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ABSTRACT

This kit features an introduction to the Computer Museum, a history of computer technology, and notes on how a computer works including hardware and software. A total of 20 exhibits are described with brief questions for use as a preview of the exhibit or as ideas for post-visit discussions. There are 24 classroom activities about the history and work of computers, computers in daily life, and post-visit activities. A list of computer education resources in Massachusetts, Connecticut, Maine, New Hampshire, and Vermont is provided, along with a list of computer related publications that can be used as reference information. A glossary of computer terminology is also included. (YP)

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COMPUTER RESOURCES FOR SCHOOLS

NOTES FOR TEACHERS AND STUDENTS



THE COMPUTER MUSEUM
300 Congress Street
Boston, Massachusetts 02210



SE050244

# The Computer Museum Exhibits

## OVERVIEW

The Computer Museum depicts the past, present, and future of computer technology, tracing the development of computers from the vacuum tube machines of the mid-1940s, through the personal computers of today, to the possiblities of artificial intelligence, robotics, and other technologies tomorrow. You will see the remarkable changes in the size, price, speed, and capability of computers during their short 40-year history.

At the Museum, your group will have a brief guided tour of the historical exhibits. Then, you will be free to explore galleries on personal computers, robotics, artificial intelligence, and computer graphics at your own pace. You will have the opportunity to [illegible] a variety computer[illegible] and interact with more than 50 hands-on exhibits.

## VACUUM TUBE ERA

Vacuum tubes were used in the earliest electronic computers to perform mathematical calculations. These tubes, the "brains" of the early computers, acted as switches that controlled the flow of information. Whirlwind was the first computer in the collection that became The Computer Museum. Built at MIT during the 1940s, Whirlwind cost $5 million and occupied an entire building. At the Computer Museum, a $2,000 personal computer sits next to Whirlwind and solves the same problems that Whirlwind solved for a television audience in 1953.

The AN/FS Q-7, or SAGE system, was the largest computer ever built. It was used by the Air Force from 1958 to 1983 to monitor U.S. airspace for enemy aircraft. Each SAGE system was housed in a four-story building and cost $13 million. You will walk through the AN/FS Q-7 and explore the parts common to all computers: the arithmetic unit, the central processing unit, different types of memory, and input and output devices.

UNIVAC I was the first commercial computer. It was used to predict the 1952 presidential election. CBS covered the event. This was the first time that many people had ever seen a computer.

## TRANSISTOR ERA

Transistors are electronic switches that use semiconductors—materials with an electrical conductivity greater than insulators, but less than good conductors. Transistors eventually replaced vacuum tubes because they were smaller, cheaper, and more reliable. Because of their smaller size and lower cost, many businesses bought "transistorized" computers during the 1960s.

The IBM 1401 is a typical business computer from the 1960s. It cost $150,000 and was housed in an office. At the time, most companies had only one computer, which was used by one person at a time.

Programmers rarely had direct access to the computer. They sat in separate offices and wrote their


The Univac I computer as it appears at the Computer Museum.

*October, 1988*

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programs by hand. A keypunch operator typed the program onto punch cards. These cards were then fed into the computer that ran the program. You will be able to type your name onto a punch card when you visit the Museum.

## INTEGRATED CIRCUIT ERA

An integrated circuit, or chip, is a small sliver of silicon with microscopic circuits in it. One chip now can replace hundreds of thousands of transistors. Several chips are displayed under a microscope so you can see their intricate circuitry. Chips have made it possible to reduce computers to the "personal" size and price that we know today.

The Apollo Guidance Computer was one of the first computers to use integrated circuits. It was used to navigate U.S. space missions during the period 1964-1972.

Early personal computers, such as the Altair and the Apple I, are on display. Other later models of personal computers, on display as hands-on exhibits, demonstrate different input and output devices and a variety of unique computer programs (software.)

## IMAGE GALLERY

The Image Gallery highlights how computers are used to create and manipulate images. You can use the computers to alter your own image, to design a car, and to experience the thrill of flying an airplane, using the flight simulator.

Other state-of-the-art graphics equipment, such as a flat plasma-display screen and a color plotter, is on exhibit, demonstrating how computers are used as tools to build designs that can be evaluated and altered before they are physically constructed. In addition, a computer-animation theater features some of the latest examples of computer graphics in entertainment.

The AN/FS Q-7 computer, used by the Air Force to monitor U.S. airspace.

## SMART MACHINES
### An Exhibit on Robots and Artificial Intelligence

Smart Machines demonstrates how robots and artificial intelligence can amplify and mimic a wide array of human skills and abilities. The machines assembled in this gallery all aim to replicate some aspect of human behavior. Decide for yourself whether they hold a promise for tomorrow or if, indeed, they threaten our future.

Artificially intelligent machines will check your grammar, take on the role of psychotherapist, and give you directions to anywhere in Boston and Cambridge. Other "smart machines" write stories, create their own unique art, and compose original music. You can even challenge a computer expert system in a game of checkers, chess, or tic-tac-toe, or bargain with a computer-vendor for a box of strawberries. Step onto a set of footprints on the floor, and accurate sensors will measure your height. Other robot sensors can see objects that you place before them, understand your voice, or sense your touch. Watch a robot arm move and manipulate objects, or watch some unusual robot feats on video. Don't miss the Smart Machines Theater, where many of our robots come to life in a multimedia presentation. Although many of these wonders are already at work today, Smart Machines offers a glimpse into the future applications of computer technology.

*The exhibit demonstrates how robots and artificial intelligence programs and systems can amplify and mimic many human skills--both mental and physical*

# A History of Electronic Computers

To compute is the term we use to describe adding, subtracting, and otherwise manipulating numbers.

Tools for computing—for counting and calculating numbers—such as the abacus, the slide rule, and even multiplication tables—have existed for hundreds of years. Most of these instruments performed simple arithmetic and were operated manually. An example is Pascal's adding machine (1640). Hollerith's tabulating machine, developed for the 1890 census, used punched cards to hold information about people and demonstrated the improved ability of machines to store and process all kinds of information.

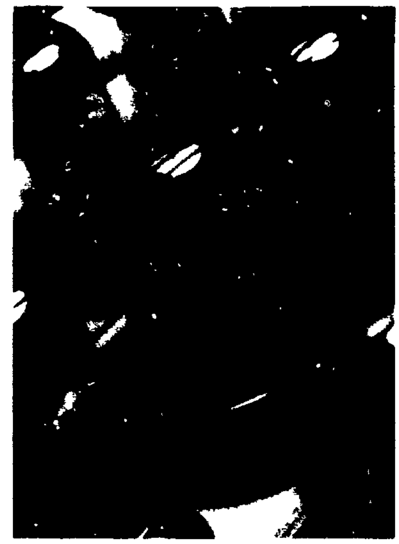
Why not create a machine that could manage numbers in all sorts of ways and solve any kind of problem? This was a challenge to many scientists. It wasn't until the 1940s, however, that the machine we know as the computer was invented. It was a device that could perform logical operations automatically, that had a memory in which to store numbers (data) and programs, and that had a way of displaying an answer. The "stored program" machine with internal "memory" (storage) was an innovation that transformed calculators into genuine computers.

