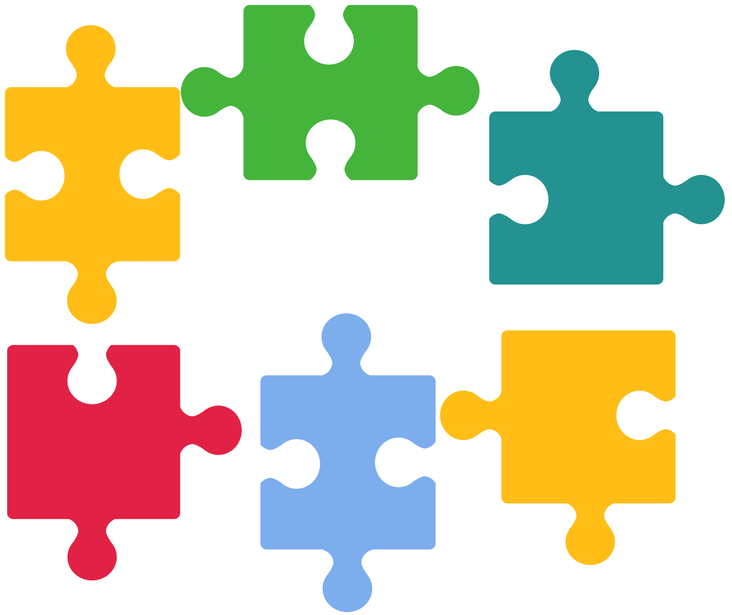
2.1. Unit testing



- **Targets:** individual functions or methods
- **How to test:** calls to these routines with different input parameters
- **What to test:**

§2. Levels of software testing

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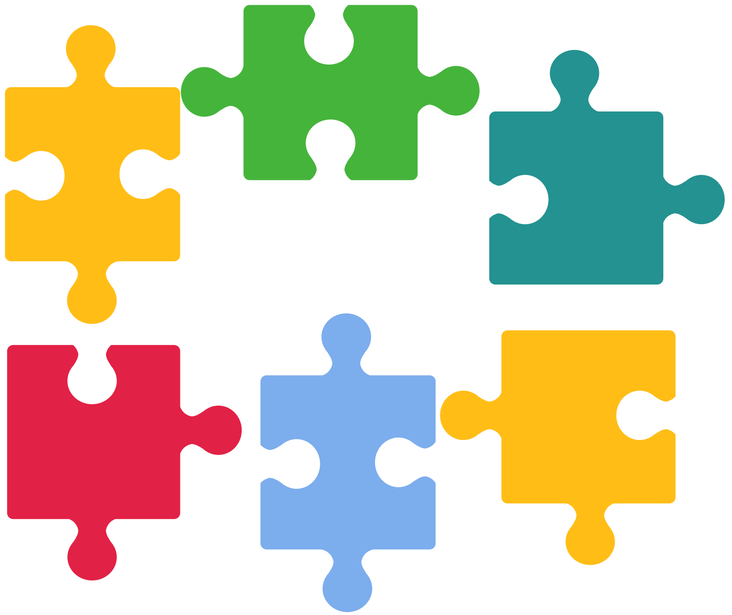
2.1. Unit testing



- **Targets:** individual functions or methods
- **How to test:** calls to these routines with different input parameters
- **What to test:**
  - test all operations associated with the object;

§2. Levels of software testing

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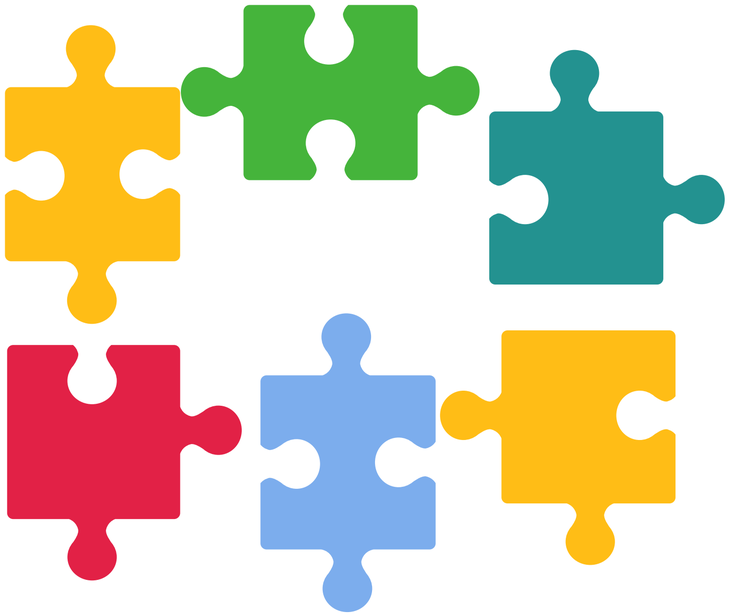
2.1. Unit testing



- **Targets:** individual functions or methods
- **How to test:** calls to these routines with different input parameters
- **What to test:**
  - test all operations associated with the object;
  - set and check the value of all attributes associated with the object

§2. Levels of software testing

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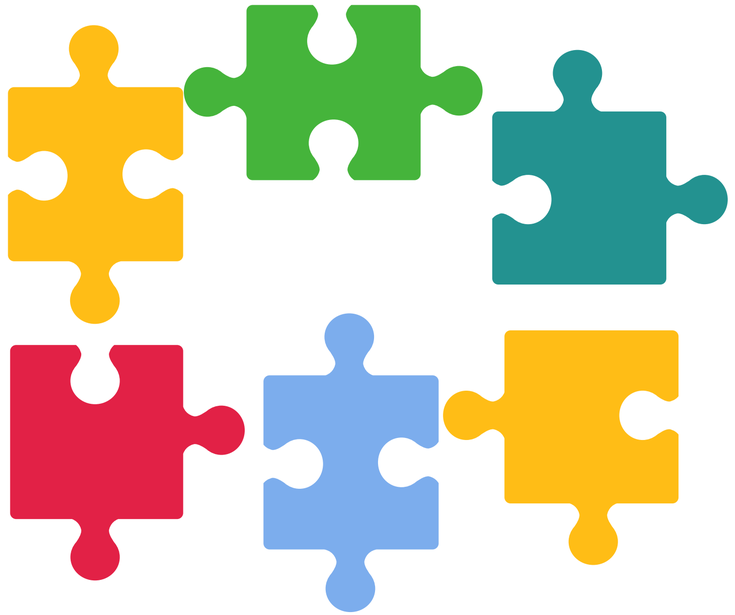
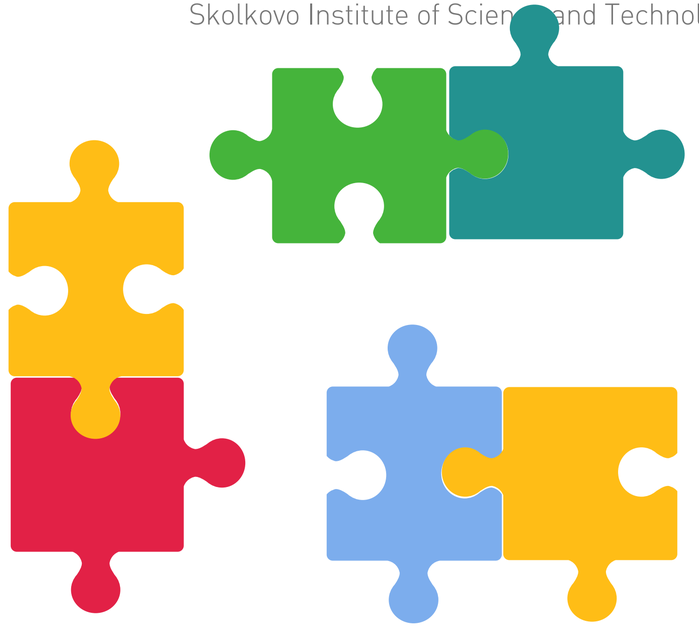
2.1. Unit testing



