Chapter 9
Software Evolution

Lecture-I

- Evolution processes
  - Change processes for software systems
- Program evolution dynamics
  - Understanding software evolution

Lecture-II

- Software maintenance
  - Making changes to operational software systems
- Legacy system management
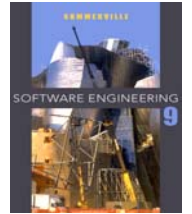 - Making decisions about software change

Chapter-9
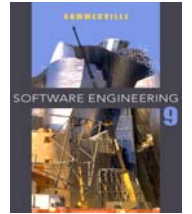
- Lecture-1
  - SOFTWARE EVOLUTION

Topics covered

- **Evolution processes**
  - Change processes for software systems

- **Program evolution dynamics**
  - Understanding software evolution

- **Software maintenance**
  - Making changes to operational software systems

- **Legacy system management**
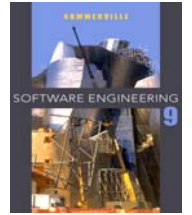 - Making decisions about software change

Software Change (1/2)

- Software change is inevitable
  - New requirements emerge when the software is used;
  - The business environment changes;
  - Errors must be repaired;
  - New computers and equipment is added to the system;
  - The performance or reliability of the system may have to be improved.

- A key problem for all organizations is implementing and managing change to their existing software systems.

Software Change (2/2)

- ## Software change is inevitable

REASONS

New equipment (computers, infrastructure)

Improved performance

New requirements

Business environment

Removal of existing errors/bugs

A key problem for all organizations is implementing and managing change to their existing software systems
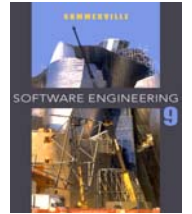
Importance of evolution

- Organizations have huge investments in their software systems - they are critical business assets.

- To maintain the value of these assets to the business, they must be changed and updated.

- The majority of the software budget in large companies is devoted to changing and evolving existing software rather than developing new software.
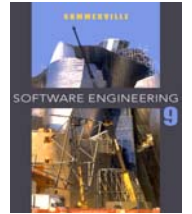
Importance of evolution

- Organizations have enough investment in their software systems

Huge Investment in IT systems

Maintenance

- The majority of the software budget in large companies is devoted to changing and evolving existing software rather than developing new software

Spiral model of development and evolution
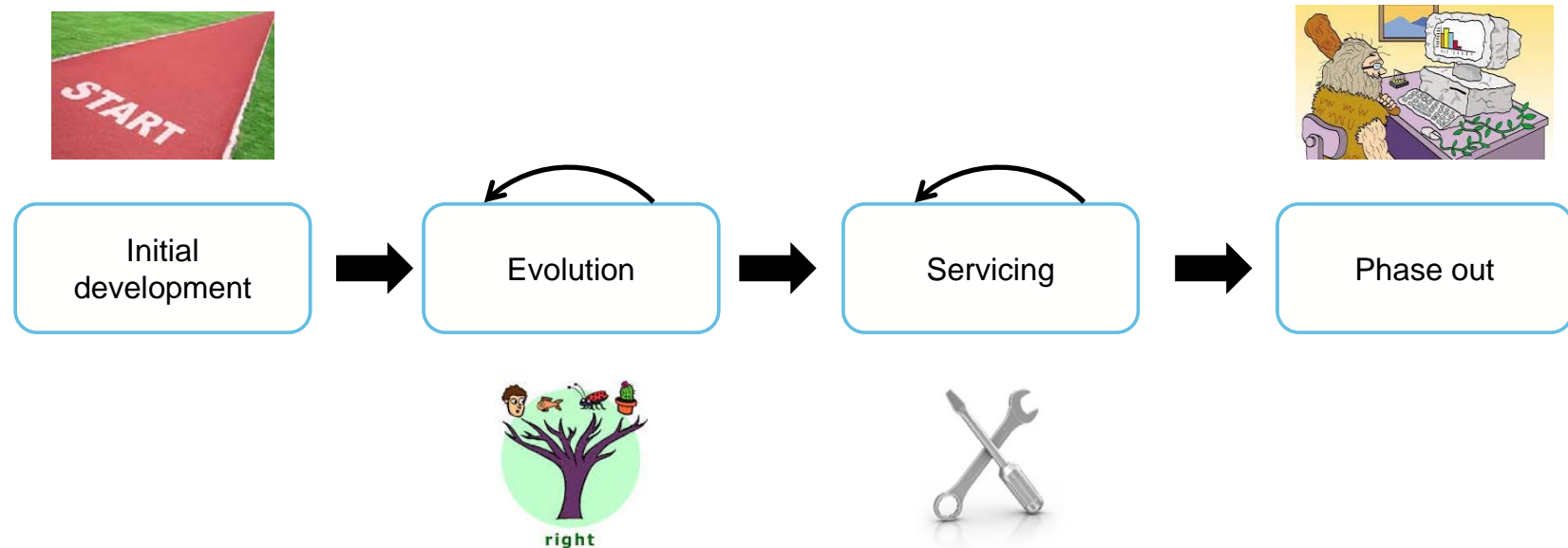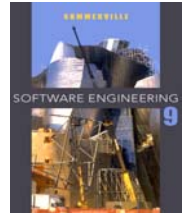
Validation

Implementation

etc..

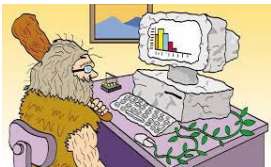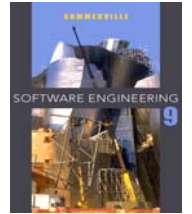start

Release 1

Release 2

Release 3
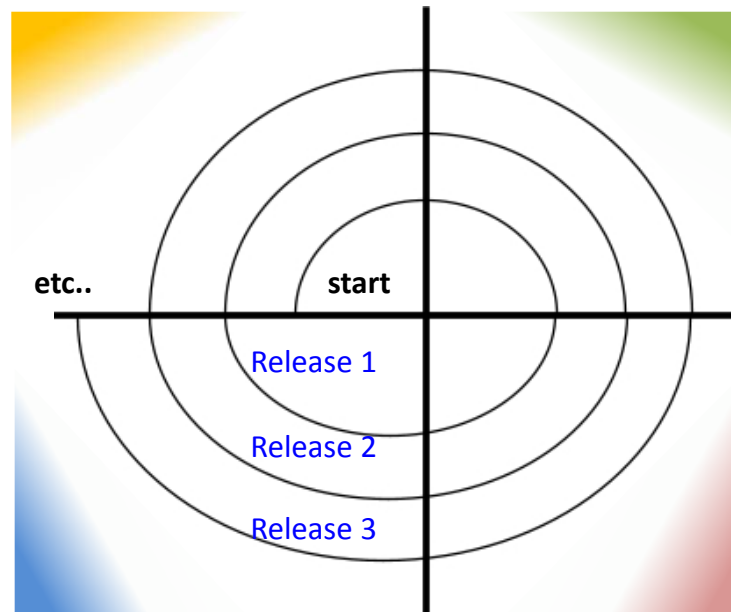
Validation

Validation

Evolution and Servicing

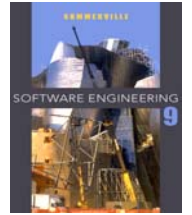Initial development → Evolution → Servicing → Phase out

Evolution and Servicing

- Evolution
  - The stage in a software system's life cycle where it is in operational use and is evolving as new requirements are proposed and implemented in the system.

- Servicing
  - At this stage, the software remains useful but the only changes made are those required to keep it operational i.e. bug fixes and changes to reflect changes in the software's environment. No new functionality is added.