Illustrations by Stuart Goldenberg

The first computer with internal memory was ENIAC, developed during World War II to calculate missile trajectories. Whirlwind was also among the first computers with internal memory. In the late 1940s at the Massachusetts Institute of Technology (MIT) Whirlwind was funded by the the U.S. Navy as a flight simulator to train naval bomber crews. It took five years to design and build for a total cost of $5 million. Whirlwind occupied an entire building at MIT and was used from 1950-1959 for scientific and engineering purposes.

UNIVAC I (Universal Automatic Computer), completed in 1951, was the first commercial computer. Most previous computers were developed as research tools for use in academic environments. These early computers wer large and expensive. they also used a lot of energy (often enough electricity to light up a small city).

Size and cost were not the only problems with these first generation computers. They were built with thousands of glass vacuum tubes—much like the light bulbs we use in



Photograph © Lou Jones

Glass vacuum tubes were used on the earliest electronic computers.

our homes. Vacuum tubes allowed the machines to compute numbers quickly because, unlike earlier inventions, they were electronic. Electrons (particles of matter with an electric charge) moved around inside the computer as information, and the new machines were not slowed down by mechanical moving parts.

But vacuum tubes were not altogether reliable. In 1948, scientists at Bell Laboratories invented what would eventually become a substitute for the vacuum tube: the transistor. Transistors are electronic switches that use semiconductors—materials with an electrical conductivity greater than insulators but less than good conductors. Like the vacuum tube, transistors act as electronic conductors of information to



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calculate numbers. Transistors use very little electricity, are small in size, and can be produced in large quantities at a low cost. In addition, they are much more reliable than vacuum tubes.

This second generation of computers, built with transistors, was much less expensive than either Whirlwind or UNIVAC. And they could be housed in a single room, rather than require an entire building. By the 1960s. transistors had replaced vacuum tubes in computers and also in other electronic appliances, such as radios and televisions.


Photograph © Lou Jones

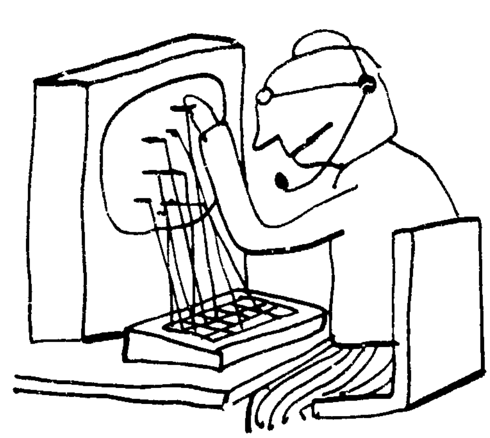
Small printed curcuit board

Transistors weren't all there was to a computer, however. Every transistor had to be connected with wires to many other parts of the computer. The large number of wire connections meant that computers were still somewhat unreliable. They required frequent preventive maintenance just to insure that all the connections were sound. In addition, although computers in the 1960s were much smaller than earlier machines, the size of the various parts kept computers from getting even smaller.

In the 1960s, scientists learned how to put transistors and the other parts of a computer onto small, thin pieces of silicon. Silicon is a common, inorganic substance that can be obtained from sand and other rocky materials. Crystals of silicon can be grown artificially and sliced into thin wafers.

*Microcomputer applications range from timing a microwave oven to controlling traffic lights to functioning as the central processing unit (CPU) in a home computer.*

Scientists were able to etch parts of a computer onto a single tiny "chip" of a silicon wafer to create an integrated circuit. The new machines built with silicon chips represented the third generation of computers—no longer the size of buildings or rooms but instead about as big as a home refrigerator. The tiny silicon chips were able to do the same jobs as the fragile vacuum tubes or the individually wired transistors in older computers.



By the 1970s, scientists had learned how to make the chips even smaller. They squeezed more and more circuits onto the surface area of a silicon chip—creating what we know today as the microprocessor.

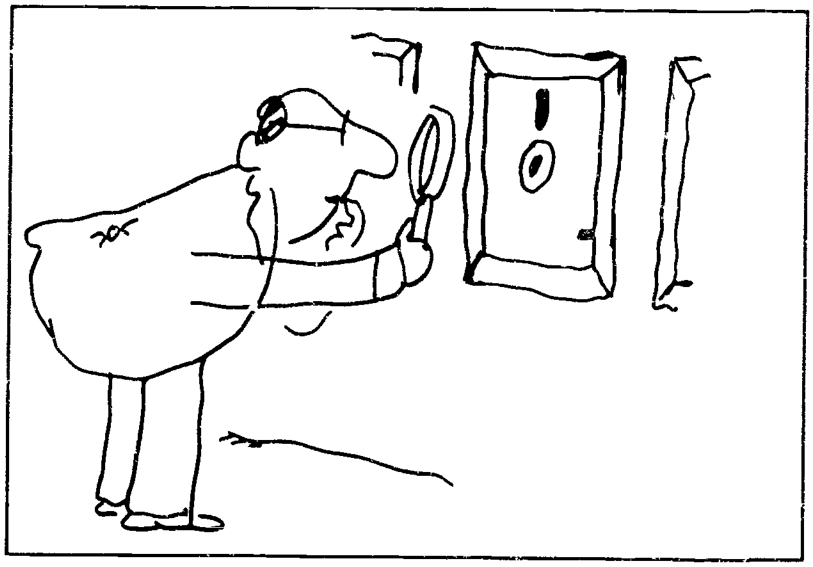
The microprocessor made it possible to reduce the size and cost of computers even further. Today, these fourth generation computers are quite small, and yet they are able to do much more than Whirlwind ever could—in much less time! Microcomputer applications range from timing a microwave oven to controlling traffic lights to functioning as the central processing unit (CPU) in a personal computer. Because of the significant decrease in price, computers now are used by a wide variety of people in many different ways

# How a Computer Works

## Hardware

Computers come in all shapes and sizes. From the outside, they look very different, but on the inside, they have much in common.

They have five basic parts: input, control, memory, arithmetic/logic, and output. Often, several of these parts are physically combined. In a microcomputer (or "personal computer"), for example, the arithmetic/logic and the control units may be combined in a single chip. The chip may, in turn, contain a substantial amount of memory.



Regardless of the actual design, all five components are essential to every computer and are a part of the computer's hardware, the physical machinery of a computer system.

Now let's look at each of the parts.

### INPUT

The part where information is put into the computer system is called the input device. Sounds logical so far. The most common way to put information into the computer is through a keyboard. Computers can take in information in different ways: from floppy disks, from reels of magnetic tape, from screens that respond to touch, from cards with holes punched in them, or from joysticks, mice or touch-sensitive pads. No matter what kind of input device you have, they all perform the same function.

Input devices change all the information they receive into a form the other parts of the computer can understand—sequences of electronic pulses that are individually either on or off. The pulses can be arranged into millions of different sequences, each with a different meaning. The computer can accept millions of pulses every second.

### CONTROL

The second part of the computer is called the control unit. Located inside the computer, the control unit tells the other parts of the computer what to do with information and when to do it. The control unit takes its directions from a list of ready-made instructions, called a program. A program is written by a person and can be stored by the computer in its memory.

### MEMORY

The third part of the computer is known as memory. Within the computer system, information and results produced by the computer are stored in the form of the electronic pulses in silicon chips. Some of those chips are designed to store information permanently - the information they contain cannot be erased or changed even if the computer is turned off. (For instance, how does the computer at your school "remember" to show a menu or cursor symbol every time you turn it on?) These permanent storage units are called read-only memories, or ROM chips.