- **Targets:** individual functions or methods
- **How to test:** calls to these routines with different input parameters
- **What to test:**
  - test all operations associated with the object;
  - set and check the value of all attributes associated with the object
  - put the object into all possible states

§2. Levels of software testing

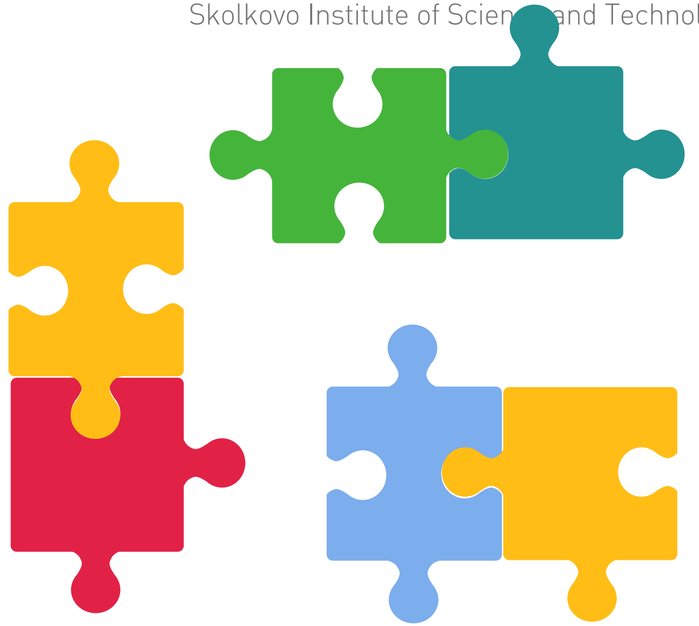
2.1. Component testing



§2. Levels of software testing

2.1. Component testing

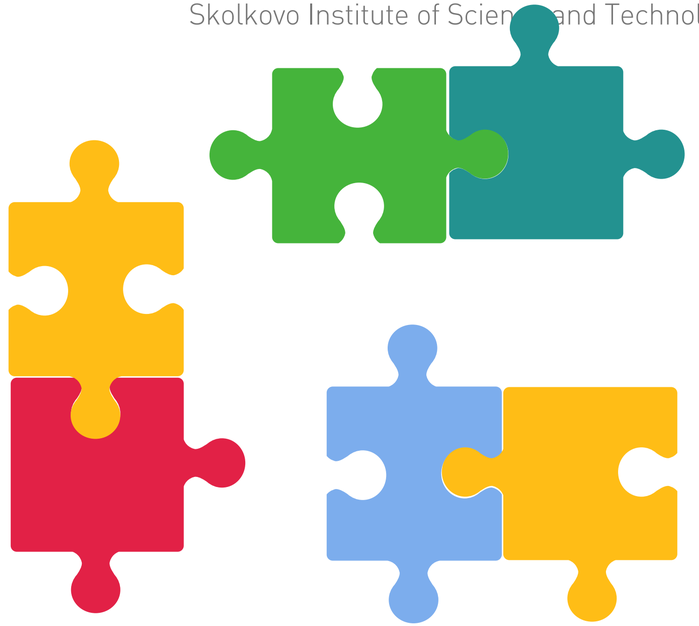
- **Targets:** interactions and interfaces between components



§2. Levels of software testing

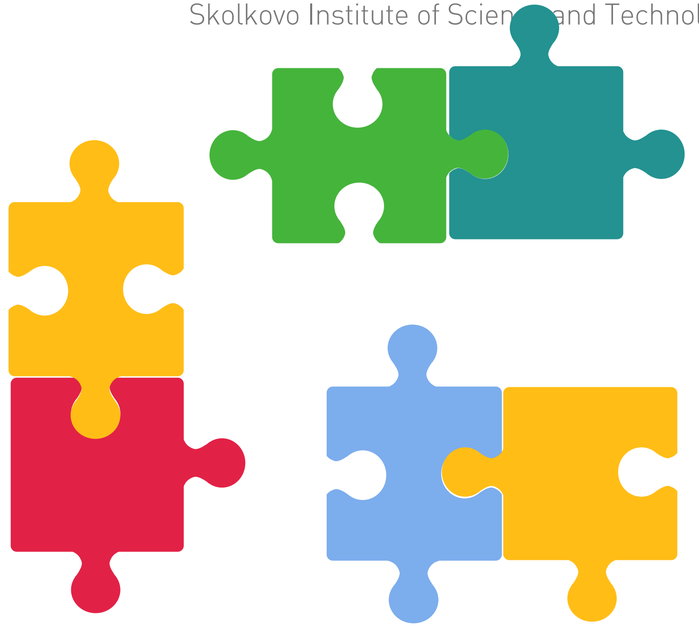
2.1. Component testing

- **Targets:** interactions and interfaces between components
- **How to test:** calling the interface of the composite component



§2. Levels of software testing

2.1. Component testing

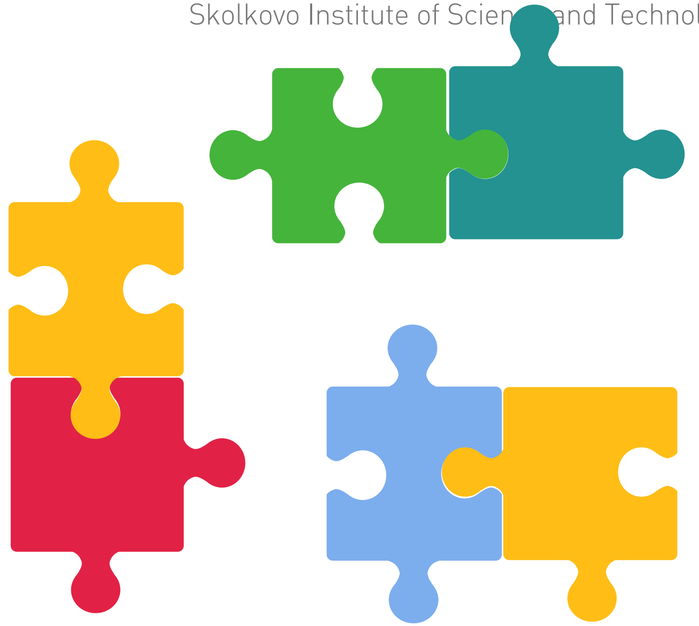


- **Targets:** interactions and interfaces between components
- **How to test:** calling the interface of the composite component
- **What to test:**

§2. Levels of software testing

2.1. Component testing

- **Targets:** interactions and interfaces between components
- **How to test:** calling the interface of the composite component
- **What to test:**
  - each call to an external component