- Phase-out
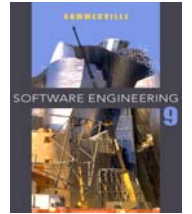 - The software may still be used but no further changes are made to it.
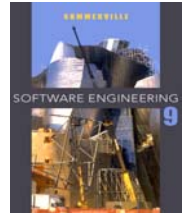
Evolution processes

- Software processes depend on

  - The type of software being maintained;

  - The development processes used;

  - The skills and experience of the people involved

- Proposals for change are the driver for system evolution

  - Should be linked with components that are affected by the change, thus allowing the cost and impact of the change to be estimated

- Change identification and evolution continues throughout the system lifetime
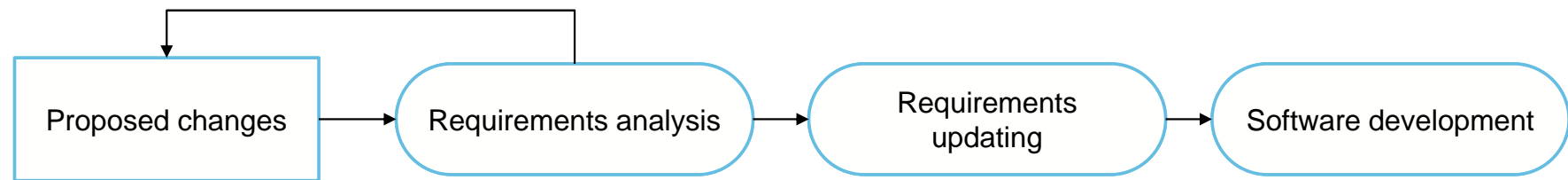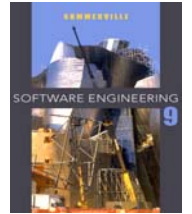
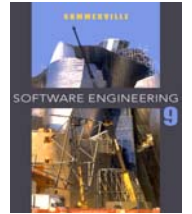# Change Identification and evolution process
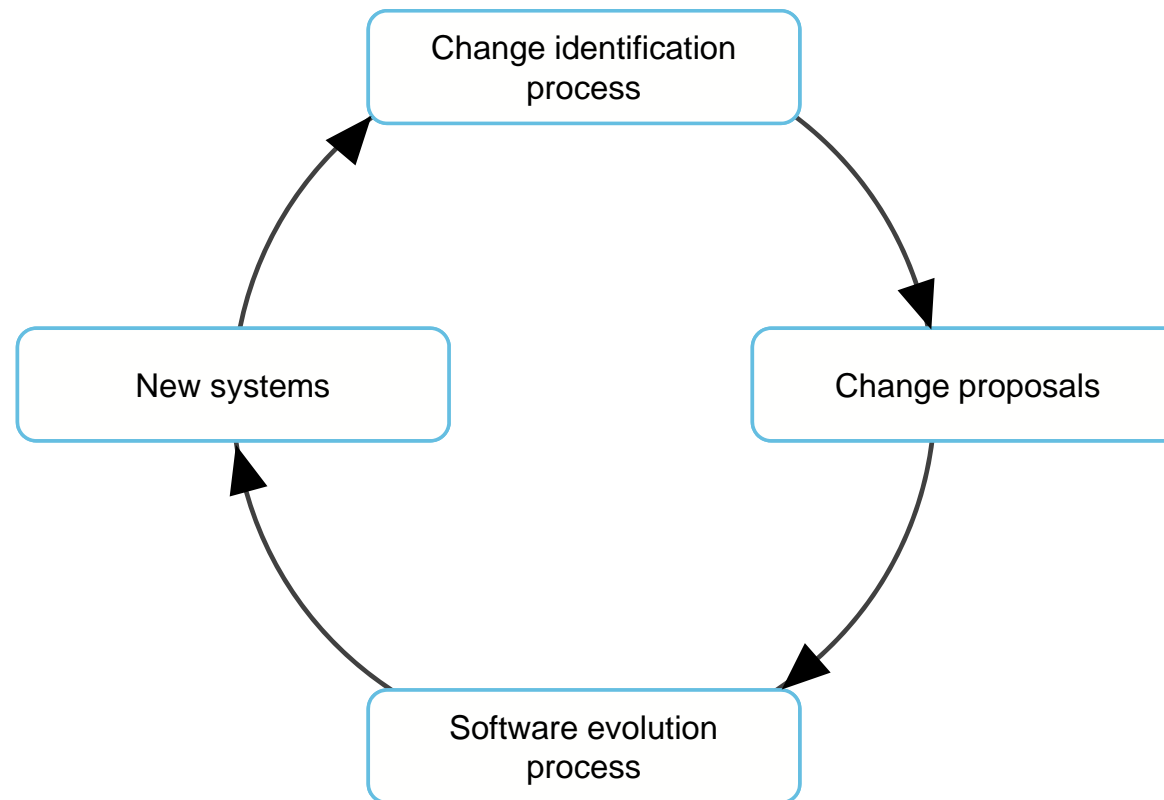
Software evolution process
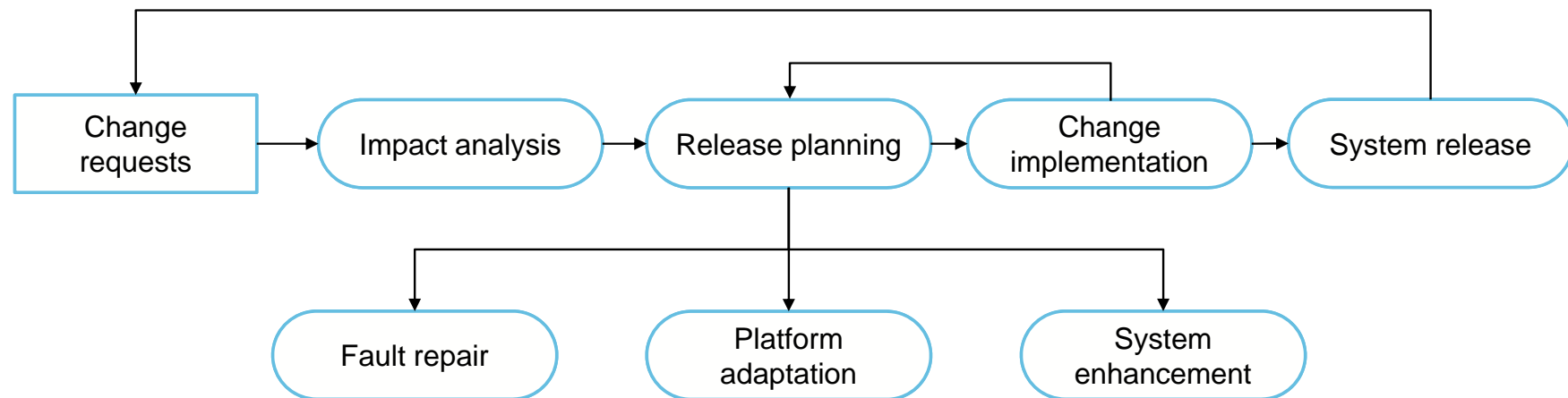
Change Implementation

Change Implementation

- Iteration of the development process where the revisions to the system are designed, implemented and tested.

- A critical difference is that the first stage of change implementation may involve program understanding, especially if the original system developers are not responsible for the change implementation.

- During the program understanding phase, you have to understand how the program is structured, how it delivers functionality and how the proposed change might affect the program.

Urgent Change requests

- Urgent changes may have to be implemented without going through all the stages of the software engineering process

  - If a serious system fault has to be repaired to allow normal operation to continue;

  - If changes to the system's environment (e.g. an OS upgrade) have unexpected effects;