A computer's memory also contains another group of memory chips called RAM chips—random-access memory. RAM chips also store information just like on/off

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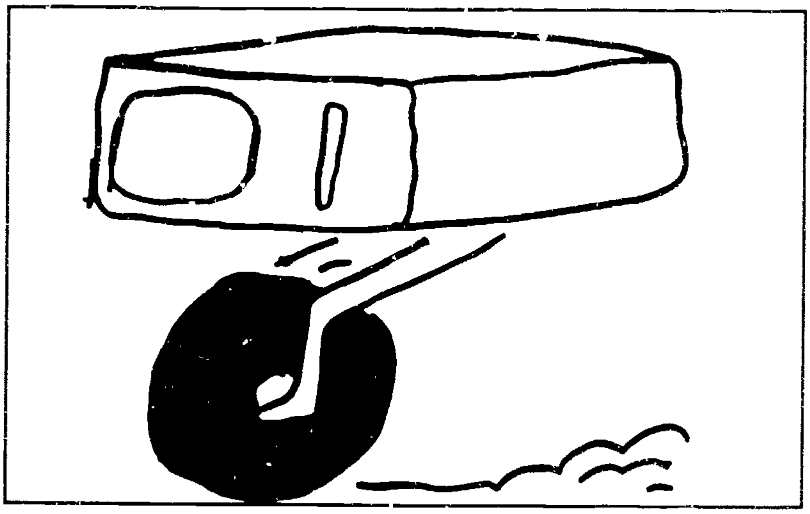
electrical switches. But information stored in RAM chips, unlike ROM chips, is not stored permanently. It can be changed, erased, or lost completely once the computer is turned off. (Think of a word-processing document that you haven't saved on a disk. What happens to it when you turn off your computer?)

Both RAM and ROM chips have a limited storage capacity. For very large amounts of information, computers can store data on a magnetic tape or disk. These are usually portable and can be easily taken out of the computer.

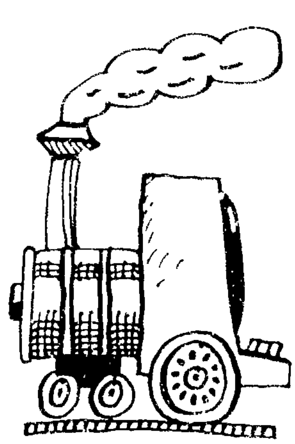


## ARITHMETIC/LOGIC

The fourth part of the computer, located inside the system, is called the arithmetic logic unit (ALU). It is the part that actually carries out the instructions of a program. We all follow directions and synthesize information every day. We remember the rules of games and apply them when we are playing; we plan surprise birthday parties for our friends; we're able to solve puzzles and brain teasers. Computers also "process" information and determine answers to very complex and difficult tasks. It so happens that most of the problem-solving operations performed inside a computer are quite simple. Computers use basic math, such as addition and subtraction, and they apply some logic, such as comparing one value with another to see which one is larger. The arithmetic/logic unit is the part of the computer that actually performs these calculations.

## OUTPUT

The last part of the computer is output. This is the part of the computer where information is put out. The output device turns the on/off electronic pulses into some other more permanent form. The two most common forms are a display on a computer screen and a paper printout or hard copy.



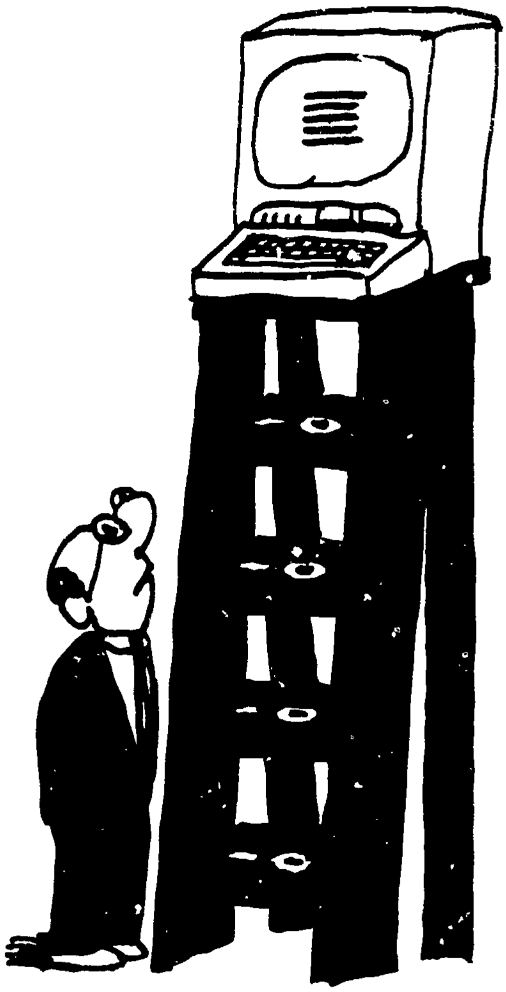
So that's it—all five basic parts of a computer. Input, control, memory, arithmetic/logic, and output. Every "computer" must have all five parts to work properly.

# Software

Software is the name given to the instructions or programs that enable a computer to do something useful. There are several kinds of programs. Internally stored programs, called operating systems, allow computers to operate efficiently. Applications software, such as word processors or spreadsheets, is designed to do specific tasks. Programming languages, another kind of software, help you write your own instructions to make computers do something.

A computer program is a well-defined series of instructions that tell a computer what to do to achieve a particular result—like a recipe in cooking. It cannot be vague or ill-defined. Given the same information, the computer always proceeds in the same fashion. It cannot tolerate mistakes in these instructions.

A program is similar to a story. Take Goldilocks and the Three Bears for example. Step by step, the story unfolds: Goldilocks takes a walk in the woods, she goes into the three bears' house, she sits in their chairs, eats their porridge, etc. When there's a question or a decision to be made, the story tells us what happens "if." (If the chair is too hard, move to the next chair; if the porridge is too hot, move to the next bowl.) Goldilocks performs each step until she achieves her desired results.



2. Controlling other machines: Computers can direct other machines with great precision. They are effective in performing tasks that are either too exact for people to do well or too boring and repetitive for people to do happily.

3. Simulation: People use computers to test ideas and designs (like building a model of a car or a bridge to see what it would look like and how it would work).

4. Communication: Computers are able to link people together with the vast amounts of information they need to do work.

Software refers only to the programs that can be stored inside the computer's internal memory or on such items as floppy disks, hard disks, magnetic tapes or keypunch cards. It is important to understand that people create computer software. Without this software, a computer does nothing—it can solve no problems. Human beings control computers.

*A Computer program is a well-defined series of instructions which tells a computer what to do to achieve a particular result- like a recipe in cooking*

The power of computer systems to do useful work rests on this "decision" feature (the "What happens if?") in programs. Since computers can work effectively on any problem that is clearly defined, they are applied to a variety of fields. For example—

1. Calculation: Imagine calculating exactly where the moon will be when your rocket arrives there.

# COMPUTER RESOURCES FOR SCHOOLS

CLASSROOM ACTIVITIES

# Guide to Exploring Smart Machines

## INTRODUCTION

Step into the future and explore Smart Machines, an exhibit that demonstrates the capability of machines to do tasks and make decisions ordinarily accomplished by people. In Smart Machines, you'll see the tremendous sophistication of the human mind and body—and the limitations scientists face in their attempts to replicate even the simplest human activity.