§2. Levels of software testing

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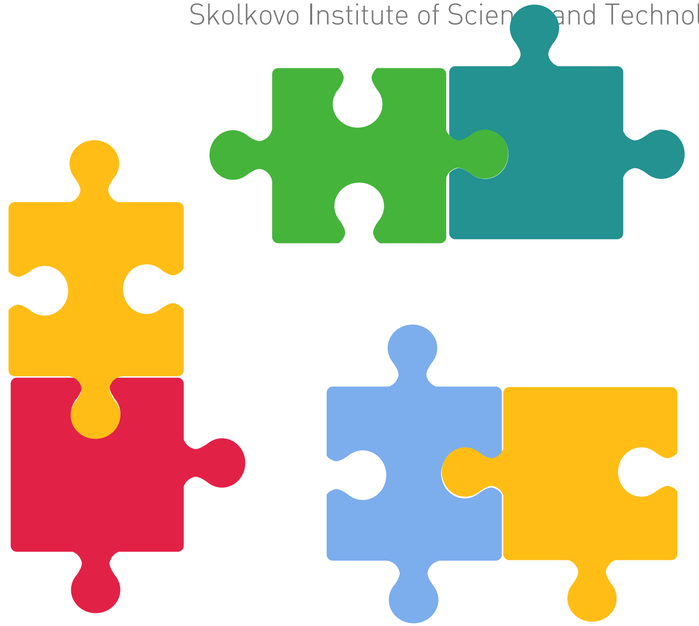
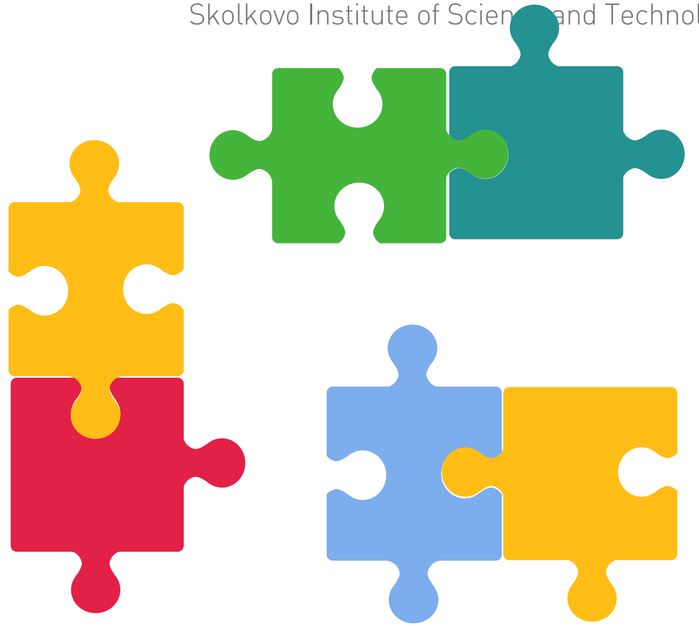


- **Targets:** interactions and interfaces between components
- **How to test:** calling the interface of the composite component
- **What to test:**
  - each call to an external component
  - test the interface with null pointer parameters

§2. Levels of software testing

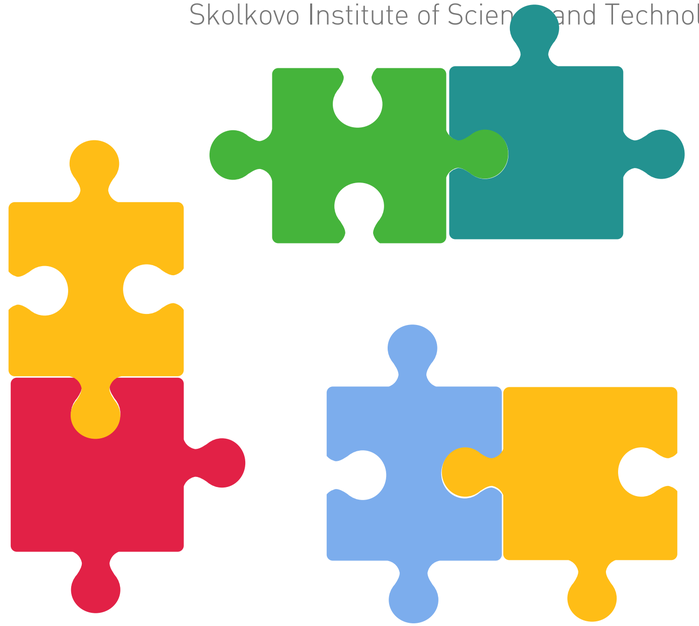
2.1. Component testing



- **Targets:** interactions and interfaces between components
- **How to test:** calling the interface of the composite component
- **What to test:**
  - each call to an external component
  - test the interface with null pointer parameters
  - design tests that deliberately cause the component to fail

§2. Levels of software testing

2.1. Component testing



- **Targets:** interactions and interfaces between components
- **How to test:** calling the interface of the composite component
- **What to test:**
  - each call to an external component
  - test the interface with null pointer parameters
  - design tests that deliberately cause the component to fail
  - stress testing in message passing systems

§2. Levels of software testing

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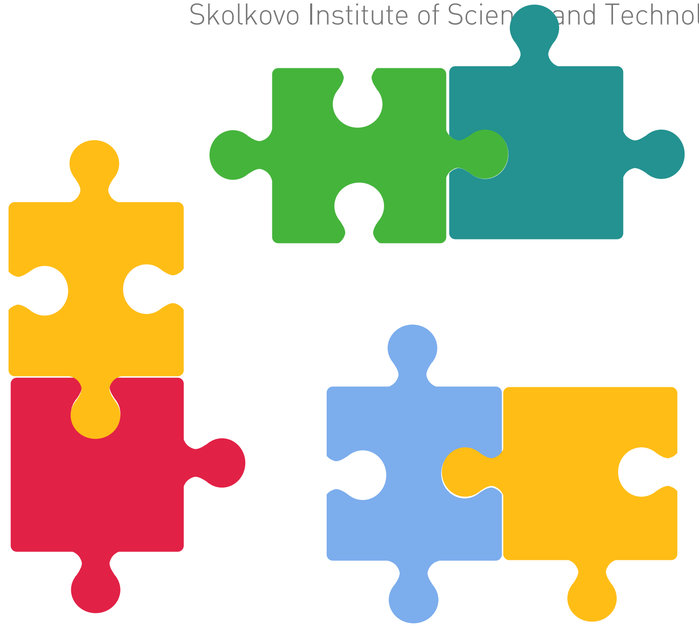
2.1. Component testing



- **Targets:** interactions and interfaces between components
- **How to test:** calling the interface of the composite component
- **What to test:**
  - each call to an external component
  - test the interface with null pointer parameters
  - design tests that deliberately cause the component to fail
  - stress testing in message passing systems
  - design tests that vary the order in which these shared memory components are activated

§2. Levels of software testing

2.1. System testing

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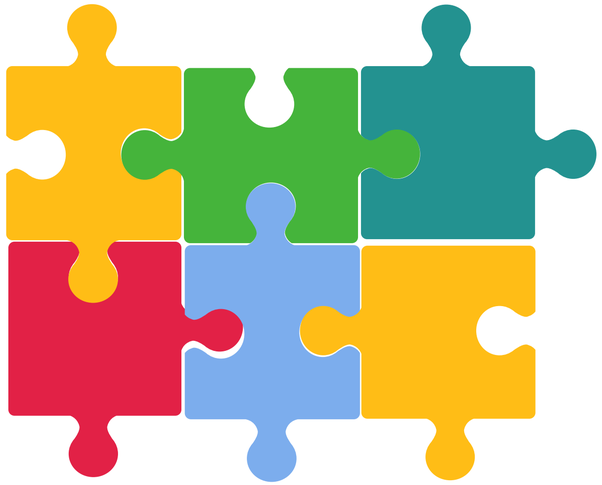