  - If there are business changes that require a very rapid response (e.g. the release of a competing product).
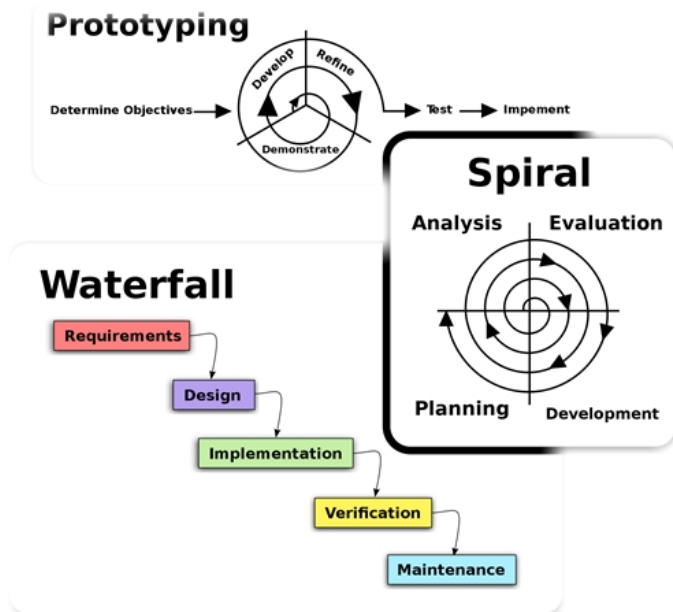
The emergency repair process
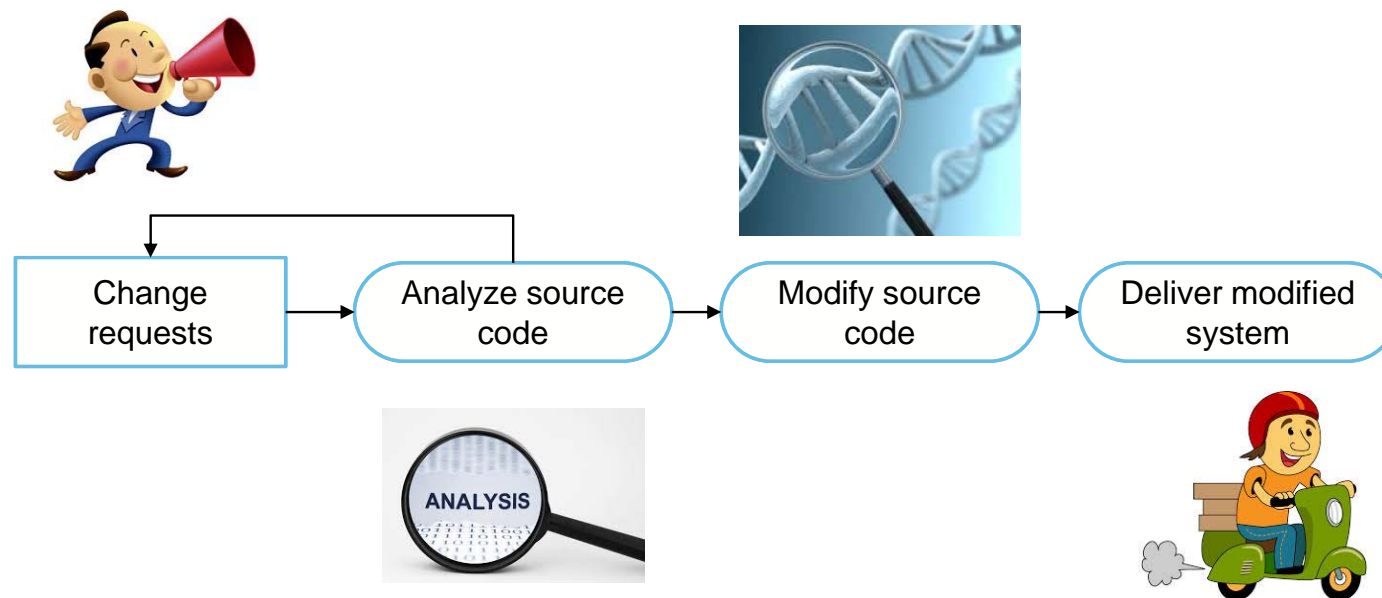
Agile methods and evolution

Waterfall

Agile

- Successful
- Challenged
- Failed
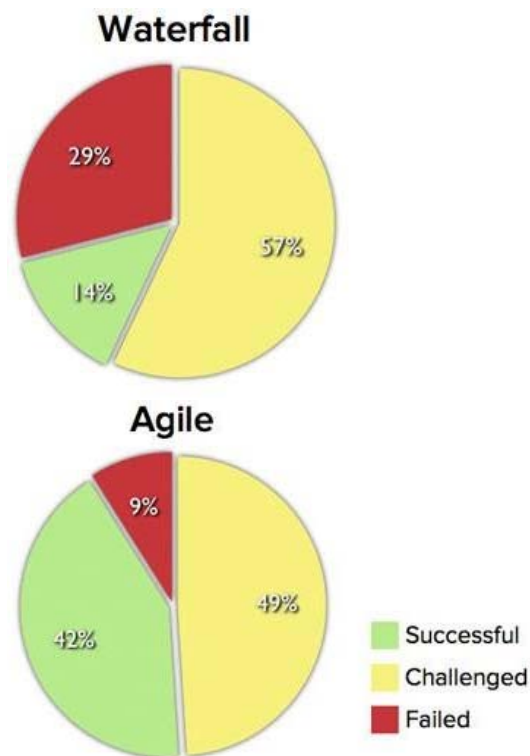
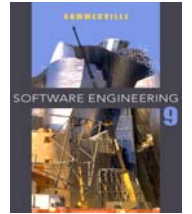- Agile methods are based on incremental development so the transition from development to evolution is a seamless one.

  - Evolution is simply a continuation of the development process based on frequent system releases.

- Automated regression testing is particularly valuable when changes are made to a system.

- Changes may be expressed as additional user stories

Agile Programing

 (3:11)

Handover problems in agile SE

- Where the development team have used an agile approach but the evolution team is unfamiliar with agile methods and prefer a plan-based approach.
  - The evolution team may expect detailed documentation to support evolution and this is not produced in agile processes.
- Where a plan-based approach has been used for development but the evolution team prefer to use agile methods.
  - The evolution team may have to start from scratch developing automated tests and the code in the system may not have been refactored and simplified as is expected in agile development.

Programming evolution dynamics

- *Program evolution dynamics* is the study of the processes of system change.

- After several major empirical studies, Lehman and Belady proposed that there were a number of 'laws' which applied to all systems as they evolved.

- There are sensible observations rather than laws. They are applicable to large systems developed by large organisations.

  - It is not clear if these are applicable to other types of software system.

Change is inevitable

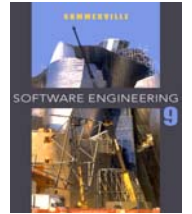- The system requirements are likely to change while the system is being developed because the environment is changing. Therefore a delivered system won't meet its requirements!

- Systems are tightly coupled with their environment. When a system is installed in an environment it changes that environment and therefore changes the system requirements.

- Systems MUST be changed if they are to remain useful in an environment.
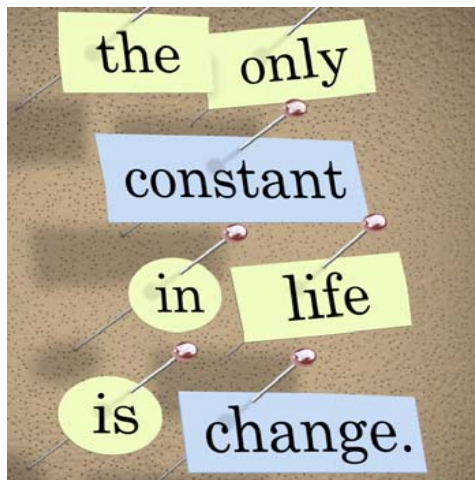
Lehman's laws

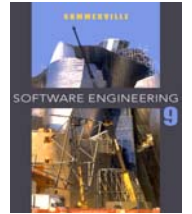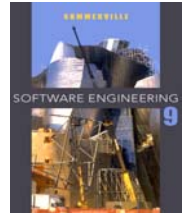| Law	Description
Continuing change	A program that is used in a real-world environment must necessarily change, or else become progressively less useful in that environment.
Increasing complexity	As an evolving program changes, its structure tends to become more complex. Extra resources must be devoted to preserving and simplifying the structure.
Large program evolution	Program evolution is a self-regulating process. System attributes such as size, time between releases, and the number of reported errors is approximately invariant for each system release.
Organizational stability	Over a program's lifetime, its rate of development is approximately constant and independent of the resources devoted to system development.

Lehman's laws

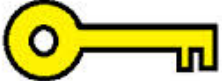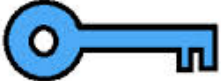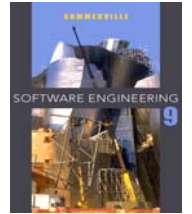| Law	Description
Conservation of familiarity	Over the lifetime of a system, the incremental change in each release is approximately constant.
Continuing growth	The functionality offered by systems has to continually increase to maintain user satisfaction.
Declining quality	The quality of systems will decline unless they are modified to reflect changes in their operational environment.
Feedback system	Evolution processes incorporate multiagent, multiloop feedback systems and you have to treat them as feedback systems to achieve significant product improvement.

Applicability of Lehman's Law

- Lehman's laws seem to be generally applicable to large, tailored systems developed by large organisations.

  - Confirmed in early 2000's by work by Lehman on the FEAST project.

- It is not clear how they should be modified for

  - Shrink-wrapped software products;

  - Systems that incorporate a significant number of COTS components;

  - Small organisations;
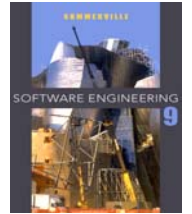
  - Medium sized systems.

Key points

- Software development and evolution can be thought of as an integrated, iterative process that can be represented using a spiral model.

- For custom systems, the costs of software maintenance usually exceed the software development costs.

- The process of software evolution is driven by requests for changes and includes change impact analysis, release planning and change implementation.