Ask your students to consider how these new technologies will affect our lives. Do they hold a promise for tomorrow, or do they threaten our future? Use these notes as a preview of the exhibit, to assign particular research projects to your students, or as ideas for post-visit activities and discussions

## EXHIBITS

### Artificial Intelligence

Artificial intelligence is a field concerned with developing intelligent computer systems. Artificially intelligent devices may understand language, learn reason, and exhibit human-like intelligence.

### The Frankenstein Set

These robots, used in the set of a television commercial aren't real, but they raise intriguing questions Might robots be able to create other robots in the future?

### Grammar Checker

Word processors make writing easier. New word processors may help you write better, too, by checking your spelling, helping you choose better vocabulary, and correcting grammatical mistakes See if the thesaurus can find a synonym for a word you use too often, or find out how the grammar checker works.

Would you prefer to have a computer check your writing for mistakes instead of your teacher? Could the computer be a better writing teacher than a human teacher?

### ELIZA

ELIZA plays the role of a computer psychotherapist. Can ELIZA help you solve your problems? Is ELIZA smart? Can you confuse ELIZA? Would you rather tell a computer or a person about personal problems?

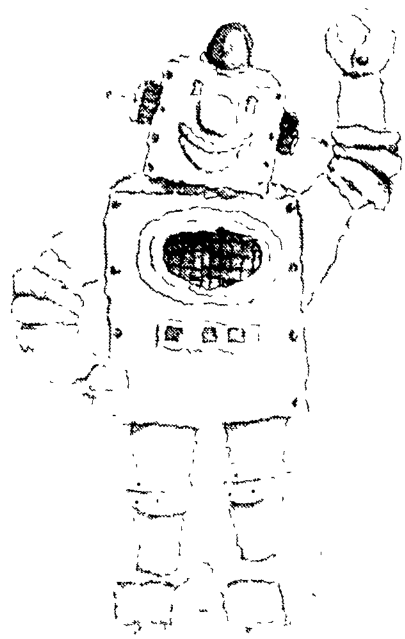
### Tale Spin

Let Tale Spin tell you a story Choose the characters, their goals and traits Does Tale Spin write as well as a human author? Would you have written the story differently?

### Direction Assistant

Step into the phone booth and find out the best way to get to any place in Boston or Cambridge. Ask for directions to a Boston landmark—or a friend's house.

Do you know a better route than the computer does? Why can't the Direction Assistant tell you how to get to places outside Boston and Cambridge?



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## Haymarket
Bargain with artificially intelligent storekeeper Nora Logical for a box of strawberries. Can you buy a box for less than $6.00? Can you get a better deal from a different storekeeper? Does the computer act like a real storekeeper? Look at the "rules" Nora Logical follows (posted above and to the left of the terminal.) Do people use similar rules when they bargain?

## Checkers and Chess
Computers can play many strategy games, like chess or checkers, as well as, if not better than, people. What can you learn from the computer's strategy as it plays? How is playing with a computer different from playing with a person? Would you rather play with a human friend?

## AARON
AARON is a computer program that draws pictures. A person (Harold Cohen) programmed the computer to draw, but now AARON draws new and different pictures every day. You can find out more about AARON and its creator by watching the video nearby.

Are AARON's drawings art? Would you like one of AARON's pictures to hang up at home? Who is the real artist, AARON or Harold Cohen? Play with AARON's stick figure at the computer terminal to the right. What does AARON need to know to draw a figure?

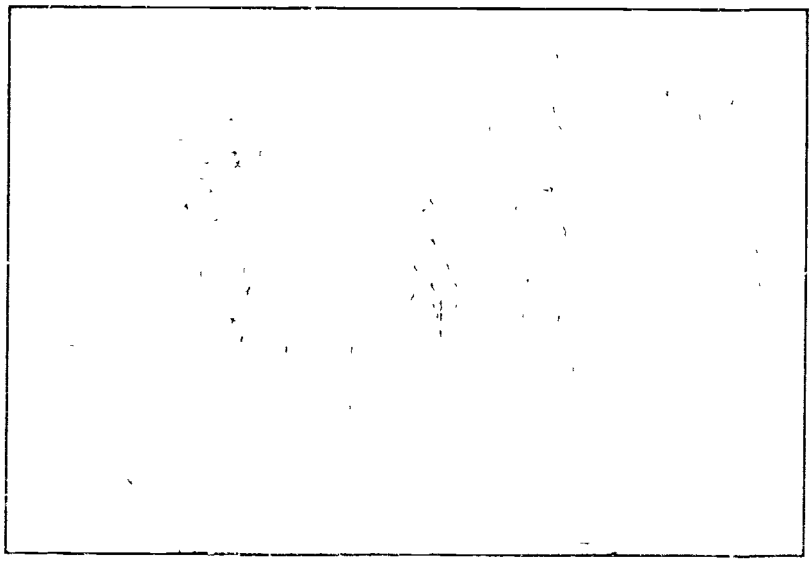
## Robots
Robots are computer-controlled devices that move, can be programmed, and are able to do a useful task. Many robots use sensors to help them detect changes and manipulate objects in their environment.

## How Tall Are You?
Step onto the feet and let an ultrasonic sensor measure your height. Is the sensor accurate? What information does the computer get from the sensor in order to determine your height? When would an ultrasonic sensor be more useful than ordinary human vision?

## Recognizing Speech
Try to paint the map of the United States using only four colors. Can the computer understand anything you say? Why not? What does the computer need to know in order to understand your speech? How would you use speech recognition?

## Sense of Touch
Try pressing on the touch sensor. What does the touch sensor detect? What kind of robots might need touch sensors? Watch the video to the right. What can robots equipped with a sense of touch do well? What do they have trouble doing?

## Robot Arm
Ask the red robotic arm to spell your name. Did it spell your name correctly? What does the robot's computer need to know in order to pick up the proper blocks and place them in the correct order?


A picture drawn by AARON

# Guide To The Computer and The Image Exhibit

## INTRODUCTION

Take a good look at how computers are used to create, enhance, and transform visual images. The Computer and the Image shows how computers are used to design three-dimensional objects, such as sneakers, as well as two-dimensional pictures. In addition, you'll see and learn about computer animation in this exhibit. Ask your students to name some familiar objects and images that are created using a computer. Many plastic objects, television commercials, and printed materials are designed this way today. Challenge students to find a design idea or technique that they might try on their own. Use these notes as a preview of the exhibit, as particular research projects for your students, or as ideas for post-visit activities and discussion. Graphics technology is changing as fast as, if not faster than, computer technology. As we constantly try to exhibit the latest technology, you may notice some changes in the gallery while we improve our exhibits