§2. Levels of software testing

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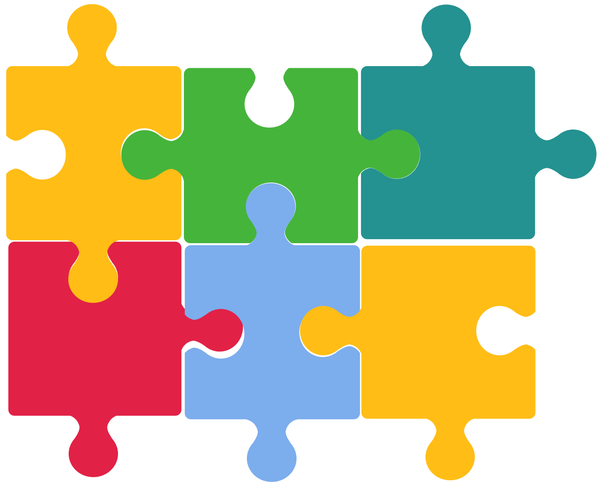
2.1. System testing



- **Targets:** testing the interactions between the components and objects that make up a system

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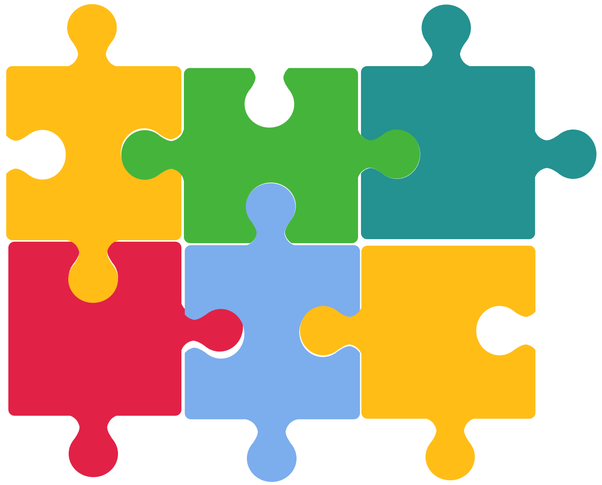
2.1. System testing



- **Targets:** testing the interactions between the components and objects that make up a system
- **How to test:** use case-based testing

§2. Levels of software testing

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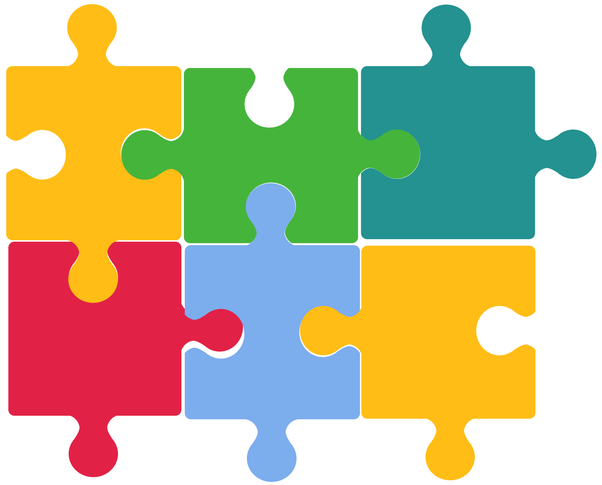

2.1. System testing

- **Targets:** testing the interactions between the components and objects that make up a system
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- **What to test:**

§2. Levels of software testing

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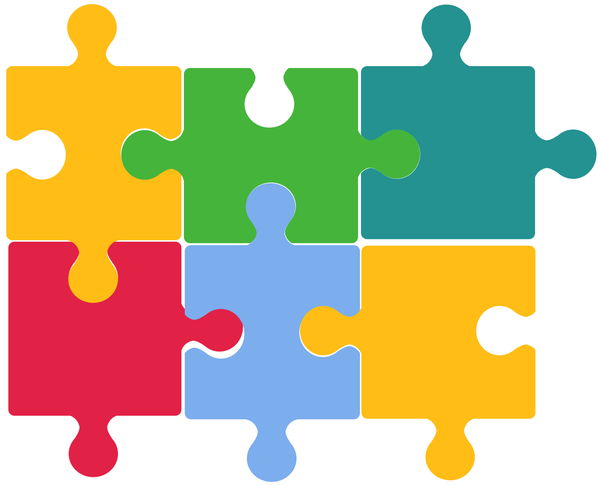

- **Targets:** testing the interactions between the components and objects that make up a system
- **How to test:** use case-based testing
- **What to test:**
  - all functions accessible through menus

§2. Levels of software testing

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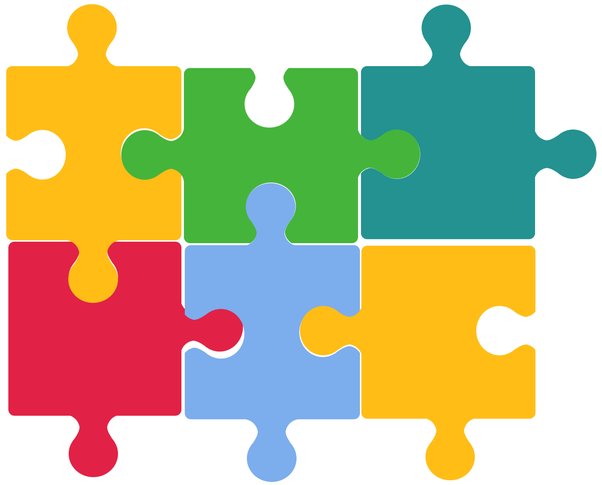

- **Targets:** testing the interactions between the components and objects that make up a system
- **How to test:** use case-based testing
- **What to test:**
  - all functions accessible through menus
  - combinations of functions accessed from the same menu

§2. Levels of software testing

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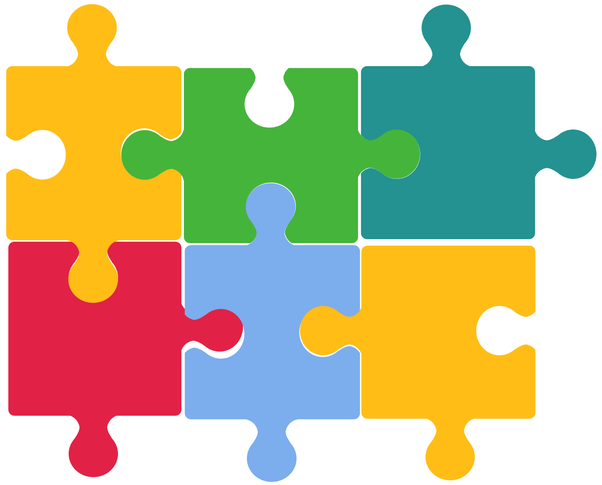

- **Targets:** testing the interactions between the components and objects that make up a system
- **How to test:** use case-based testing
- **What to test:**
  - all functions accessible through menus
  - combinations of functions accessed from the same menu
  - functions taking user input (correct or incorrect)