- Lehman's laws, such as the notion that change is continuous, describe a number of insights derived from long-term studies of system evolution.
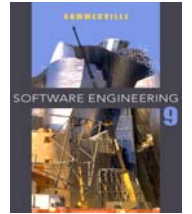
Lecture 2

SOFTWARE EVOLUTION

Software maintenance

- Modifying a program after it has been put into use.

- The term is mostly used for changing custom software. Generic software products are said to evolve to create new versions.

- Maintenance does not normally involve major changes to the system's architecture.

- Changes are implemented by modifying existing components and adding new components to the system.

Post use modification

Customized software

Maintenance

Versioning

Generic software
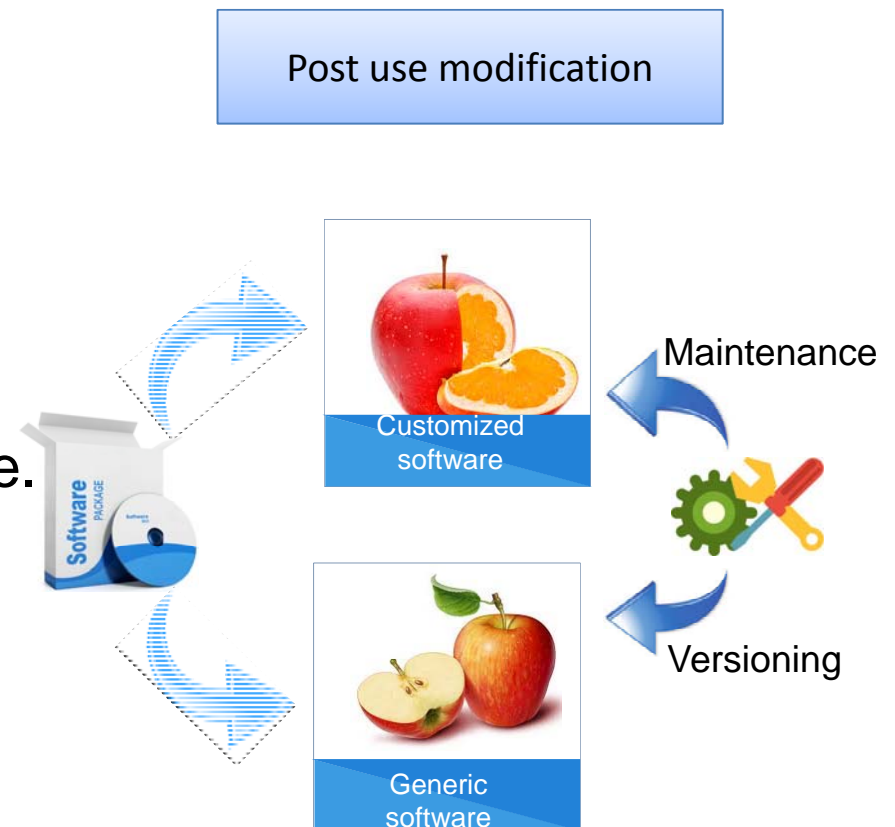
Types of Maintenance

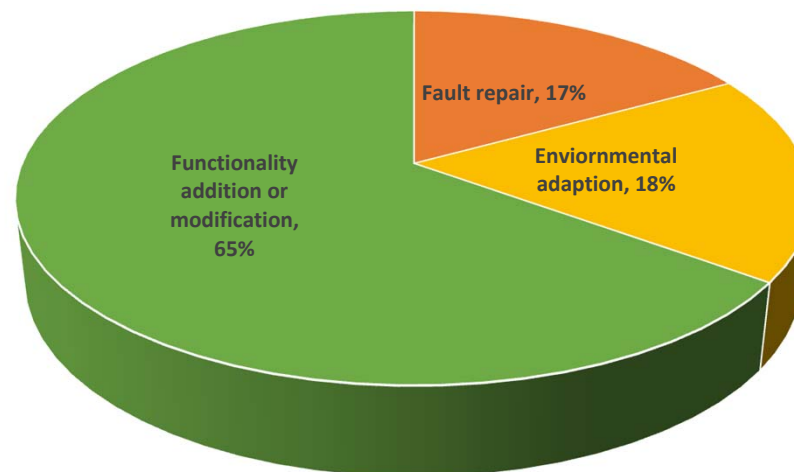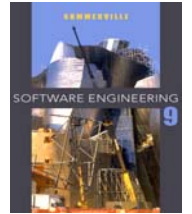| Maintenance of..		
Software Faults	**Software Adaption**	**Changing OS**
Changing a system to correct deficiencies in the way meets its requirements.	Modifying the system to satisfy new requirements	Changing a system so that it operates in a different environment (computer, OS, etc.) from its initial implementation

Maintenance effort distribution (Figure 9.8)

- Fault repair
- Enviornmental adaption
- Functionality addition or modification

Maintenance costs

Development   **Maintenance**

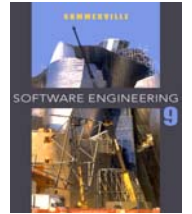Maintenance $ $ \overset{2\%-100\%}{>} $ Development $
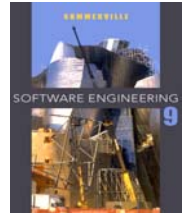
Maintenance $ increases because…

- Affected by both technical and non-technical factors.
- Maintenance corrupts the software structure so makes further maintenance more difficult.
- Ageing software can have high support costs (e.g. old languages, compilers etc.).

Figure 9.9 Development and maintenance costs

Maintenance Cost Factors

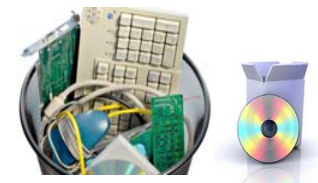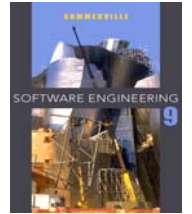| Maintenance Cost Factors			
Team Stability	**Contractual responsibility**	**Staff skills**	**Program age and structure**
Maintenance costs are reduced if the same staff are involved with them for some time.	The developers of a system may have no contractual responsibility for maintenance so there is no incentive to design for future change.	Maintenance staff are often inexperienced and have limited domain knowledge.	Maintenance staff are often inexperienced and have limited domain knowledge.

Maintenance prediction

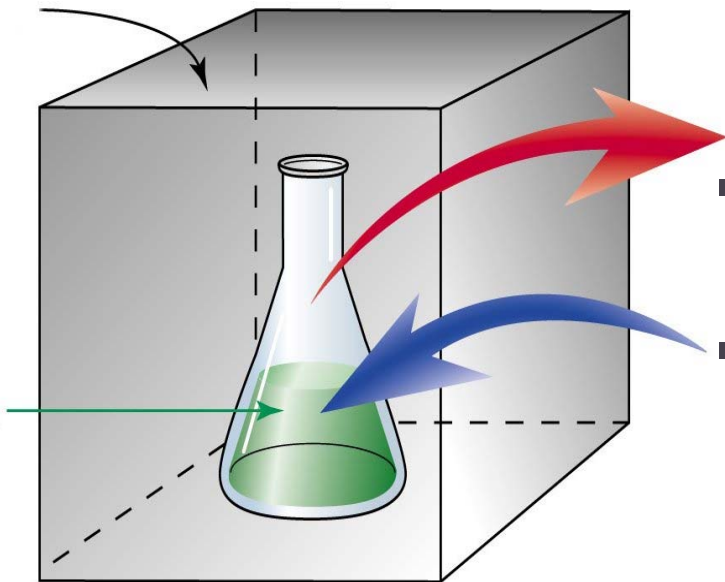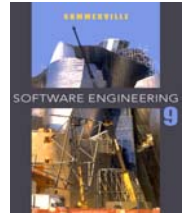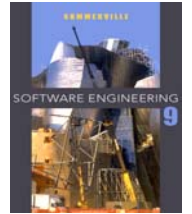- Maintenance prediction is concerned with assessing which parts of the system may cause problems and have high maintenance costs

  - Change acceptance depends on the maintainability of the components affected by the change;

  - Implementing changes degrades the system and reduces its maintainability;

  - Maintenance costs depend on the number of changes and costs of change depend on maintainability.

Maintenance prediction

Predicting

Maintenance cost
- What will be the costs of maintaining this system over the next year
- What will be the lifetime maintenance costs of this system?

Maintainability
- What parts of system will be most expensive to maintain?