## EXHIBITS

### Drawing

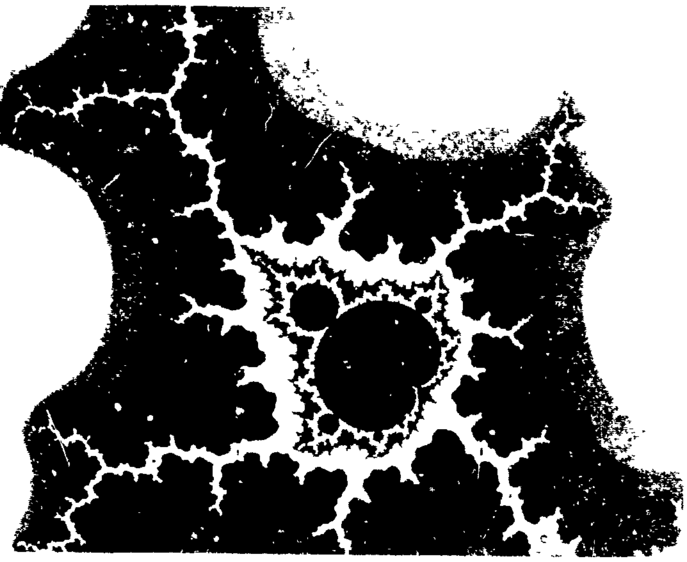
Manual and Electronic Tools like the two large pantographs and the set of compasses, scales, and pens helped people draw before the advent of electronic tools. Now computers use mathematical formulas to draw and copy curves and figures accurately.

Trace the figure of the house with the wooden pantograph; then try the computer-simulated pantograph. What advantages does the computer simulation have? Are there any disadvantages?

### Anatomy of an Image

Digital images, such as the ones you see on a computer's monitor, are composed of many small rectangular elements called pixels. The quality of an image is determined by the number of pixels in an image (spatial resolution) and how many distinct colors or shades of gray a pixel can become (gray-scale resolution)

Experiment with the resolution of your image. When can you no longer recognize yourself?



A fractal image created by a computer using a mathematical formula

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## A Window Full of Polygons
A photograph taken from a museum window was digitized so that a computer could manipulate this image. The photograph was separated into tiny pieces and each piece was coded with a number according to its shade. Using that information, the computer rebuilt the image as an assortment of polygons — shapes with a varying number of sides.

Try to view the skyline as geometric figures. Can you find any circles? Any pentagons?

## Teapots: Real and Synthetic
In 1974, Martin Newell assembled all the information needed to describe the visual image of a teapot to a computer. Since then, he and many other researchers have used the "teapot data" to investigate synthetic images. The computer in this exhibit does not receive a camera image of the teapot; only information about which colored lights are lit is sent as data. Why do you think Newell's information was useful?

## Fractals
Fractals are figures containing patterns that repeat again and again in ever-decreasing size. Often seen in natural forms, such as clouds, snowflakes, or a coastline, fractals have an intriguing property of self-similarity. A small piece of a fractal image may look identical to the entire image.

Choose the colors to paint this landscape.

In the series of images of a coastal landscape, the second image (top, right) is an enlargement of the boxed area of the image on the upper left. Try to follow the sequence of images as the perspective becomes even closer. The actual coastline seems to grow longer as you zoom in closer.

Create your own fractal—like the Koch snowflake—using a "generator" object and a repeating "initiator." Or, explore a fractal landscape like the Fractal Dragon.

Where else might you find fractals in the natural world? Could you create your own fractal without using a computer?

## Computer Graphic Paint Systems
**Computer graphics systems enable computer artists to create drawings and graphics for hundreds of different uses—everything from technical illustrations to t-shirts.**

Try MacPaint. Use different drawing tools. How would an "electronic" paintbrush help you draw better? What would you use it for?

# A History of Electronic Computers

**1.** Have students find and then photocopy pictures of early to modern electronic computers. These pictures can be found in most local libraries or in introductory computer texts, which often contain a short history of computers. Have the students arrange the pictures in chronological order on a classroom bulletin board or wall so that they will become more familiar with the development of computers.

**2.** Discuss the four generations of computers, giving students a sense of how computers have changed in terms of size, cost, and capability. Have students collect examples, pictures, or drawings of a vacuum tube, a transistor, an integrated circuit board, and a microprocessor chip. (These items can be collected from books, magazines, or even local companies.) Prepare a display of the four generations of computers or construct a model of an early computer, using cardboard and any collected parts.

**3.** Help students to recognize several significant developments that contributed to the evolution of the modern computer. Students could learn to manipulate some of the following items or do class presentations on others.

- abacus
- Napier's Bones: 1617, John Napier
- digital calculating machine; 1642, Blaise Pascal
- slide rules; circa 1630, William Oughtred, et al.
- Jacquard's loom; 1801, Joseph Marie Jacquard
- analytical engine; 1840s, Charles Babbage
- recording adding machine; 1880, William S. Burroughs
- Hollerith Tabulator; 1890, Herman Hollerith
- differential analyzer; 1930, Vannevar Bush
- Harvard Mark I; 1944, Howard Aiken
- ENIAC; 1946, John Mauchly and J. Presper Eckert

**4.** Have students construct an abacus with rods and beads and demonstrate how it is used to perform simple calculations; or ask students to report on the abacus to determine how it works, the value of the beads, its country of origin, and where it is still in use. Can students describe how an abacus is like a computer?

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# 5.

Have students research the life and contributions of one of the following people

- Blaise Pascal
- John William Mauchly
- Joseph Marie Jacquard
- William Schockley
- Charles Babbage
- Grace Hopper
- Ada Lovelace
- J Presper Eckert
- Thomas J. Watson, Sr.
- Robert Noyce (Integrated Circuit)
- Jay Forrester (Core Memory

Ask students to role-play the character they have chosen and to—

a) defend their "invention" to non-believers, or
b) defend the merits of their machine to others.


# How a Computer Works

**Help students to differentiate between hardware and software.**

## 1.

Collect information and pictures of computer hardware from magazines and newspapers (or students can write down information pertaining to hardware that they see on television). Have students post the information and pictures on a classroom bulletin board, and ask them to label the computer components.

## 2.

Write a short television or newspaper advertisement announcing a new piece of software. The advertisement should include a name for the software, a brief description of it, and an explanation of why a customer should purchase this item.

**Help students to recognize that people control what computers do:**

**A computer receives instructions from a program written by a person. Computers cannot "think" in the way that we normally use the word. Computers cannot answer every question or make value judgments as people are able to do.**

## 3.

Read aloud a dictionary definition of "think." Discuss the definition and make a list of the different kinds of thinking. Use your list to determine if computers are capable of performing the different kinds of thinking. Can students explain why computers are not capable of thinking as humans do?

## 4.

Have your students write a set of directions for making a peanut butter and jelly sandwich. The directions are to be very detailed, designed to be read and followed by a person who has never made or even seen a peanut butter and jelly sandwich. Each student or group of students should write a set of directions.

Have students pair up and follow each other's directions exactly. Students will see that unclear directions can produce unexpected (and messy) results. The demonstrator is not allowed to use "common sense" to fill in gaps or to avoid disaster. For example, suppose that an instruction specifies, "put the peanut butter on a slice of bread." You could pick up the jar of peanut butter and set it on a slice of bread. Or, if an instruction says, "take some peanut butter out of the jar and spread it on a slice of bread," you might scoop a handful of peanut butter out of the jar with your hands and spread it on the slice of bread.

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Ask students to rewrite their directions so that they are foolproof (if students have written instructions in a paragraph form, ask them to rewrite them in the form of a numbered list). They will see how difficult it is to write a foolproof set of directions. The writer must understand precisely what the agent (the person or machine that will follow the directions) is able to understand and do. A substantial part of learning to program a computer is figuring exactly how it understands and executes a set of directions. Classroom discussion should follow.