Integration and Regression Testing

§2. Levels of software testing

2.2. Integration testing and regression testing

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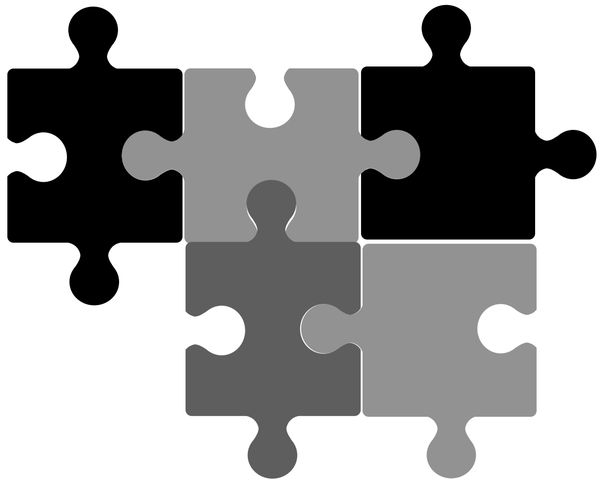
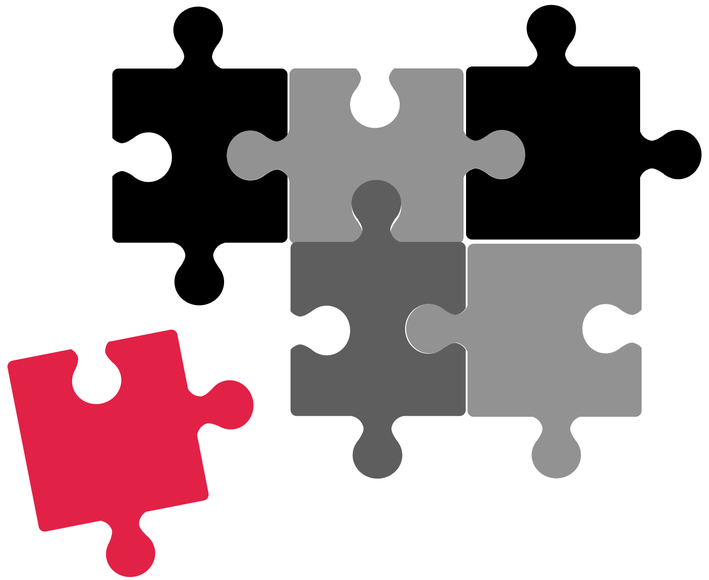
§2. Levels of software testing

2.2. Integration testing and regression testing



§2. Levels of software testing

2.2. Integration testing and regression testing



§2. Levels of software testing

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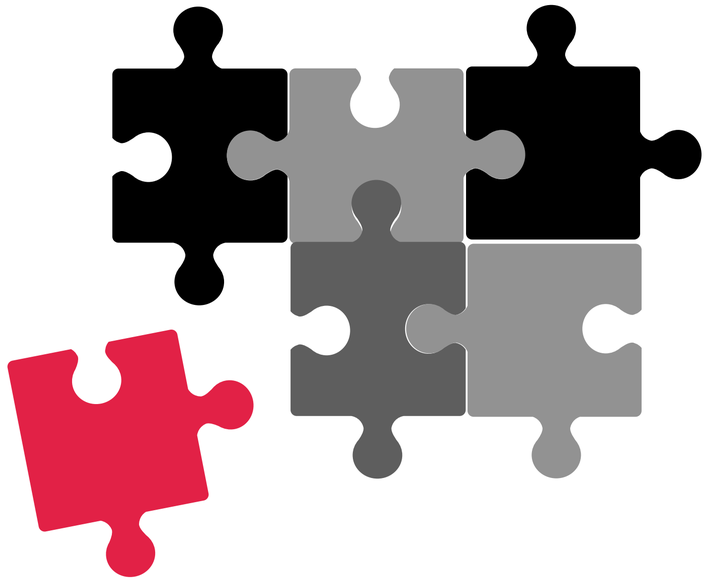
2.2. Integration testing and regression testing



- **Integration testing:** verify that the newly introduced code interacts well with the existing codebase

§2. Levels of software testing

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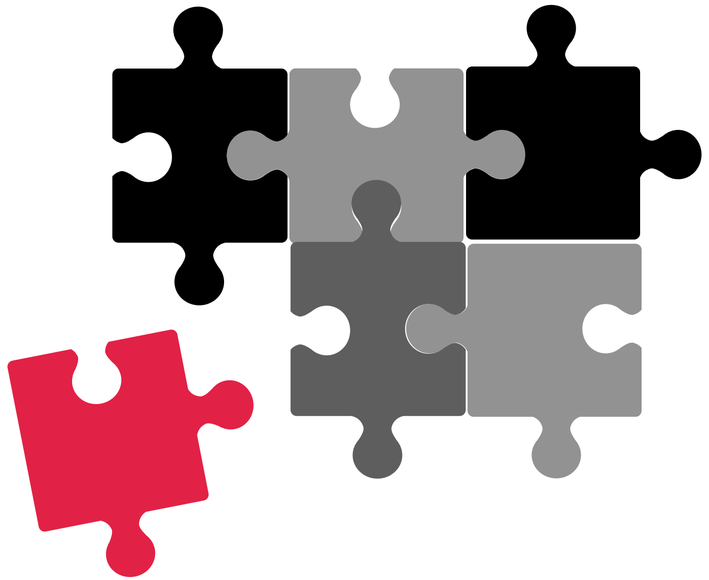
2.2. Integration testing and regression testing



- **Integration testing:** verify that the newly introduced code interacts well with the existing codebase

- **Regression testing:** discover bugs introduced by merging the new code into the codebase

§2. Levels of software testing

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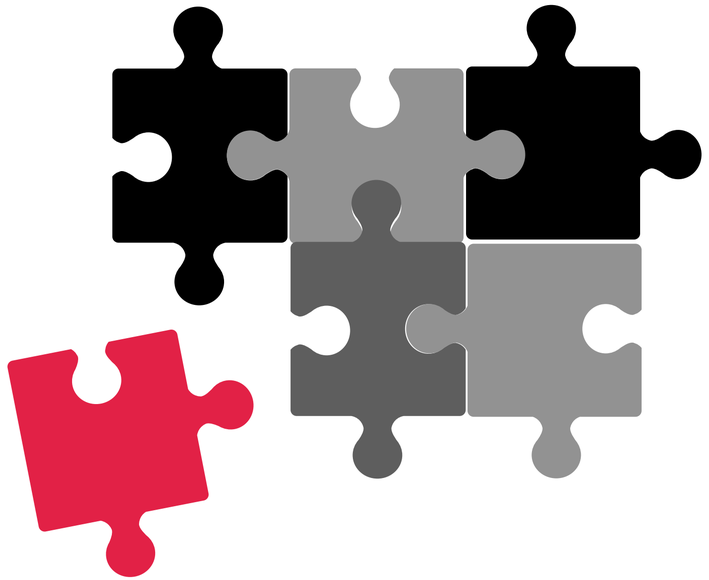
2.2. Integration testing and regression testing

- **Integration testing:** verify that the newly introduced code interacts well with the existing codebase

- **Regression testing:** discover bugs introduced by merging the new code into the codebase

- **Continuous integration / testing:** run integration/ regression tests every time an increment is complete (in the limit: every commit to VCS)