System Change
- What parts of the system are most likely to be affected by change requests?
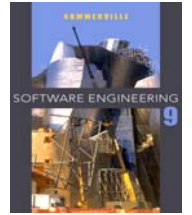- How many change request can be expected?
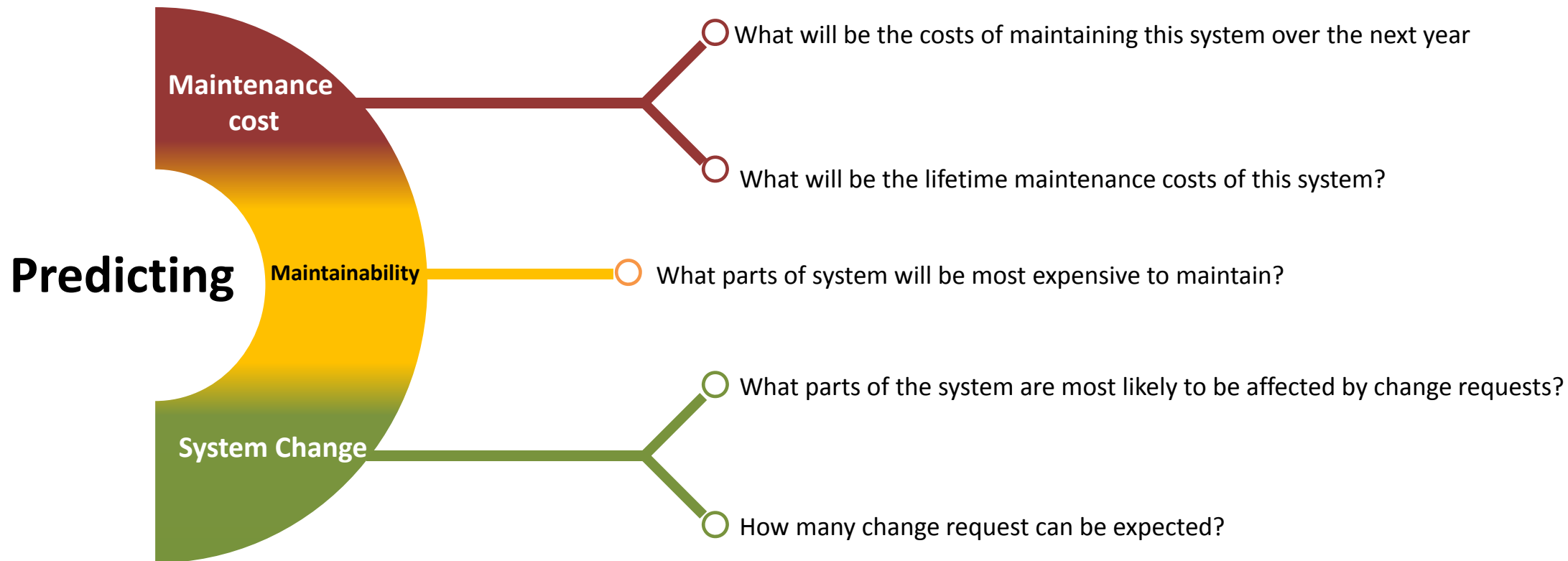
Change prediction

- Predicting the number of changes requires and understanding of the relationships between a system and its environment.

- Tightly coupled systems require changes whenever the environment is changed.

- Factors influencing this relationship are

  - Number and complexity of system interfaces;

  - Number of inherently volatile system requirements;

  - The business processes where the system is used.
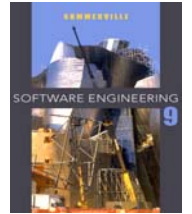
Complexity metrics (1/2)

- Predictions of maintainability can be made by assessing the complexity of system components.

- Studies have shown that most maintenance effort is spent on a relatively small number of system components.

- Complexity depends on
  - Complexity of control structures;
  - Complexity of data structures;
  - Object, method (procedure) and module size.
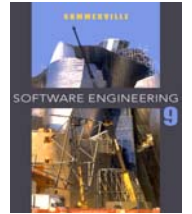
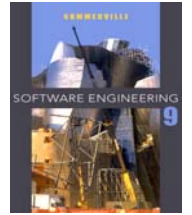# Complexity metrics (2/2)

COMPLEXITY

Depends on…

- Control structures;
- Data structures;
- Object, method (procedure) and module size.

Process metrics

- Process metrics may be used to assess maintainability

  - Number of requests for corrective maintenance;

  - Average time required for impact analysis;

  - Average time taken to implement a change request;

  - Number of outstanding change requests.

- If any or all of these is increasing, this may indicate a decline in maintainability.
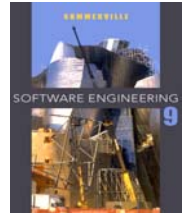
System re-engineering

- Re-structuring or re-writing part or all of a legacy system without changing its functionality

- Applicable where some but not all sub-systems of a larger system require frequent maintenance.
- Re-engineering involves adding effort to make them easier to maintain. The system may be re-structured and re-documented
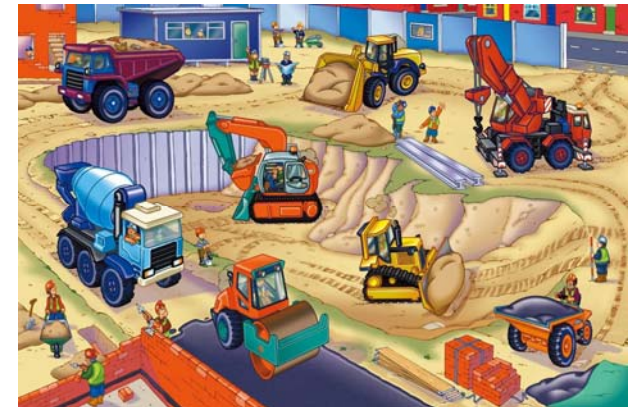
Advantages of reengineering

**Modifications/
Reengineering**

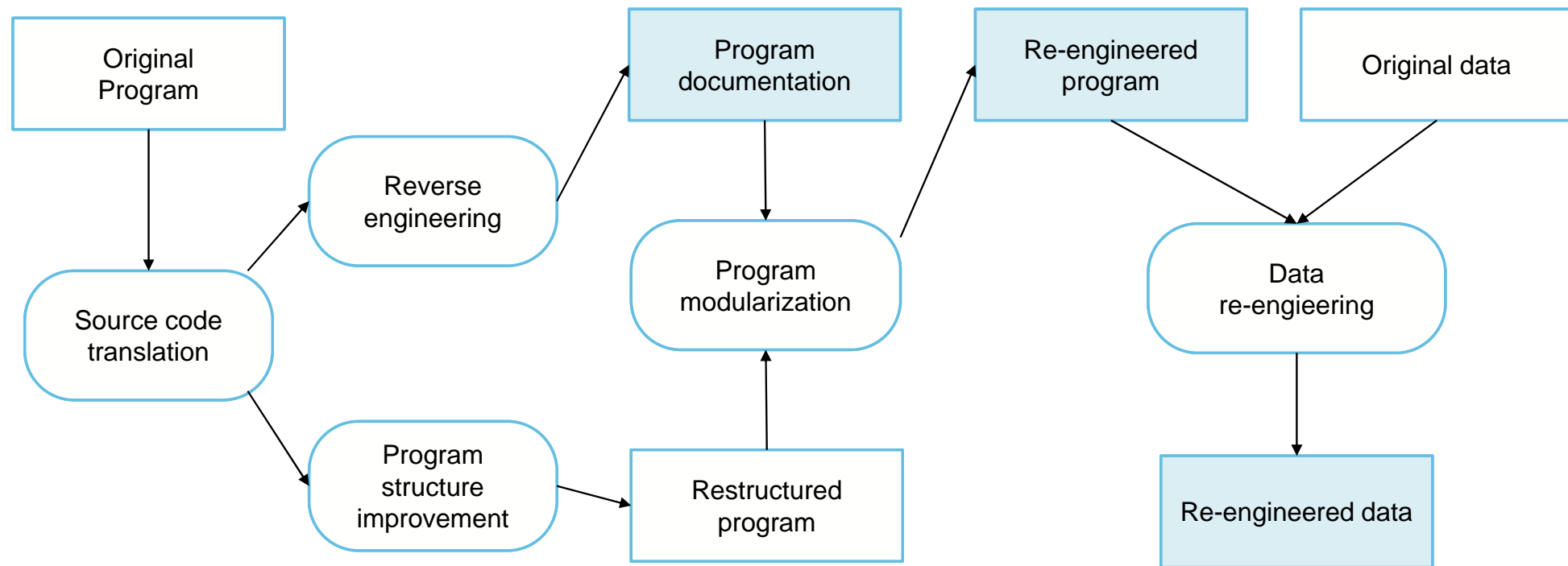**New Development**

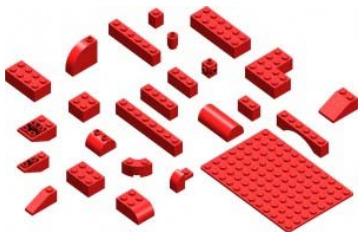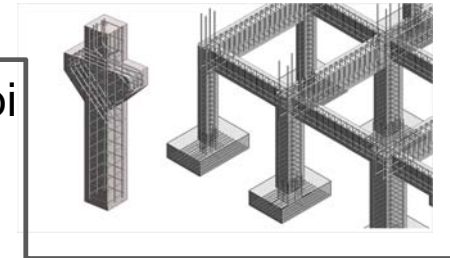|		
Low	Development risk	High
Low	Development problems	High
No	Staff problems	Yes
Few	Specification issues	Many
Low	Engineering cost	High

The reengineering process

Reengineering process activities

- Source code translation
  - Convert code to a new language.
- Reverse engineering
  - Analyze the program to understand it
- Program structure improvement
  - Restructure automatically for understandabi
- Program modularization
  - Reorganize the program structure;
- Data reengineering
  - Clean-up and restructure system data.