**Help students to relate the major parts of a computer to the input-processing-output sequence of computers.**

# 1.

Begin with experiences that are familiar to students. Provide examples of input and processing and have the students supply examples of output.

Examples:

| INPUT | PROCESSING | OUTPUT |
|---|---|---|
| broken pencil | sharpen | |
| straight hair | gets a permanent | |
| Kool-Aid | freeze | |

# 2.

Relate human input/output, involving the five senses, to computer input/output.

Ask students to identify the five senses from which people receive "input" or produce "output." (smell, taste, touch, hearing, sight)

Next, identify how computers receive input or provide output. Compare and contrast input and output for people and for computers.

Samples

| People Input | People Output | Computers Input | Computers Output |
|---|---|---|---|
| seeing | | keyboard | |
| hearing | | joystick | |
| tasting | | mouse | |
| smelling | | microphone | |
| | muscle activity | | video screen |
| | (run, jump, write) | | disk drive |
| | sound | | synthesized speech |
| | (talk, sing, cry, yell) | | printer |


# Computers in Our Lives Today

**Microprocessors or integrated circuits are the primary components of a computer. They are found increasingly in other common objects such as cars, digital watches, televisions, videocassette recorders, and microwave ovens.**

**Demonstrate to students the broad use of microprocessors and illustrate that machines, like humans, have histories.**

**1.** Give examples of common computerized items. (Some suggestions: calculators, microwave ovens, digital watches, cash registers, blenders, automatic cameras, traffic lights, thermostats in large buildings, televisions, and radios). Ask students to help you extend the list. Which of these gadgets do students use most frequently? What did they (or their parents) use before this item was computerized?

**2.** Ask students to construct a pictorial timeline that traces the history of a particular item (for example, a watch, a typewriter, a car, a loom). Use pictures to describe the social and technological advances of each successive "generation."

**Help increase student awareness about competetors.**

**1.** Have students interview their parents or other adults to determine their attitudes toward computers. Do parents/adults feel that they understand and are comfortable with computers? Do they want their children to learn about computers and if yes, why? How have computers changed their work or home activities?

**2.** Have students "invent" a computerized item that they would enjoy owning, such as a robot to make their bed in the morning. How would this item help them and what would it be able to do? What are some of the potential problems or obstacles they might face in developing this new technology? If their "invention" will supplant humans, can they consider some of the social implications of their new technology?

For example, if a student "invents" a robot that can scoop ice cream or wash cars, get him or her to discuss the ethical dilemmas that such a machine poses. How does one choose between efficiency and cost effectiveness and such human needs as jobs, job satisfaction, and interpersonal contact? What jobs have been eliminated by computers? What might be done for people whose jobs have been eliminated by computers.

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# COMPUTER RESOURCES FOR SCHOOLS

CLASSROOM ACTIVITIES

# Post-Visit Activities

**Drawing on their experiences and observations at the Computer Museum, help students to predict how computers might be used in the future.**

**1.** Ask students to prepare a drawing showing technological advances. Students should be prepared to discuss their pictures and to indicate whether they believe these changes are achievable during their lifetime.

**2.** Design (and build a model of) a city of the future. Describe the means of transportation, communication, education, entertainment, etc., in your city.

**3.** Design a model computer and describe how it works. Include input, processing, and output. Would you consider your computer realistic or purely fictional?

**Analyze questions of equity as portrayed by the media.**

**1.** Have students look through magazines and count the number of advertisements picturing people and computers. They should record the sexes and races of the people, and then construct a graph using that information. Students can analyze the more subtle aspects of the ads; for example, which people are pictured actually using the computer and which are just watching.

Discussion questions:
•Who is pictured most often using the computer?
•What attitudes do these advertisements reflect?
•How might advertising influence our attitudes toward who is most competent in using computers?

**Based on their knowledge of computers after visiting the Computer Museum, have students debate the advantages and limitations of computers.**

**1.** •Computers cannot think, judge, or feel emotions. On the other hand, computers are fast, accurate, do repetitive tasks, and work in dangerous situations without jeopardizing human life.

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Students could determine and discuss whether computers or humans can best accomplish the following tasks: see, sort, hear, taste, love, observe, write, enjoy, compare, predict, forget, smell, create, recite, invent, judge, rearrange, classify, compose, remember, identify, feel, imagine, guess, match, estimate, compute, recognize, describe, calculate, or choose.

2. •Have the entire class generate a list of problems computers cause or might cause for society. Some possibilities include terrorists gaining control of nuclear weapons, increasing government surveillance of private citizens' actions, computer terminals causing eye problems, etc. When students have generated a sufficiently large list, have them identify those problems that are current and those that may arise sometime in the future. Classify the problems as issues of employment, access, crime, or privacy.

3. •Have each student choose an occupation and pretend to be an authority within that particular area. Have them list five factors (in rank order of importance) that they would consider in choosing between people or computers to do a specific job (e.g., the cost of installing computers; what jobs will be eliminated or created; what will happen if the computer breaks down).

Ask for volunteers to list some of their factors on the blackboard. Most factors will fall into one of two categories: efficiency/cost-effectiveness considerations (whether computers do the job more efficiently at less expense) or human needs considerations (whether more people can be hired with a possible higher rate of job satisfaction). Have the class categorize and discuss the implications of each factor.

4. •Point out that, like the government and credit bureaus, schools maintain student records that include not only student grades but also letters of recommendation from teachers and guidance counselors. Whether or not students should have access to this information has been a subject of controversy in recent years. Have two teams of students research the current laws on access to student records and debate this topic in class. Each team should present one scenario: one case where students might need access to their own files and another where they should not be given access.

Questions:
How important is it that you be allowed access to school, government, or credit files containing information about yourself? How might the contents of these files be different if you had or didn't have access? At what point do such records impinge on one's privacy?

Help students to identify computer-related careers.

1. Collect information from employment agencies, career/guidance counselors, colleges and universities on the most in-demand computer-related jobs, the responsibilities and educational prerequisites, the average salary, and courses or degrees available. Post this information on a "career" bulletin board, along with advertisements, want ads, articles, or other related resources. Try to include information on computer specialists (programmers, software engineers, technical writers, etc.) and non-specialists (data processors, word processors, support staff, computer sales, etc.)

Other sources of computer-related career information are these

**Careers in Science**
**Association for Women in Science**
**2401 Virginia Ave, NW**
**Suite 303**
**Washington, D.C. 20037**
**(202) 833-1998**
**$2**

The Chicago branch of AWIS offers a Compilation of Recommended Career Guidance Sources that can be obtained from the above address for $2. This 1984 edition offers an excellent bibliography of resources for science careers, including computer science and engineering/technology. It also provides a list of women's groups offering career assistance. An updated version is expected to be released in late 1988.

Also, Encouraging Science Education and Careers is a two-page flyer listing resources for educators, counselors and others interested in information on promoting careers in the sciences. Free to anyone. Please send them a self-addressed, stamped envelope.

**Occupational Outlook Handbook, 1987-88 edition**
**U.S. Department of Labor**
**Bureau of Labor Statistics**
**Washington, D.C.**
**Available in most public libraries**

**JETS, Inc. (Junior Engineering Technical Society)**
**1420 King Street, Suite 405**
**Alexandria, VA 22314-2715**

To obtain any publications please send them a self-addressed, stamped envelope.

