Objectives:

Upon completion of this module, the student will be able to:

- identify computer component hardware and software
- describe computer hardware and software functions
- discuss the functions of computer hardware and software in radiation oncology

Computer System Components: Introduction

A computer system consists of hardware, software, and networking

- The hardware is any physical component of a computer
- The software is any set of instructions used to operate the computer or perform mathematical operations
- Networking is the linking of all computers

Hardware: System Unit

*System Unit* = the case or box-like housing for the internal hardware devices
Hardware: System Unit

Components in the System Unit:
Hardware: System Unit: Motherboard

Components in the System Unit:

**Mother Board** - the central or primary circuit board of the computer; contains CPU, memory, adapter cards, expansion slots, ports and connectors
Hardware: System Unit: CPU

Components in the System Unit:

**Central Processing Unit (CPU)** – the central electronic chip that determines the processing power of the computer; connected to motherboard; also called processor or microprocessor; executes instructions in program to process data (examples: Intel Pentium, Celeron)

a) control unit – directs and coordinates operations in computer; repeats 4 basic operations

- Fetch – obtain program data from memory
- Decode – translate instruction into commands
- Execute – carry out command
- Store – write result to memory

b) Arithmetic/logic unit (ALU) – performs arithmetic (add, subtract, divide, multiply), comparison (greater than, equal to, or less than), and logical (and, or, not)
CPU also includes a register (temporary storage) and a system clock

**Hardware: System Unit: CPU**

Components in the System Unit:

**Central Processing Unit (CPU) Speed**

- Speed of CPU is measured in hertz

Hertz = one cycle/second

- Need to measure time to determine cycles/second

All computers have clock built in for timing cycles

- Clock located on motherboard

Most computers have CPU in Megahertz (MHz) or Gigahertz (GHz) range

MHz = \(10^6\) hertz

GHz = \(10^9\) hertz

**Hardware: System Unit: CPU**
Hardware: System Unit: Memory

Components in the System Unit:

**Memory** – part of computer that temporarily stores applications and documents; chip reside on motherboard or on circuit board in expansion slot inside system unit; memory measured in bytes and stored in unique address

- 2 types of system unit memory:
  - Volatile – loses contents when computer power is turned off
  - Nonvolatile – does NOT lose contents when computer power is turned off
Memory

a. RAM (random access memory)
   - Volatile
   - More RAM, faster computer operations
   - Memory chips can be read from and written to by processor (can be erased and written over)
   - Keeps instructions and data for current program
   - You can add RAM to your computer, but it's based on the design of the motherboard

b. ROM (read-only memory)
   - Nonvolatile
   - Data can be read; cannot be modified
   - Memory chips contain data, instructions, or information that is recorded permanently
   - Instructions used by CPU

Hardware: System Unit: Memory
Components in the System Unit:
Memory
RAM (random access memory)
Hardware: System Unit: Power Supply
Components in the System Unit:

Power Supply

- Converts AC power into DC power
- Fan keeps system unit components cool
- External peripherals use an AC adapter which is an external power supply

Hardware: System Unit: Hard (disk) Drive
Components in the System Unit:

Hard (disk) drive – primary device for storing computer information
Stores programs, data files, saves files, organizes files

- Located inside system unit
- Magnetically stores data on stacks of rotating disks called platters
- Permanent storage

Hardware: System Unit: Storage Devices
Components in the System Unit:

Other storage devices:

Internal hard drive
- Floppy drive – stores/retrieves information on floppy disk
- CD-ROM drive – reads information on compact disc using later technology
- CD-RW drive – writes information on compact disc using laser technology
- DVD drive – reads data from CDs, DVDs, or DVD movie discs
- Zip drive – removable disk holding large amounts of information

Hardware: System Unit: Storage Devices
Hardware: System Unit: External Drives

Components in the System Unit:

External Drives – not within the system unit, but attached via cables

Examples: external hard drive for additional storage; or DVD/CD-RW external drive for reading and writing DVDs

Hardware: System Unit: Adapter Cards
Components in the System Unit:

**Adapter cards** – placed in expansion slots on motherboard; cards enhance system unit to provide connection to external peripherals

Examples:

- Video card – generate & output images to monitor
- Sound card – facilitates input & output of audio signals to/from computer
- Network interface card – implements circuitry to communicate over computer network; newer computers – this is built directly onto motherboard
- Modem card – converts one form of signal to another which is suitable for transmission over communication circuits; typically digital to analog and then analog to digital

**Hardware: System Unit: Adapter Cards**

Components in the System Unit:

Adapter cards
Hardware: System Unit: Memory Card

Components in the System Unit:

PC/Flash Memory card

- PC cards add memory, storage, sound, fax/modem, communications, and other capabilities to notebook computers
- Flash memory card allows users to transfer data from mobile devices to desktop computers
  i.e. USB flash drives

Hardware: System Unit: Ports & Connectors

Components in the System Unit:

Ports & Connectors

- Ports connect external devices to the system unit
  - Connector joins cables to peripherals; they have male and female gender ends

Types: audio, video, firewire, mouse, network, printer, serial, monitor, speaker, keyboard, microphone

Hardware: System Unit: Ports

Components in the System Unit:

Ports:

a. Serial port – transmits 1 bit of data at a time
   - Connects slow-speed devices, such as mouse, keyboard and modem

b. Parallel port – connects devices that can transfer more than 1 bit at a time, such as a printer

USB port – universal serial bus

- Can connect up to 127 different peripherals together with single connector
- PCs usually have 6-8 USB ports on front or back
- Single USB port can be used to attach multiple peripherals in a daisy chain
Hardware: System Unit: Ports & Connectors

Gemini RJ22 Connector
4 Pin, 4 Connector (RJ45) Plug
(Pin 1 is normally unused but is required to function properly)

Pin 1 (TxD)
Pin 2 (RxD)
Pin 3 (Gnd)
Pin 4 (unused)

DIN-8 Male Connector
For Apple Mac Serial Ports

Pin 1 (TxD)
Pin 2 (RxD)
Pin 3 (Gnd)
Pin 4 (unused)

DB-9 Female Connector
For PC Serial (Comm) Port

Pin 1 (TxD)
Pin 2 (RxD)
Pin 3 (Gnd)
Pin 5 (Gnd)

DB-25 Female Connector
For PC Serial (Comm) Port

Pin 1 (TxD)
Pin 2 (RxD)
Pin 3 (Gnd)
Pin 5 (Gnd)

Hardware: System Unit: Buses

Components in the System Unit:

Buses

- A bus is a channel that allows devices inside the system unit to communicate with each other
• Group of wires or fibers used to transfer data in parallel; bits may be transferred simultaneously along each of several connections

• System bus connects processor & RAM

• Bus width determines # of bits transmitted at one time; word size determines # of bits processor can interpret and execute at one time

• An expansion bus allows processor to communicate with peripherals

• Located on motherboard

Hardware: Mass Storage Devices

Mass Storage Devices

• Programs and data are stored permanently on devices incorporating magnetic or optical encoding

• Common devices: magnetic disks, optical disks, magnetic tape

• Magnetic disks and tapes store data by magnetizing small regions called domains; when domains are oriented together by a magnetic field, their combined magnetic fields become detectable; the domains are grouped in small regions on the disk; information is not lost when power is removed

• Modern digital audio tape (DAT) cassette can hold as much as 8 gigabytes and is useful for making backups of other media or transferring large volumes of data such as digitized medical images; slower but inexpensive

• Forms: flexible or floppy disks which are inexpensive but hold little information are unreliable; hard disks come in fixed and removable formats and hold megabytes to gigabytes

• Information embedded on disks is read with a read/write head that hovers a small distance above the disk; data is stored along tracks and divided into sectors; head moves radially across the disk to access different tracks

• Optical disks (such as compact disks or CD's) are removable glass or plastic disks with a thin coating of metal. To write data to the disk, a laser burns a pattern of holes in the metal coating, and then the pattern can be read by the laser to retrieve the data; WORM drives are "write once, read many" times. Other devices have been developed that allow rewriting of optical disks.
Hardware: Input/Output Devices

**Input/Output devices**

- Devices can send or receive data serially or in parallel by use of sequencing voltage pulses of high or low levels
- Required to enable the operator to enter information into and retrieve information from the computers

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<thead>
<tr>
<th>Device</th>
<th>Input</th>
<th>Output</th>
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<tr>
<td>Keyboard</td>
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<td>Light Pen</td>
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<td>Joystick</td>
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<td>Disk/Tape drive</td>
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<td>Network Interface</td>
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<td>Digital Camera</td>
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**Computer Software**

*Computer software* provides instruction that tells the computer how to operate.