User Acceptance Testing

§2. Levels of software testing

2.3. User Acceptance Testing

§2. Levels of software testing

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2.3. User Acceptance Testing

Image Credit: Daily Mirror

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2.3. User Acceptance Testing

Image Credit: Daily Mirror

Image Credit: Parents.com

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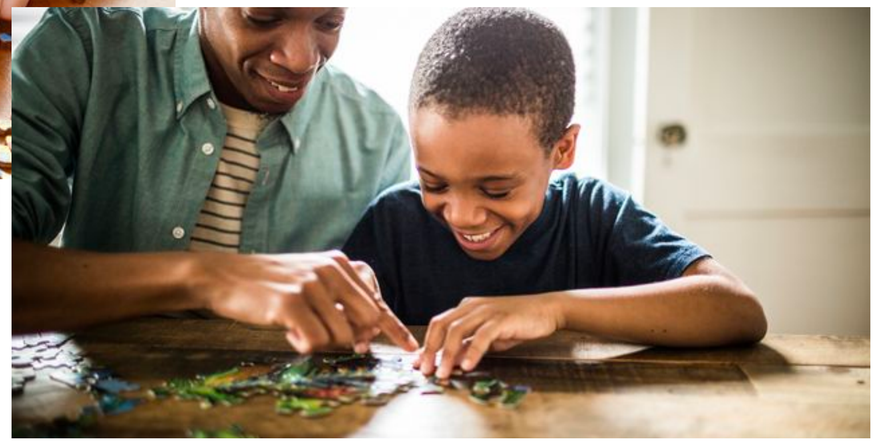

Image Credit: womansday.com

§3. The software testing process

Automated Testing

§3. The software testing process

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3.1. Automated testing

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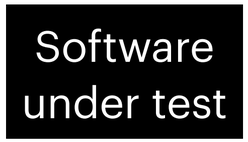

- **Software under test:** a module or unit of code where we can exercise some behaviour

§3. The software testing process

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3.1. Automated testing

- **Software under test:** a module or unit of code where we can exercise some behaviour
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§3. The software testing process

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3.1. Automated testing

- **Software under test:** a module or unit of code where we can exercise some behaviour
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§3. The software testing process

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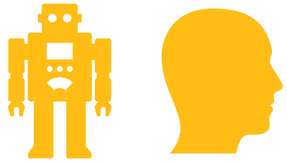
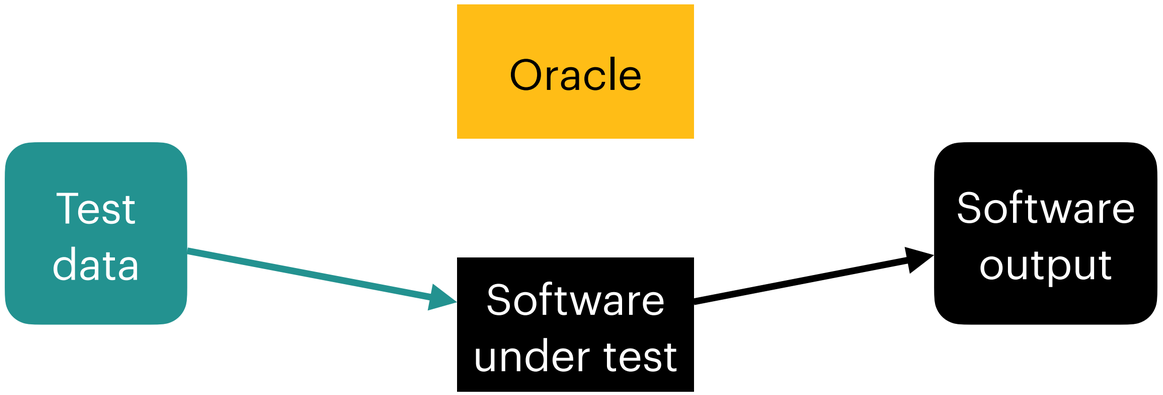
3.1. Automated testing





- **Software under test:** a module or unit of code where we can exercise some behaviour
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§3. The software testing process

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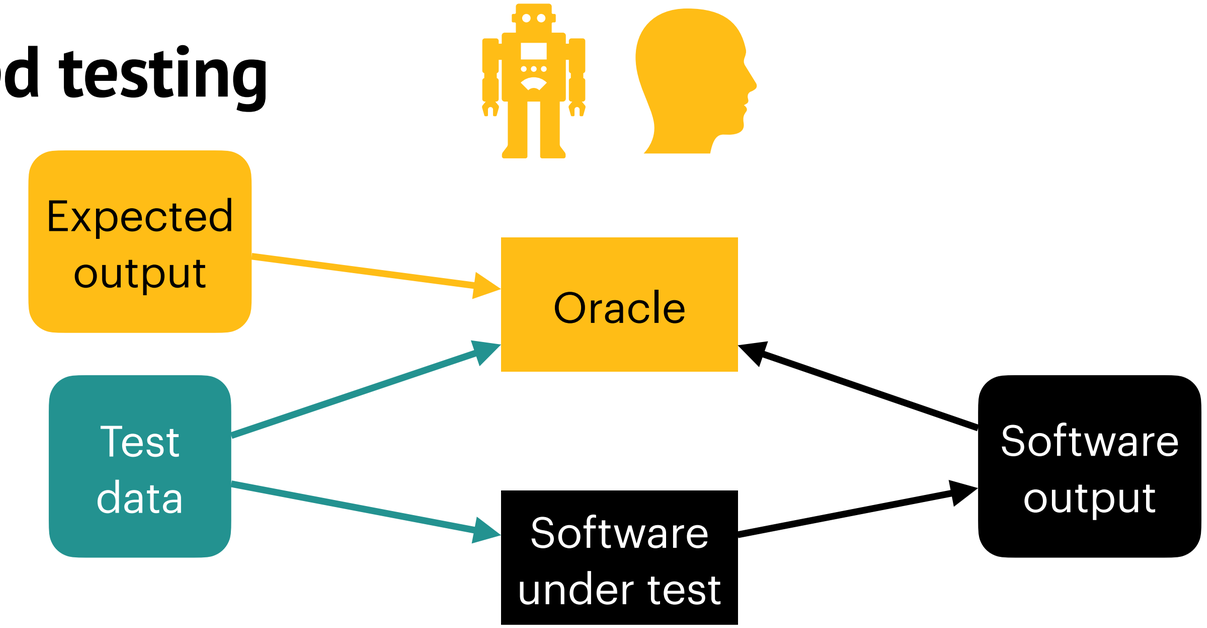
3.1. Automated testing