**Higher Education Information Center**
**Boston Public Library**
**666 Boylston Street**
**Boston, MA 02116**
**(617) 536-0200**
**(800) 442-1171**

The Higher Education Information Center is a clearinghouse of information on post-secondary education and financial aid, providing free information and guidance services to youth and adults. The Center now has computerized information on schools, careers, and career planning through the Guidance Information System (GIS). Contact the Center directly for more information.

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# Computer Education Resources In New England

## Massachusetts

**The Boston Computer Society**
**One Center Plaza**
**Boston, MA 02108**
**(617) 367-8080**
**Contact Gerri Abrams, Education SIG.**

The Boston Computer Society offers a variety of services for its members, including publications, meetings, workshops, software, referrals, and other resources. For a basic membership fee of $35, individuals receive several BCS publications and can join any of the 50 user and special interest groups, including user groups organized specifically for primary and/or secondary school educators. Both novices and more experienced computer users are welcome.

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**The Boston Museum of Science**
**Science Park**
**Boston, MA 02114-1099**
**(617) 589-0300**
**Contact Ginny Woolley.**

ComputerPlace, at the Museum of Science, is a microcomputer education center that offers a wide variety of workshops and courses for both teachers and families. Call ComputerPlace directly for a listing of courses and computer-related activities.

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**Center for Applied Special Technology (CAST)**
**39 Cross Street**
**Peabody, MA 01960**
**(617) 531-8555**
**Contact Bart Pisha.**

CAST is a nonprofit research and educational facility providing instructional services, professional training, and consultation in the use of computers and other technologies with special needs students.

CAST welcomes individuals with a special interest in learning about computers, those with special educational needs, and those with developmental or acquired handicaps.

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**Chapter One Computer Cooperative Center**
**c/o Walsh Middle School**
**Brook Street**
**Framingham, MA 01701**
**(508) 788-0094**
**(617) 431-1821**
**Contact Chuck Hitchcock.**

The Chapter One Computer Cooperative Center offers a number of services and workshops for educators. Among the Center's resources are 2,000 commercial software packages, a variety of microcomputers, over 100 disks of public domain software, reference manuals and educational publications, evaluations of hardware and software, and staff-developed training and reference materials.

The Center is open to Chapter One administrators and teachers, and to teachers who serve Chapter One students in their classrooms. Non-Chapter One teachers must coordinate their involvement at the Center with their local Chapter One director.



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| | |
|---|---|
| **EdCo Computer Center**<br>**Lincoln-Eliot School**<br>**191 Pearl Street**<br>**Newton, MA 02158**<br>**(617) 965-1771**<br>**(617) 738-5600**<br>**Contact Eileen McSwiney.** | The EdCo Computer Center serves its 20 member school districts by providing computer-related training for school personnel. The Center's activities include computer workshops; courses and seminars for teachers and administrators on instructional uses of computers; group purchase arrangements for software and hardware; Master's Degree and Certificate Programs in Educational Technology (offered in conjunction with Fitchburg State College); and partnership in the Educational Technology Center at Harvard University.<br><br>EdCo is open to all teachers from membership communities. Its services are available on a fee-for-service basis to non-EdCo communities. |
| **The Education Cooperative (TEC)**<br>**c/o The Wellesley Middle School**<br>**50 Kingsbury Street**<br>**Wellesley, MA 02181**<br>**(617) 237-3028**<br>**Contact Gail Ross-McBride.** | The Education Cooperative houses a software (and limited video) preview center and offers ongoing workshops as needed or requested by teachers. Some recent examples of TEC workshops include Telecommunications, Integrating Software into the Curriculum, and Word Processing for Teachers. TEC is open to all teachers. Teachers from TEC membership towns can use the resources free, while a nominal fee will be charged to non-members. |
| **The French River Education Center**<br>**P.O. Box 476**<br>**North Oxford, MA 01537**<br>**(617) 987-0219**<br>**Contact Michael H. Fields.** | The French River Education Center is an educational collaborative that provides professional development for teachers and consulting for schools. The Center has developed several computer-related programs, including Project 50/50, a program that specializes in helping females and minorities to use computers and to develop job-readiness skills, and The Computer Bus, a mobile unit that trains both students and teachers.<br><br>The Center offers "customized" training, ranging from software evaluation to word-processing training to the development of a full curriculum that uses the computer as a tool. |
| **MassCUE**<br>**Box 82-188**<br>**Wellesley, MA 02181**<br>**Contact Alan November.** | Massachusetts Computer-using Educators (MassCUE) is a statewide organization that facilitates professional development in the area of computer education. MassCUE hosts two statewide conferences each year, sponsors several user groups (including a new group specifically for special-needs educators), and is active politically at the state level. Their bimonthly newsletter and monthly calendar contain grant information, a listing of upcoming events, innovative curricula, job listings, and addresses of related organizations. Membership in MassCUE is $20/year for teachers and $15/year for students. Write Lucille Harper for more information. |
| **Merrimack Education Center, Inc. (MEC)**<br>**101 Mill Road**<br>**Chelmsford, MA 01824**<br>**(617) 256-3985** | The Merrimack Education Center is an educational service agency for 22 school districts in the Merrimack Valley, providing a full range of technology support services for school districts and educational institutions. Professional improvement programs, computer applications planning, and design and delivery of customized curriculum skills labs are some of the available consulting services. A training center housing a large preview collection of software and video products is available for visitation by teachers and administrators. |

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|---|---|
| **Minuteman Tech**<br>**758 Marrett Road**<br>**Lexington, MA 02173**<br>**(617) 861-7150**<br>**Contact Earle Hancock.** | Minuteman Tech offers a variety of workshops on computers. ranging from introductory to advanced levels in word processing, spreadsheets, databases, and desktop publishing. The major focus is on Apple II and Macintosh computers. Special course times and/or subjects can be arranged by request. Contact the Adult Education Office after 4:00 p.m. at 861-7150 for course information. |
| **Mt. Everett Regional H. S.**<br>**Computer Resources Collection**<br>**South Berkshire Regional Dist.**<br>**P.O. Box 218**<br>**Sheffield, MA 01257**<br>**(413) 229-8734**<br>**Contact J. Wayne Eline.** | The Computer Resources library collects books, magazines, journals, hardware and software catalogs, and computer software. Both classroom and administrative programs are available to teachers and administrators. Hardware includes Apple II+, Commodore, and IBM XT. |
| **Special Education Technology Center**<br>**Boston Public Schools**<br>**400 The Fenway**<br>**Boston, MA 02115**<br>**(617) 232-7913**<br>**Contact Madelaine Pugliese.** | The Special Education Technology Center assists Boston public school students in the use of technology in classroom settings. Individuals working directly with special needs students will find a number of services available through the Center, including staff assistance in adapting computers to meet the needs of individual students, classroom technical support, training in the uses of modified computers, a software and 'assistive device' lending library, and computer career planning for students. |
| **Technical Education Research Centers (TERC)**<br>**1696 Massachusetts Avenue**<br>**Cambridge, MA 02138**<br>**(617) 547-0430** | TERC is a private nonprofit research and development organization open to all teachers and administrators. It houses a library of software, books, and periodicals. The classroom software covers math, science, and special needs; the hardware and software are predominantly Apple. Please call TERC in advance to arrange times for using the library. |
| **Bureau of Educational Technologies**<br>**Massachusetts Dept. of Education**<br>**75 Acton Street**<br>**Arlington, MA 02174**<br>**(617) 641-3710**<br>**Contact Susan Foote.** | The Bureau of Educational Technologies and its representatives in each of Massachusetts's six regional education centers provide information on a variety of services pertaining to instructional technology, including grants programs, software review services, state-distributed software packages, video materials, and curriculum development. Contact BET or your local regional education center for more information. |
| **South Coast Educational Collaborative**<br>**Computer Technology Center**<br>**c/o North Middle School**<br>**Whetstone Hill Road**<br>**Somerset, MA 02726**<br>**(508) 672-2060**<br>**Contact Martin Huntley.** | The Computer Technology Center serves its school districts with a full range of long- and short-term training on all facets of educational computing. Workshops and inservice programs can be custom-designed to meet the needs of particular schools or school districts, but the Center also provides an ongoing series of teacher workshops. The Center has an extensive preview library of educational software and a wide selection of computer-related publications and services. |