1. Software are also called programs
2. Programs are usually created using other software called programming
Programs—sets of computer instructions in a logical sequence designed to solve problems and feed them into the computer's memory through keyboards and other input devices

Computer Software

If instructions are unclear, or the software has bugs (errors), the output may not be what the user wanted.

The challenge for software developers is to devise instructions that put simple operations together in ways that are useful and appropriate.

Algorithm— a set of step-by-step procedures for accomplishing a task

A programmer's job is to turn an algorithm into a program by adding details, hammering out rough spots, testing procedures, and debugging (correcting errors).

Computer Software

Types of Software:

1. System software
   - Used by computer to accomplish task
   - Controls internal function of the computer
   - Controls other devices connected to the motherboard

2. Application Software
   - Used by people to accomplish a specific task
   - Common application software includes word processor, database, spreadsheet, games, web page browsers

Computer Software

Kinds of Software:

a. Public domain software (more commonly referred to as Open-Source)
   - No copyright
b. Freeware
   - Has copyright, but someone gave rights to use it and make copies
   - Can't be changed

c. Shareware
   - Has copyright
   - Allowed to use software before paying for it
   - Can be demo
   - Can only give exact copies of software
   - Can set time to use software
   - Can't be changed

d. Commercial
   - Has most resistive copyright
   - Must buy software before using it
   - Can usually make a copy as a backup copy
   - Can't change
   - Usually best software in the world

Computer Software: Computer Languages

Computer Languages

*Machine language*—used numeric codes to represent the most basic computer operations

Most programmers use programming languages such as C++, C#, Java, Visual Basic, .NET, FORTRAN, BASIC, SQL

- These are referred to as *high-level languages*

*Compiler*—a translator program that compiles a complete translation of the program in a high-level language before the program runs for the first time

- Can run again and again and doesn't need to be recompiled unless
As translators become more sophisticated, programmers can communicate in computer languages that more closely resemble natural languages (languages people speak and write every day).

**Computer Software: Installation**

**How do you put software into computers?**

1. Built into computer's circuits, the ROM chips
2. Loaded into computer from secondary storage device like floppy or hard disk drive
3. Typed in from keyboard (need programming language)

The system software is built into the computer via ROM chips and BIOS; this helps setup the computer and start it (i.e. Mac OS 9 or Windows 2000)

**Computer Software: Operating System**

**Operating System**

1. Usually located on a disk
   - Can be either on hard disk drive, floppy drive, or CD-ROM disk
   - Must be loaded into RAM before it can be used
2. Used by computer's hardware to work with it's parts
   - Tells computer how to display information on screen, use a printer, or store information on secondary storage devices
   - Controls peripherals through software called *drivers*
3. Works with application software
   - Does basic tasks like printing documents and saving files
   - Starts (launches) application software so it can be used

**Computer Software: User Interfaces**
User Interfaces

This is how the computer's operating system presents the information to the user and the user gives instructions (commands) to the computer.

2 kinds of interfaces:

- Text interface – presents information in form of text
- Graphic User Interface – presents information to use in form of pull down menus and icons

Computer Software: Applications

Application Software

Works with operating system to help you use your computer to do specific types of work such as word processing to type a letter.

Used to solve general problems such as planning, writing, record keeping, calculating, drawing, etc.

Examples: Microsoft Word, Microsoft Excel, FileMaker, Adobe PageMaker, Paint Shop Pro

Computer Software: Utilities

Utilities

Allows you to complete certain tasks on your computer such as file organizations.

- Helps computer work better and avoid problems
- Some built into operating system
- Examples include Anti-virus software, Disk Maintenance Software
- File management
- Security

Computer Software: Market Applications

Vertical-market applications (custom applications)

Applications designed for a particular business or industry.
Examples:
Medical billing, R & V systems, Treatment Planning Systems

These tend to be more expensive due to less people using them

**Computer Software: Multi-user Operating Systems**

**Multi-user Operating Systems**

Due to historical ties to academic and government research sites, the Internet is still heavily populated with people using UNIX operating systems.