Reengineering approaches (Figure 9.12)

Automated Source code conversion

Automated Program reconstructing

Automated restructuring with manual changes

Program and data restructuring

Restructuring plus architecture changes

Increased cost
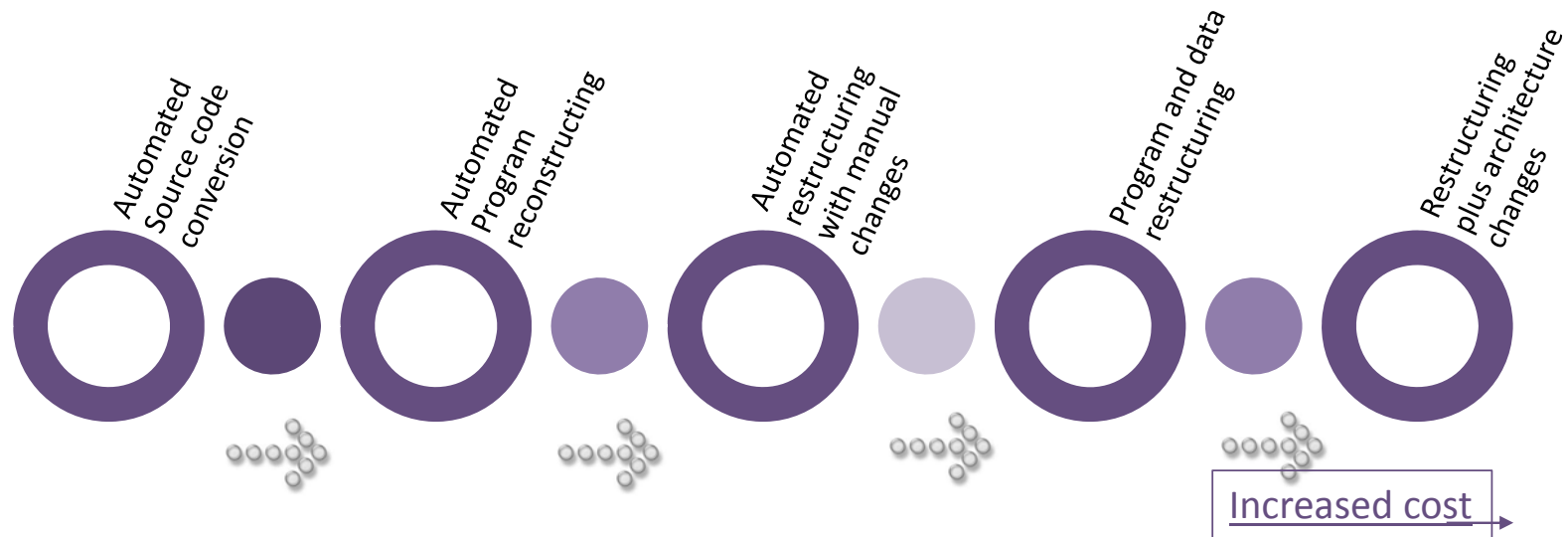
Reengineering cost factors (1/2)

- The quality of the software to be reengineered.
- The tool support available for reengineering.
- The extent of the data conversion which is required.
- The availability of expert staff for reengineering.
  - This can be a problem with old systems based on technology that is no longer widely used.

Reengineering cost factors (2/2)

Expert Staff

Data conversion

Tool Support

Software Quality
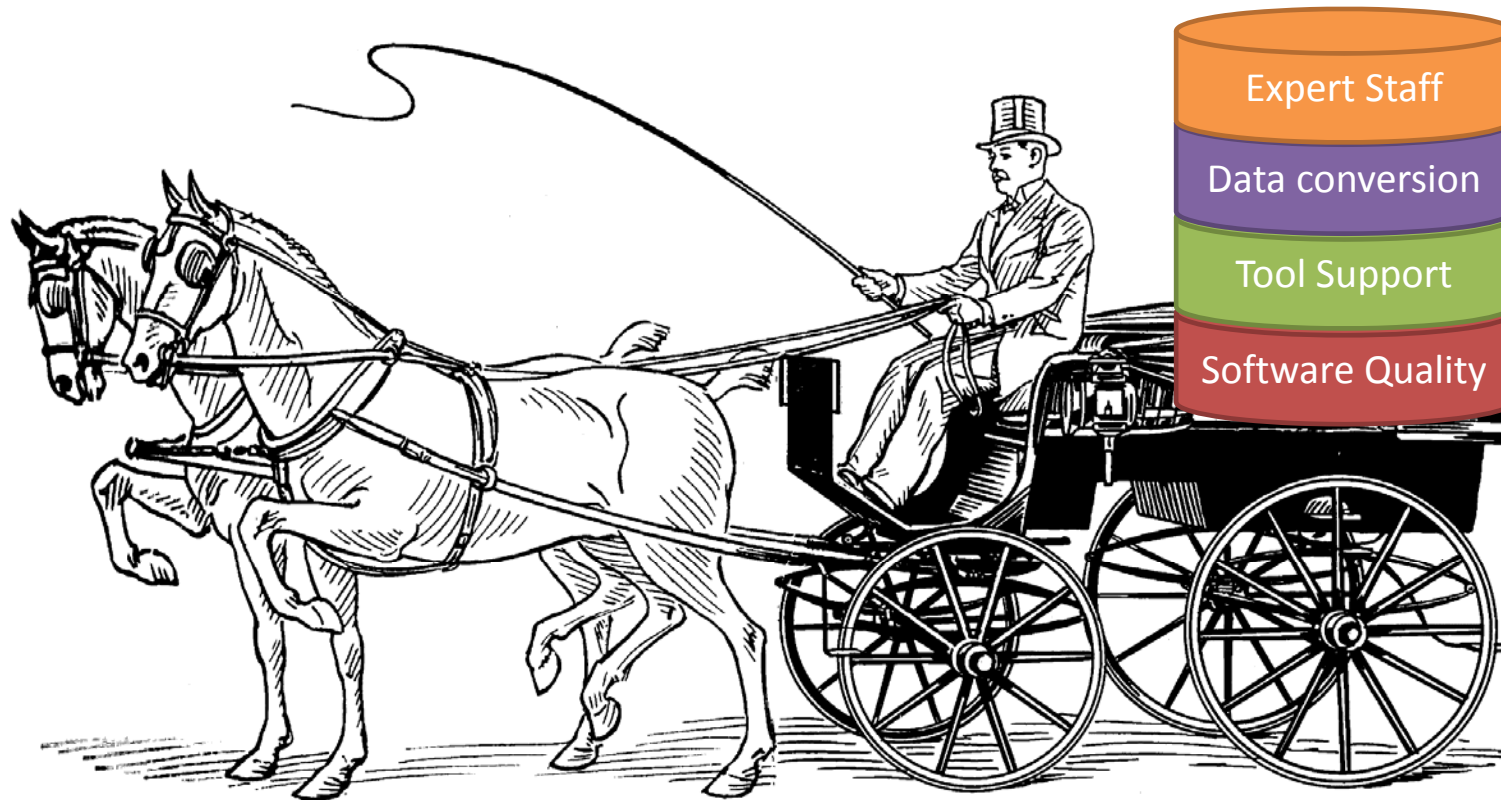
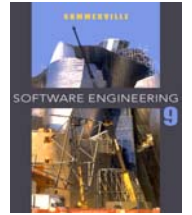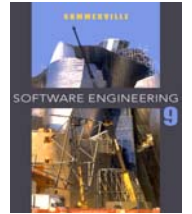# Preventative maintenance by refactoring

- Refactoring is
  - slowing down program degradation by making improvements
  - 'preventative maintenance' that reduces the problems of future change.
  - modifying a program to improve its structure, reduce its complexity or make it easier to understand.
  - improvement in existing program without adding extra functions.

