I. Software Development (Chap. 1 — read)

5 phases of software life cycle

A. Problem Analysis and Specification (§1.1)

— Easy in courses, not always in real world
— Statement of specifications becomes:

→ the formal statement of the problem's requirements
→ the major reference document
→ a benchmark used to evaluate the final system

Sometimes stated precisely using a *formal method*

B. Design (§1.2)

Programs, libraries, classes:

In CS courses	In the real world
small — ≤ a few hundred lines of code	large systems — thousands of lines of code
simple, straightforward	complex

Object-centered design:

1. Identify the **objects** in the problem's specification and their types.
2. Identify the **operations** needed to solve the problem.
3. Arrange the operations in a sequence of steps, called an **algorithm**, which, when applied to the objects, will solve the problem.

Data types:

- Simple
- Structured — **data structures**

Algorithms

- Different ones may work, but may not be equally efficient (pp. 7-8)
  - O(n) — grows linearly with size (n) of the input
  - O(1) — is constant — independent of size of input

  More later about measuring efficiency
- Can't separate data structures and algorithms
  - *Algorithms + Data Structures = Programs*
- Properties of instructions (p. 9)
  - — Definite and unambiguous
  - — Simple
  - — Finiteness
- Usually written in pseudocode
- ~~Can be unstructured~~

  Should be structured (pp. 10-12)

ALGORITHM (UNSTRUCTURED VERSION)

/* Algorithm to read and count several triples of distinct numbers
and print the largest number in each triple. */

1. Initialize *count* to 0.
2. Read a triple *x*, *y*, *z*.
3. If *x* is the end-of-data flag then go to step 14.
4. Increment *count* by 1.
5. If *x* > *y* then go to step 9.
6. If *y* > *z* then go to step 12.
7. Display *z*.
8. Go to step 2.
9. If *x* < *z* then go to step 7.
10. Display *x*.
11. Go to step 2.
12. Display *y*.
13. Go to step 2.
14. Display *count.*

Note the *spaghetti logic*!

/* Algorithm to read and count several triples of distinct numbers
and print the largest number in each triple. */

1. Initialize *count* to 0.
2. Read the first triple of numbers *x*, *y*, *z*.
3. While *x* is not the end-of-data-flag do the following:
   a. Increment *count* by 1.
   b. If *x* > *y* and *x* > *z* then
      Display *x*.
      Else if *y* > *x* and *y* > *z* then
      Display *y*.
      Else
      Display *z*.
   c. Read the next triple *x*, *y*, *z*.
4. Display *count.*

C. Coding (§1.3): Implementing the design plan in some programming language.

Integration: Combining program units into a complete
software system.

— What language?
— Programs must be correct, readable, and understandable
(therefore, must be well-structured, documented,
written in good style — read guidelines on pp. 15-18)
Why? see page 15

D. Testing, Execution, and Debugging

Validation: checking that the documents, program modules, etc. produced match the customer's requirements.

Verification: checking that products are correct, complete, consistent with each other and with those of the preceding phases.

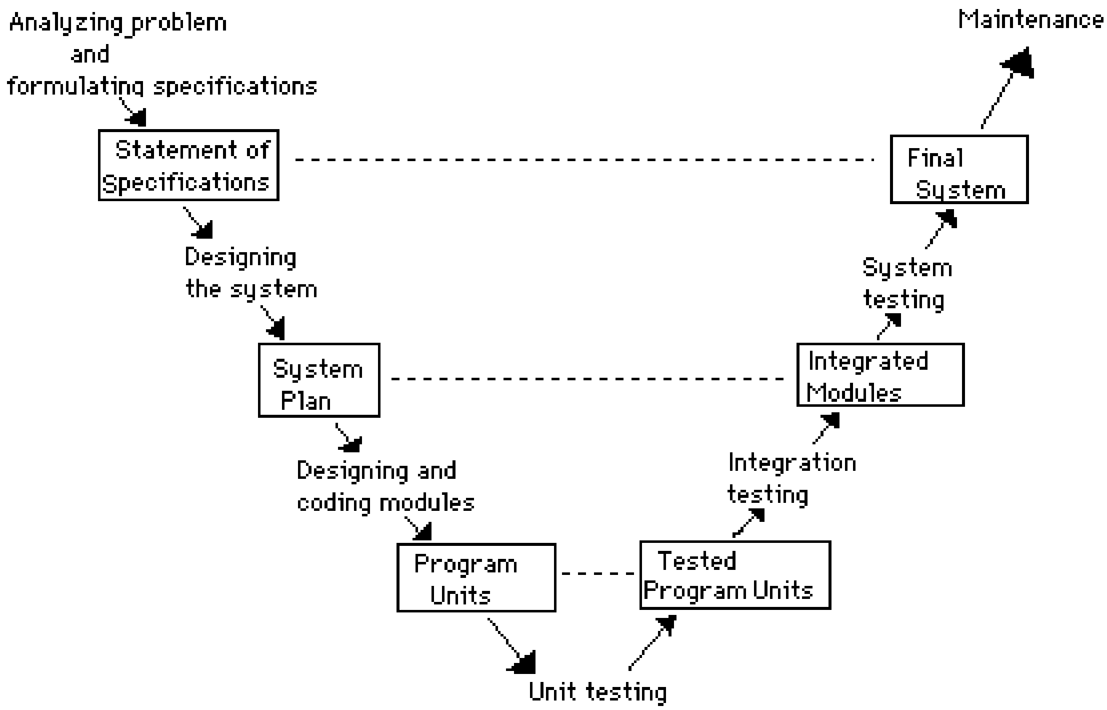
Validation: "Are we building the right product?"