**UNIX** enables a timesharing computer to communicate with several other computers or terminals at one time.

- Long been the operating system of choice for workstations and main frames (specifically in research and academic settings)
- Most widely used multiuser operating system today
- Commercial brands of UNIX are available from many companies such as Sun (Solaris), HP, IBM (even MacOSX is built around UNIX version)
- It's a command-line, character-based operating system
- Use in servers and workstations
- Some Treatment Planning Systems are UNIX OS

**Computer Software: Multi-user Operating Systems**

**Multi-user Operating Systems**

**LINUX**

- Open-source software
- Versatile, can be customized
- UNIX fork (meaning LINUX is derived from UNIX)
- Distributed for free and supported without a cost by a savvy group of users
• Use is serves and workstations
• Some Treatment Planning Systems are LINUX OS

**Computer Software: OS Overview**

**Operating System Overview**

PC: Microsoft Windows, Mac OS
Handhelds: Windows CE, Palm OS
Servers: LINUX, UNIX

**Computer Software: Treatment Planning Algorithms**

Correction-based algorithms use parameters of dose measured in a water phantom and correct the data to apply to the patient's specific situation.

Model-based algorithms directly compute the dose to the patient by modeling the beam and its interactions in the patient representation.

Dose computation algorithms for TPS's utilize a balance between speed and accuracy; more accurate algorithms (such as convolution/superposition and Monte Carlo) are becoming commonplace with modern computing systems.

ICRU has divided **PHOTON BEAM CALCULATION** methods into four classifications:

1. analytical
2. matrix
3. semiempirical
4. three-dimensional integration

**Computer Software: Treatment Planning Algorithms**

**Analytical**

• uses one equation for depth dose and one for the cross-beam profile
• computes the dose at a point by multiplying these two equations
Matrix

- uses two dimensional tables for various field sizes to determine the dose from a beam
- generates beam profiles from a) the width of the beam on a CT image and b) depth dose from the equivalent square field size
- are very fast in displaying the dose on a given axial image

Computer Software: Treatment Planning Algorithms

Semiempirical

Clarkson method

1. calculating dose in an irregularly shaped field
2. divided into sectors the span no more than 10 degrees
3. primary radiation calculated to be affected by 3 components: penumbra, block or collimator transmission, and flattening filter effects
4. dSAR (differential scatter-air ratio) calculation is calculated to factor the scatter dose not counted in the primary calculation

Computer Software: Treatment Planning Algorithms

Note: 1, 2, and 3 all based on homogeneous water phantoms

Heterogeneity techniques: ratio of TAR method, power law TAR method, equivalent TAR method

1. these corrections would be applied after the calculation methods 1, 2, and 3 are already applied
2. ratio of TAR’s and power law TAR - one dimensional techniques in that they consider only the effect of heterogeneities that fall on a line from the source to point of calculation
3. equivalent TAR method considers heterogeneities that fall away from the line connecting the source and the point of interest
4. most computer planning systems using equivalent TAR method have essentially used 2½ dimensional calculation in that they have implemented this algorithm collapse 3D patient volume into a 2D slide through the isocenter in order to reduce calculation time
Monte Carlo Calculations (model-based dose computation)

- used to characterize the clinical beam, to produce convolution kernels, and as computation benchmarks
- used in a limited fashion to develop a description of the dose distribution following a limited number of photon interactions within a patient
- this 3D dose distribution represents the transport of photons and electrons away from the primary interaction site (commonly referred to as dose spread array, point spread functions, or simply a kernel)
- dose in treatment volume is then computed by superimposing the dose kernel throughout the 3D irradiated volume, weighted by the total energy released per unit mass at each point
- change in dose distribution near field boundaries is considered by modeling the change in primary photon fluence at these boundaries
- effects of heterogeneities are included by a) determining the change in primary photon fluence as a result of passage through the heterogeneity and b) scaling the dimensions of the dose kernel according to the density of the patient
- availability of advanced computer technologies have prompted the development of treatment planning software that uses convolution techniques
  - Convolution - a number of kernels computed for different energies are summed together according to the spectrum of the primary photon fluence, to compute the dose distribution throughout a 3D volume. These calculations are complex and time-consuming, but as computer power and speed have increased, they have become more practical for clinical treatment planning
interaction (see Khan p.426 Figure 19.7 (4th ed.) for geometry of radiation transport)