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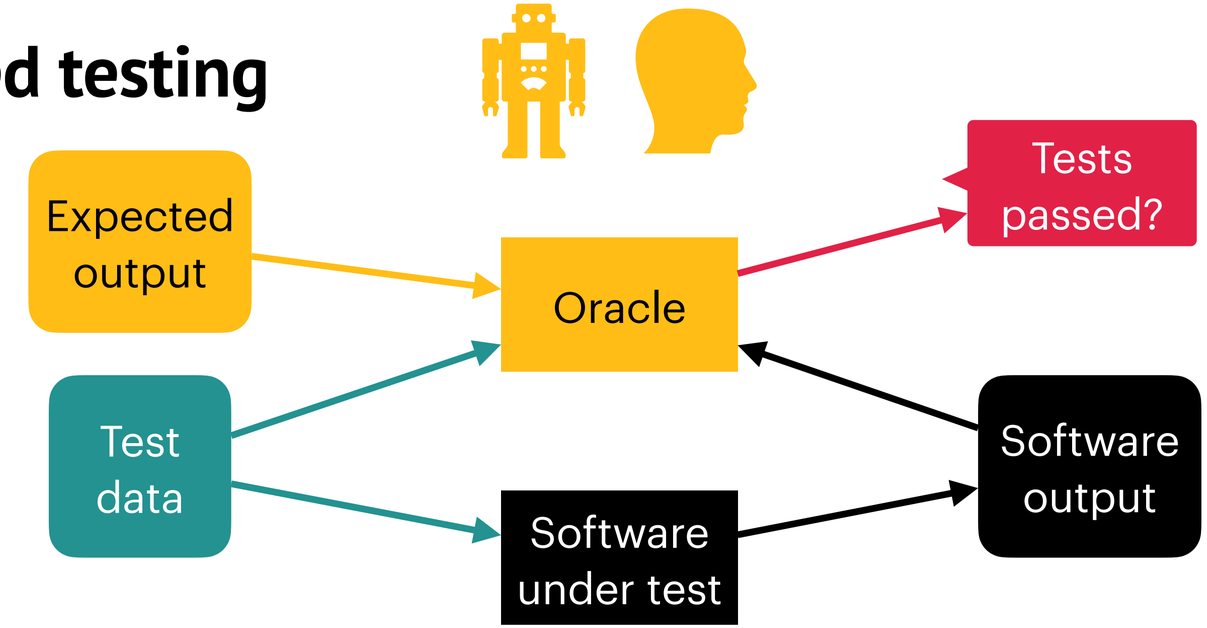

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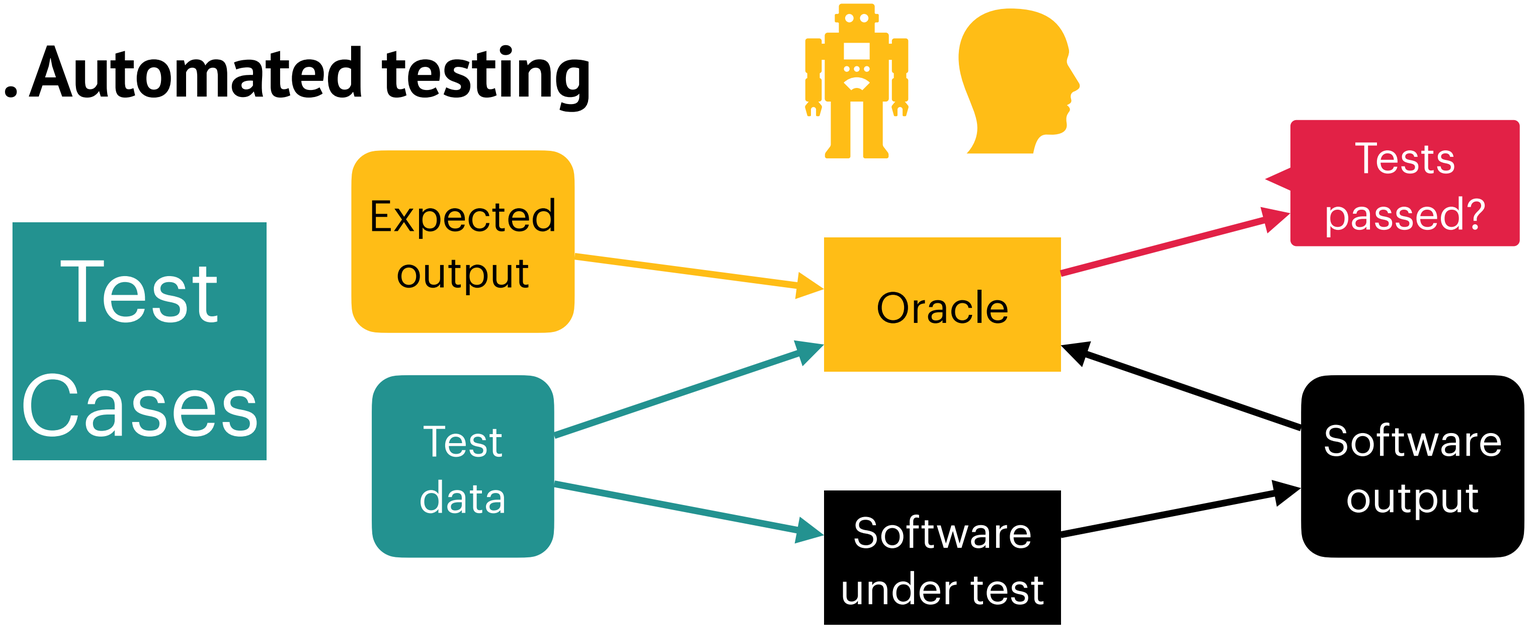

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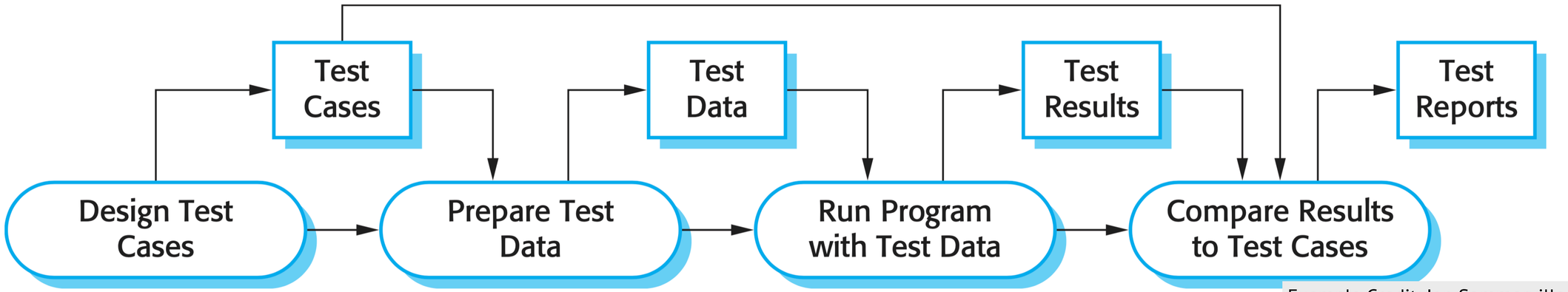

Example Credit: Ian Sommerville

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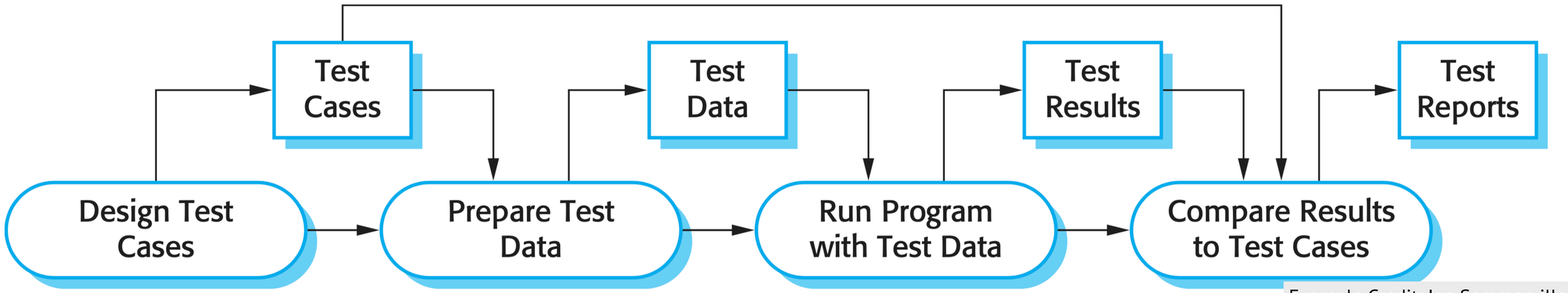