Verification: "Are we building the product right?"

1. Errors may occur in any of the phases:
   — Specifications don't accurately reflect given information or the user's needs/requests
   — Logic errors in algorithms
   — Incorrect coding or integration

2. Different kinds of tests required to detect them:
   Unit tests: Each individual program unit works?
   Integration tests: Units combined correctly?
   System tests: Overall system works correctly?

The "V" Life Cycle Model.



Unit testing:
— probably the most rigourous and time-consuming
— surely the most fundamental and important

3. Kinds of errors
— syntax
— linking
— run-time
— logical

4. Kinds of tests:
— **Black box** or **functional test** : Outputs produced for various inputs are checked for correctness without considering the structure of the module itself. (Program unit is viewed as a black box that accepts inputs and produces outputs, but the inner workings of the box are not visible.)

—**White box** or **structural test**: Performance is tested by examining its internal structure. Test data is carefully selected so that the various parts of the program unit are exercised.

5. Example: Binary search (pp. 19-23)

```
 /* INCORRECT FUNCTION ----------------------------------
 BinarySearch() performs a binary search of a for item.

 Receive:   item and an array a having n items, arranged
            in ascending order
 Pass back: found and mid, where found is true and
            mid is the position of item if the search
            is successful; otherwise found is false.
---------------------------------------------------------*/
void BinarySearch(NumberArray a, int n,  ElementType item,
                  bool & found, int & mid)
{
  int first = 0,     // first and last positions in sublist
      last = n - 1;  // currently being searched *)
  found = false;
  while (first <= last && !found)
  {
    mid = (first  + last ) / 2;
    if item < a[mid]
      last = mid;
    else if item  > a[mid]
      first = mid;
    else
      found = true
  }
}
```

Black box test: Use n = 7 and array a of integers:

a[0] = 45
a[1] = 64
a[2] = 68
a[3] = 77
a[4] = 84
a[5] = 90
a[6] = 96

Test with `item` = 77 returns `found` = true, `mid` = 4
Test with `item` = 90 returns `found` = true, `mid` = 6
Test with `item` = 64 returns `found` = true, `mid` = 2
Test with `item` = 76 returns `found` = false

But, . . ., **must consider special cases**:

e.g., searching at the ends of the list: `item` ≤ 45, `item` ≥ 96

`item` = 45: `found` = true and `mid` = 1 as it should.
`item` = 96: doesn't terminate; must "break" program.

White-box test would also find an error:

e.g., Use `item` < 45 to test a path in which the first condition `item < a[mid]` is always true so first alternative `last = mid;` is always selected.

Use `item` > 96 to test a path in which the second condition `item > a[mid]` is always true so second alternative `first = mid;` is always selected.

6. Techniques to locate error:
— Debugger (Project 1)

— Debug statements (p. 21): e.g.,

```
cerr << "DEBUG:  At top of while loop in BinarySearch()\n"
     << "first = " << first << ", last = " << last
     << ", mid = " << mid << endl;
```

Output:

```
DEBUG:  At top of while loop in BinarySearch()
first = 0, last = 6, mid = 3
DEBUG:  At top of while loop in BinarySearch()
first = 3, last = 6, mid = 4
DEBUG:  At top of while loop in BinarySearch()
first = 4, last = 6, mid = 5
DEBUG:  At top of while loop in BinarySearch()
first = 5, last = 6, mid = 5
DEBUG:  At top of while loop in BinarySearch()
first = 5, last = 6, mid = 5
DEBUG:  At top of while loop in BinarySearch()
first = 5, last = 6, mid = 5
        :
        :
```

— Trace tables (p. 22 & Lab 1A)

— *Quick-and-dirty patches are bad!* (p. 23)

E. Maintenance — pp. 23-24

— Large % of computer center budgets
— Large % of programmer's time

Why? Poor structure, poor documentation, poor style.