3. *Terma* - product of mass attenuation coefficient and primary energy fluence; stands for total energy released per unit mass; analogous to *kerma* which represents kinetic energy released per unit mass in form of electrons set in motion by photons

4. kernel - dose matrix generated per unit terma at interaction site

5. product of terma and dose kernel when integrated (convolved) over a volume gives the dose

6. convolution kernel - represented by a dose spread array obtained by calculation or by direct measurement (most common method is Monte Carlo)

**Computer Software: Treatment Planning Algorithms**

**Electron Beam Computational Algorithms**

**Pencil Beam algorithm**

1. most accurate electron beam dose distribution calculations
2. based on Gaussian pencil beam distribution with application of multiple scattering theory
3. spatial distribution of absorbed energy is dictated by multiple scattering of electrons
4. dose spread array covers a smaller area, because of the decreased range of electrons
5. dose distribution in a broad beam can be generated by superposition of many electron pencil beam distributions
6. extension of pencil beam method to 3D has been accomplished, and efforts have been made to incorporate heterogeneity corrections
7. based on multiple scattering theory and used for electron beam planning

Analytical representation of pencil beam allows for calculation of dose distributions for fields of any shape and size, irregular or sloping surface contours, and tissue heterogeneities in 3D

Limitations: inaccuracies at different density tissues such as tissue-lung, tissue-bone, and bone edges; within homogenous media of any density, accuracy approximately 5% in central regions of field and approximately 2mm spatial accuracy in penumbra.
Brachytherapy Treatment Planning Dose Calculation algorithms

- not 3D dose calculated
- limited to point or linear source calculation
- future use of Monte Carlo
- When devising calculation algorithms, these guidelines should be used:
  1. when distributing lines of sources, attempt to keep them spaced no closer than 8mm (smaller volumes) and no farther than 2cm (larger volumes) apart
  2. the periphery of the treatment volume is generally not farther than 5cm from the center of gravity of the source distribution
  3. the very high doses close (less than 5mm) to the sources are not prescribed or evaluated as to clinical significance
  4. at distances greater than 10cm from the center of the implant, the dose delivered is low and the precise dose is not considered a treatment objective

Dose computation algorithms for TPS's utilize a balance between speed and accuracy. More accurate algorithms, such as convolution/superposition and Monte Carlo, are becoming commonplace with modern computing systems.

Computer Software: Dose Volume Histograms (DVH)

There are two types of DVH's:

1. Differential
2. Cumulative

We know that the dose is what the patient receives.

The Volume is demonstrated as a % of total organ or cm$^3$

Computer Software: Dose Volume Histograms (DVH)

Differential (direct) DVH

- the number of voxels that receive that dose are tabulated and grouped accordingly to a dose bin without regard to its anatomic location
- a plot of the number of voxels in each bin versus the bin dose range is, by definition, a differential DVH
• display shows total volume receiving a particular dose which is useful when analyzing dose homogeneity

**Computer Software: Dose Volume Histograms (DVH)**

**Cumulative (integral) DVH**

• This is the same dose-volume data displayed in a different way
• a plot in which each bin represents the volume or percentage of volume which received a dose equal or greater than an indicated dose; this is the most common way to view dose-volume relationships
• vertical axis is a percentage of total tissue volume that receives a dose equal to or greater than a particular dose
• horizontal axis express the units of cumulative dose
• can be used to compare competing treatment plans
• many values can be extracted such as minimum and maximum point doses
Computer Software: Dose Volume Histograms (DVH)

**DVH Overview:**

Differential (Direct) DVH: the volume of an organ receiving a dose within a specific dose interval

Cumulative (integral) DVH: a graph of the fractional volume of an organ that receives a dose greater than or equal to a specified dose

So, why the difference and how are they used?

The differential DVH is probably used more for research and reporting statistics. Cumulative is useful for every day treatment planning.

DVH analysis:

A disadvantage might be that they do not provide us with any information as to the location of the hot or cold spot; or if there is more than one hot spot.
Some TPS allow you to superimpose more than one DVH from several competing plans on one plot and compare them directly for an organ of interest. As always, the complexity of the treatment plan should also be reviewed, which is useful when analyzing dose homogeneity.