Example Credit: Ian Sommerville

- **Test cases:** specifications test inputs / system outputs

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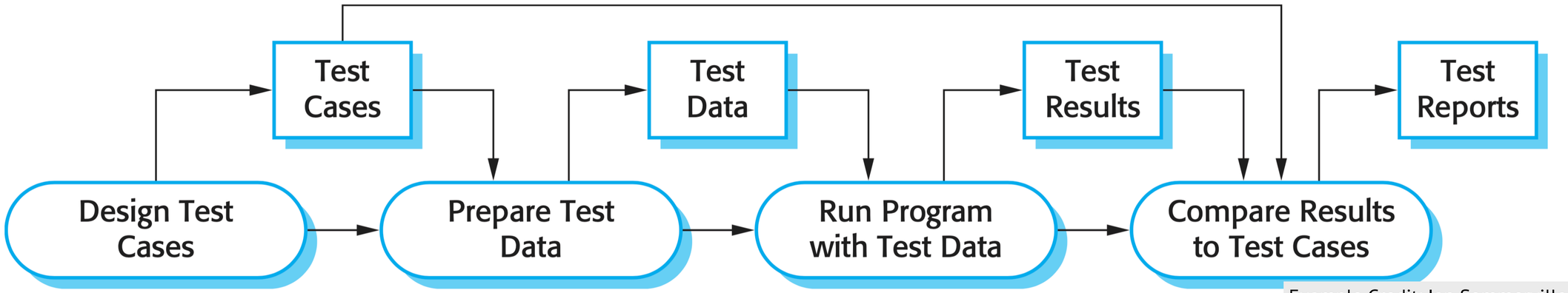
3.1. Automated testing



Example Credit: Ian Sommerville

- **Test cases:** specifications test inputs / system outputs
- **Test data:** inputs devised to test a system

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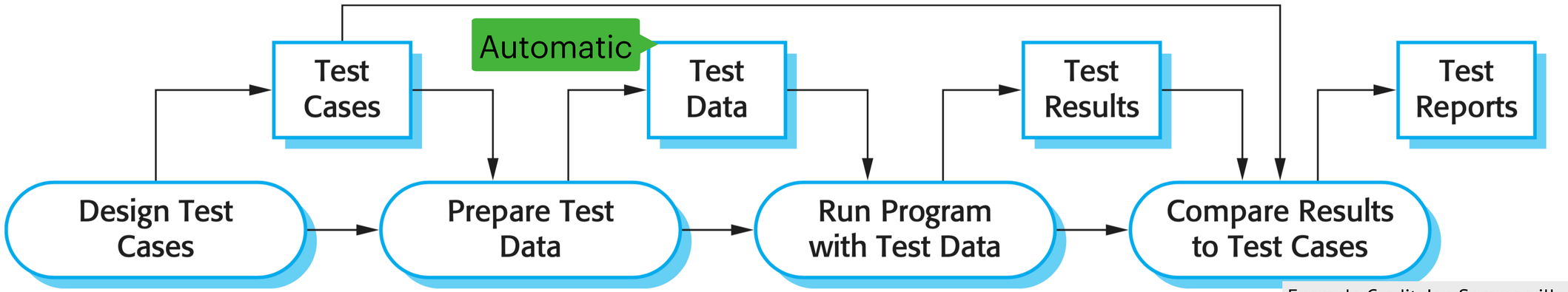

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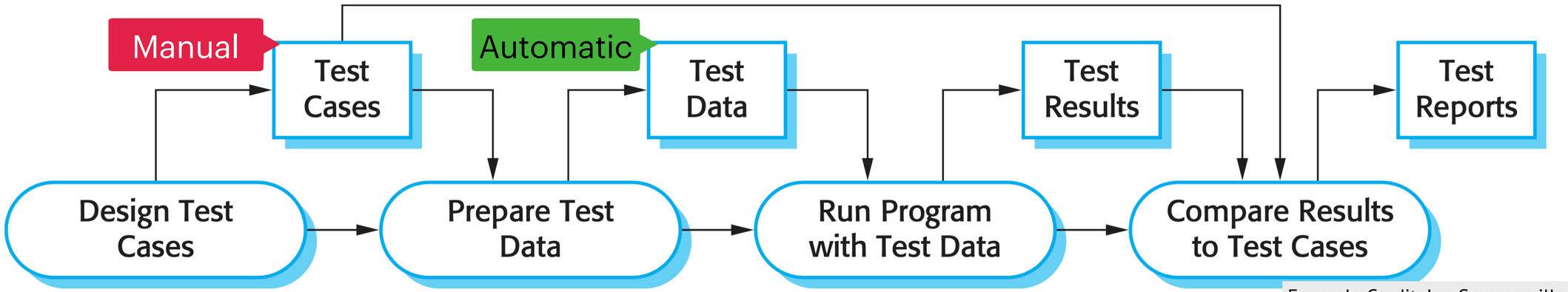

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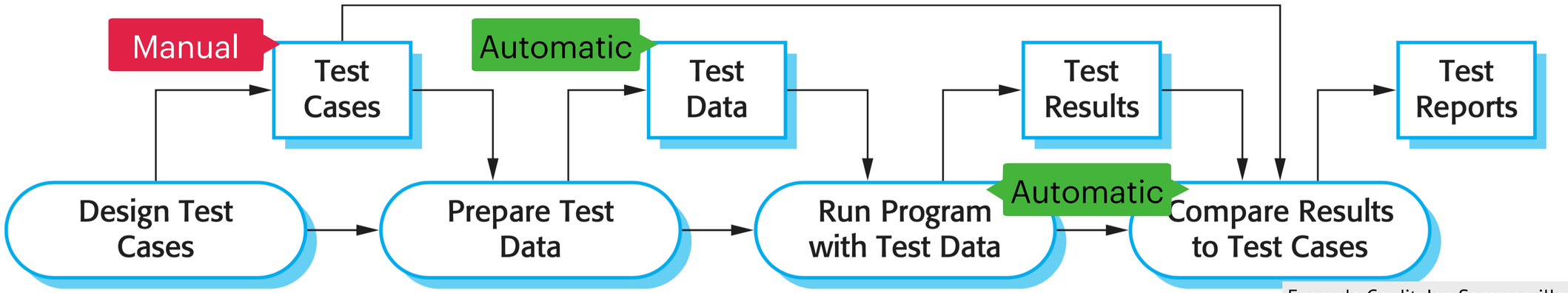

Example Credit: Ian Sommerville

- **Test cases:** specifications test inputs / system outputs
- **Test data:** inputs devised to test a system
- **Test runner:** compare expected results with predicted results

References

1. R. Stephens (2015). Beginning software engineering. John Wiley & Sons.
2. I. Sommerville (2020) *Software engineering 9th Edition*.