Refactoring and Reengineering

- Re-engineering takes place after a system has been maintained for some time and maintenance costs are increasing. You use automated tools to process and re-engineer a legacy system to create a new system that is more maintainable.

- Refactoring is a continuous process of improvement throughout the development and evolution process. It is intended to avoid the structure and code degradation that increases the costs and difficulties of maintaining a system.

Refactoring and Reengineering (2/2)
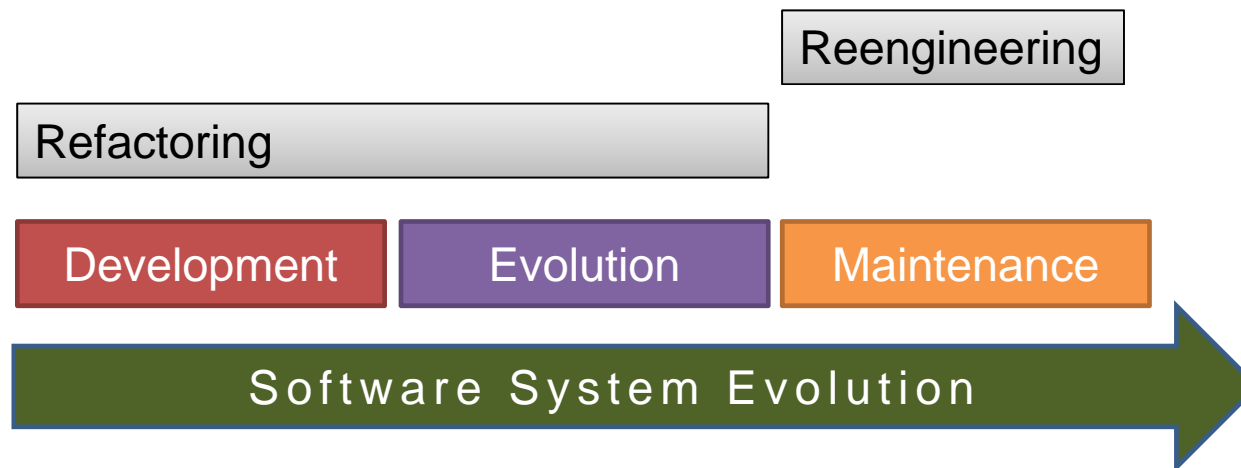
'Bad smells' in program code (1/3)

- Duplicate code
  - The same or very similar code may be included at different places in a program. This can be removed and implemented as a single method or function that is called as required.

- Long methods
  - If a method is too long, it should be redesigned as a number of shorter methods.

- Switch (case) statements
  - These often involve duplication, where the switch depends on the type of a value. The switch statements may be scattered around a program. In object-oriented languages, you can often use polymorphism to achieve the same thing.

'Bad smells' in program code (2/3)

Duplicate Code
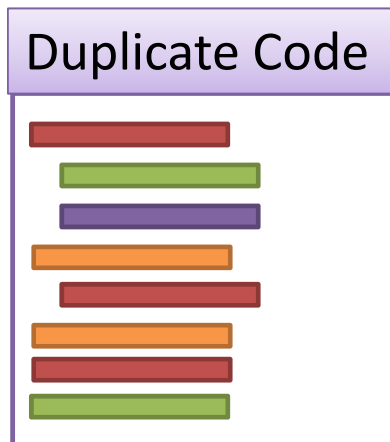
Use functions to avoid code replication

Long Methods
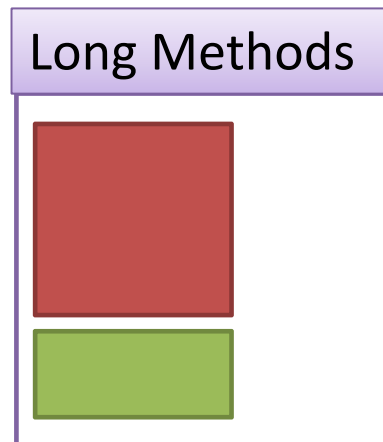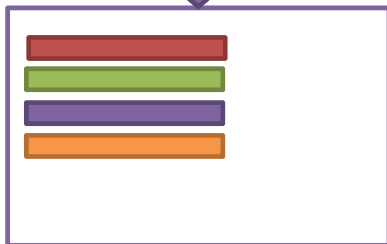
Break long functions into smaller ones
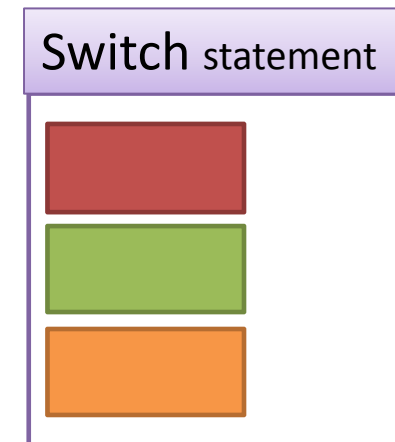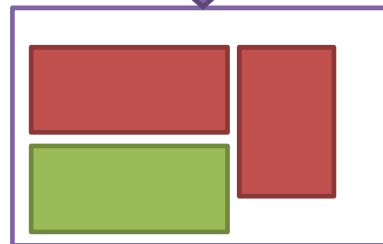
Switch statement

Use polymorphism instead of switch statement

'Bad smells' in program code (3/3)

Data Clumping
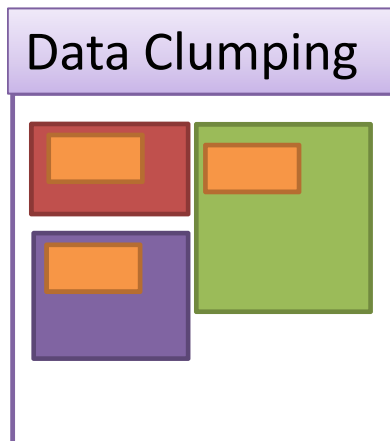
Use encapsulation for same group of data items

Speculative Generality
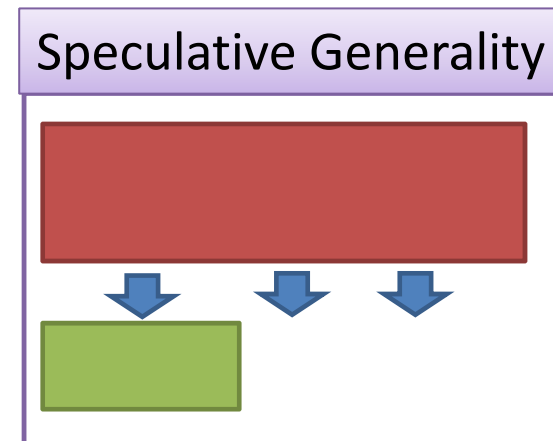
Avoid unnecessary generality

Legacy system management

Organisations that rely on legacy systems must choose a strategy for evolving these systems

- Scrap the system completely and modify business processes so that it is no longer required;
- Continue maintaining the system;
- Transform the system by re-engineering to improve its maintainability;
- Replace the system with a new system.

The strategy chosen should depend on the system quality and its business value.

An example of a legacy system assessment
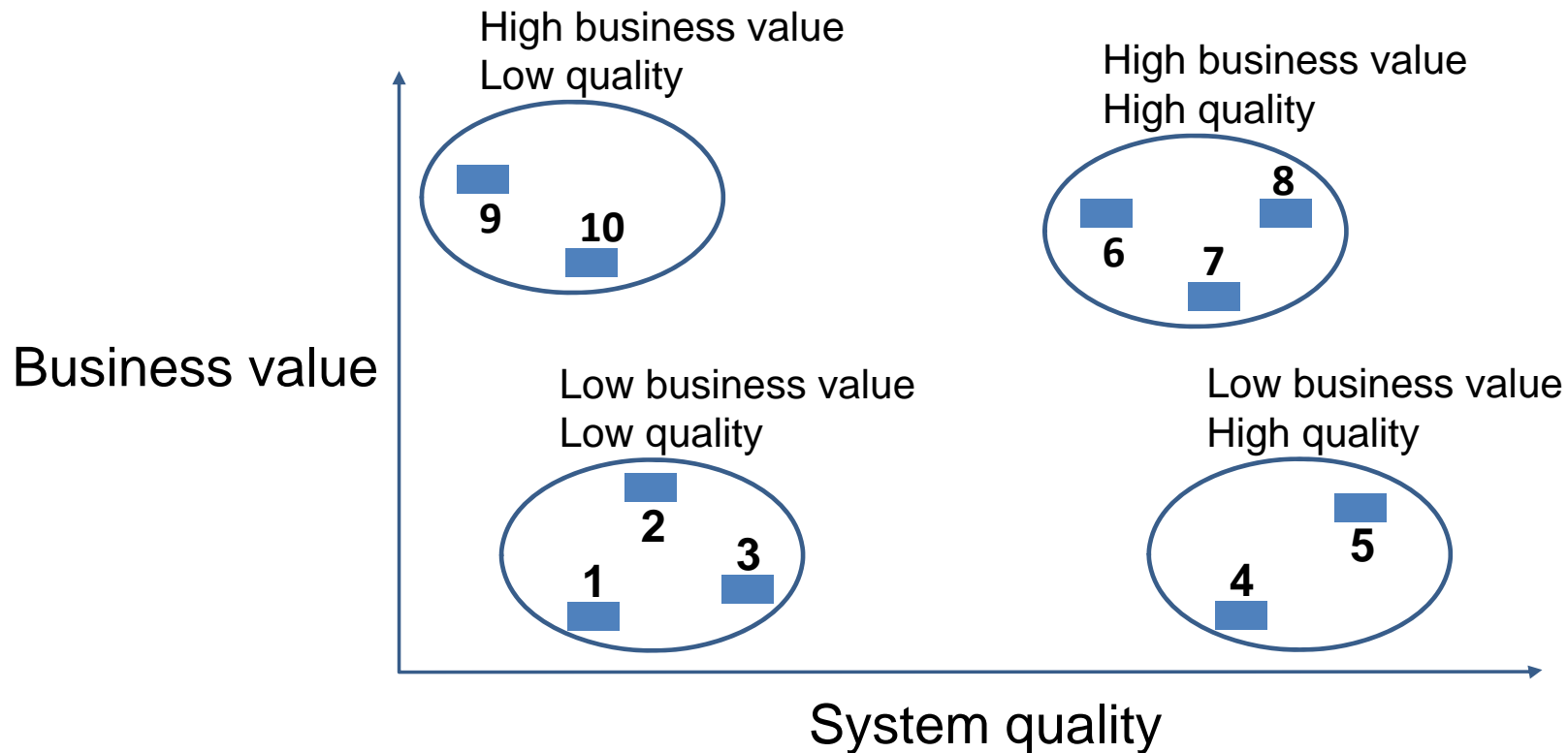
Legacy system categories

Sno	System Quality	Business Value	Recommendation
1	Low	Low	System should be scraped
2	Low	High	Should be Re-engineered or replaced if suitable system is available
3	High	Low	Replace with COTS, scrap completely or maintain
4	High	High	Continue in operation using normal system maintenance

Business value assessment

- Assessment should take different viewpoints into account

  - System end-users;
  - Business customers;
  - Line managers;
  - IT managers;
  - Senior managers.

- Interview different stakeholders and collate results.

Issues in business value assessment

- The use of the system
  - If systems are only used occasionally or by a small number of people, they may have a low business value.

- The business processes that are supported
  - A system may have a low business value if it forces the use of inefficient business processes.

- System dependability
  - If a system is not dependable and the problems directly affect business customers, the system has a low business value.

- The system outputs
  - If the business depends on system outputs, then the system has a high business value.

System quality assessment

- **Business process assessment**
  - How well does the business process support the current goals of the business?

- **Environment assessment**
  - How effective is the system's environment and how expensive is it to maintain?

- **Application assessment**
  - What is the quality of the application software system?

Business process assessment

- Use a viewpoint-oriented approach and seek answers from system stakeholders
  - Is there a defined process model and is it followed?
  - Do different parts of the organisation use different processes for the same function?
  - How has the process been adapted?
  - What are the relationships with other business processes and are these necessary?
  - Is the process effectively supported by the legacy application software?
- Example - a travel ordering system may have a low business value because of the widespread use of web-based ordering.
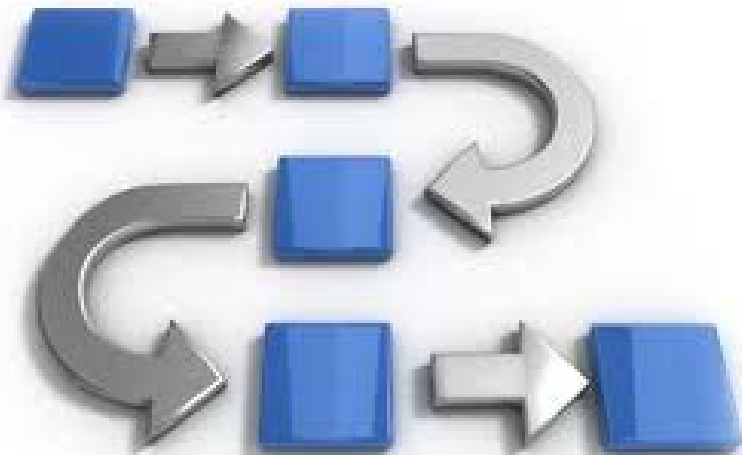
Factors used in environment assessment

Factor	Questions
Supplier stability	Is the supplier still in existence? Is the supplier financially stable and likely to continue in existence? If the supplier is no longer in business, does someone else maintain the systems?
Failure rate	Does the hardware have a high rate of reported failures? Does the support software crash and force system restarts?
Age	How old is the hardware and software? The older the hardware and support software, the more obsolete it will be. It may still function correctly but there could be significant economic and business benefits to moving to a more modern system.
Performance	Is the performance of the system adequate? Do performance problems have a significant effect on system users?

Factors used in environment assessment

Factor	Questions
Support requirements	What local support is required by the hardware and software? If there are high costs associated with this support, it may be worth considering system replacement.
Maintenance costs	What are the costs of hardware maintenance and support software licences? Older hardware may have higher maintenance costs than modern systems. Support software may have high annual licensing costs.
Interoperability	Are there problems interfacing the system to other systems? Can compilers, for example, be used with current versions of the operating system? Is hardware emulation required?

Factors used in application assessment

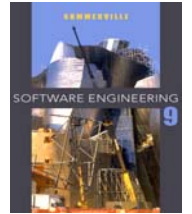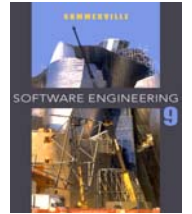| Factor	Questions
Understandability	How difficult is it to understand the source code of the current system? How complex are the control structures that are used? Do variables have meaningful names that reflect their function?
Documentation	What system documentation is available? Is the documentation complete, consistent, and current?
Data	Is there an explicit data model for the system? To what extent is data duplicated across files? Is the data used by the system up to date and consistent?
Performance	Is the performance of the application adequate? Do performance problems have a significant effect on system users?

Factors used in application assessment

Factor	Questions
Programming language	Are modern compilers available for the programming language used to develop the system? Is the programming language still used for new system development?
Configuration management	Are all versions of all parts of the system managed by a configuration management system? Is there an explicit description of the versions of components that are used in the current system?
Test data	Does test data for the system exist? Is there a record of regression tests carried out when new features have been added to the system?
Personnel skills	Are there people available who have the skills to maintain the application? Are there people available who have experience with the system?

System measurement

Quality assessment of application system by collecting data from …

1

Number of
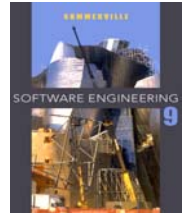system change requests

2

Number of
Interfaces used
by the system

3

Volume of data
Used by system

Key points

3 types of software maintenance	• Bug fixing • Software modification • Implementing changed requirements

Software Re-engineering	• Concerned with
	    • Re-structuring
	    • Re-documenting

Re-factoring	• System improvements with preserved functionalities
Business Value	• Decision about legacy system based on its function and maintenance

References

- http://www.designingprojectmanagement.com/SoftwareProcessModels.html
- http://www.csse.monash.edu.au/~jonmc/CSE2305/Topics/07.13.SWEng1/html/text.html
- http://slideplayer.us/slide/684196/
- http://ifitistobeitisupto.us/ifitistobeitisupto.us.htm (agile development) http://www.maori.geek.nz/post/waterfall_to_agile_an_introduction_to_the_waterfall_scrum_and_kanban_software_method_ologies (history)