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**Computer Resource Center**
**Greater Springfield Regional**
**Education Center**
**Macek Drive**
**Chicopee, MA 01013**
**(413) 594-8511**
**Contact Neil Davidson.**

The Computer Resource Center provides services for computer-using educators and acts as a technology "information broker" for the western Massachusetts region. The Center has five different types of microcomputers, houses a software preview library, offers training opportunities, and assists teachers who are interested in developing computer curricula. The Center's educational programs are designed for all grade levels as well as for pre-school, adult, and bilingual education.

## Connecticut

**Connecticut Educators**
**Computer Association**
**700 North Salem Road**
**Ridgefield, CT 06877**
**(203) 227-5469**
**Contact Judith Crawford.**

CECA, Inc. is a nonprofit organization of Connecticut computer-using educators representing all grade levels and disciplines.

## Maine

**Maine Computer Consortium**
**P.O. Box 620**
**Auburn, ME 04210**
**(207) 783-0833**
**Contact Doris Ray.**

The Maine Computer Consortium, a division of the Maine Center for Educational Services, exists to help educators advance the use of computer-related technology in schools. The Consortium is a membership organization open to public and private educational institutions within the state of Maine.

## New Hampshire

**New Hampshire Association for**
**Computer Education Statewide**
**c/o CEFS, Morrill Hall**
**University of New Hampshire**
**Durham, NH 03824**

NHACES facilitates communication about computing among people involved in education in primary and secondary schools, institutions of higher learning, and the New Hampshire Department of Education. The Association publishes a regular newsletter and sponsors conferences, workshops, and other activities.

## Vermont

**Champlain Valley**
**Computer Consortium**
**25 Tanglewood Dr.**
**S. Burlington, VT 05403**
**(802) 658-6177**
**Contact Ed Barry.**

The Champlain Valley Computer Consortium offers non-technical workshops and events that focus on the use of technology in the classroom. The Consortium meets four times during the year in the Greater Burlington area.

**Vermont Council on**
**Educational Technology**
**Castleton State College**
**Castleton, VT 05735**
**(802) 468-5611**
**Contact Dr. Virginia Larrabee.**

The Council's regular meetings offer teachers an opportunity to see computer hardware for the classroom and educational software demonstrated.

# Computer-Related Publications

## Magazines

| | |
|---|---|
| **Classroom Computer Learning**<br>**Peter Li, Inc.**<br>**2451 E. River Rd.**<br>**Dayton, OH 45439**<br>**(800) 543-4383**<br>**$3/issue; $22.50/8 issues** | In non-technical language, this magazine covers many aspects of classroom computing and educational technology. Short feature articles are written for administrators and classroom teachers in primary and secondary schools. It contains a software review column, ideas for classroom activities, and other helpful features. A directory of educational resources is published annually. |
| **The Computing Teacher**<br>**ICCE**<br>**University of Oregon**<br>**1787 Agate Street**<br>**Eugene, OR 97403**<br>**(503) 686-4414**<br>**$4/issue; $28.50/9 issues** | *The Computing Teacher*, published by the International Council for Computers in Education, is written for people interested in the instructional use of computers. Included free with membership in ICCE, *The Computing Teacher* contains material for immediate classroom use, software and book reviews, classroom activities, regular columns, and an annual index. |
| **Electronic Learning**<br>**Scholastic, Inc.**<br>**730 Broadway**<br>**New York, NY 10003-9538**<br>**(212) 505-3051**<br>**$3.50/issue; $23.95/8 issues** | *Electonic Learning* provides a non-technical introduction to educational computing. Articles are written for beginning and intermediate users of calculators, computers, and other electronic learning aids at the K-12 and college level. |
| **Teaching and Computers**<br>**Scholastic, Inc.**<br>**730 Broadway**<br>**New York, NY 10003-9538**<br>**(212) 505-3482**<br>**$3.50/issue; $19.95/year** | Written for elementary school teachers, this magazine provides information and practical suggestions for incorporating computers into the classroom. *Teaching and Computers* publishes information about how computers work, different lesson ideas, and reviews of new books, software, and other resources. |



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**T.H.E. Journal**
**2626 South Pullman**
**Santa Ana, CA 92705**
**(714) 261-0366**
**Free to qualifying schools and organizations.**

Published eight times a year, *Technological Horizons in Education (T.H.E. Journal)* covers both theoretical and practical aspects of educational technology, with an emphasis on postsecondary education.

## Reference Materials

**ICCE Preview Guide**
**University of Oregon**
**1787 Agate Street**
**Eugene, OR 97403-9905**
**(503) 686-4414**
**Published annually; $8 plus $2.50 for shipping and handling.**

The latest edition (available as of August 1988) lists over 500 titles of favorably reviewed software for K-12 classroom use. Designed to assist in locating software for preview, it does not endorse products for purchase without examination. The Guide was developed by the Educational Software Evaluation Consortium, representing 29 computer-education organizations in North America.

**MicroGram EPIE Institute**
**P.O. Box 839**
**Water Mill, NY 11976**
**(516) 283-4922**
**$55/12 issues**

Brief descriptions of more than 150 pieces of software, along with information on availability.

**Software Reviews on File**
**Facts on File, Inc.**
**460 Park Avenue, South**
**New York, NY 10016**
**(212) 683-2244**
**Published monthly; $175/year**

Monthly review of educational and business software, as well as programs with other applications. An updated index accompanies each issue.

**TESS—The Educational Software Selector**
**EPIE Institute, P.O. Box 839**
**Water Mill, NY 11976**
**(516) 283-4922**
**1986-87 TESS: $59.95 plus $7 postage and handling**
**1988 supplement: $32.95 plus $3 postage and handling**

A directory of software programs designed for preschool through college that describes over 7,200 available programs. A 1988 supplement also includes 3,800 additional titles. *TESS* also includes EPIE recommendations, citations of reviews by others, important ordering policies of software publishers, and a guide to responsible software selection and use. Starting in fall, 1988, *TESS* will be published as subject-specific quarterlies.

**The Neuter Computer**
**Women's Action Alliance, Inc.**
**370 Lexington Avenue**
**Suite 603**
**New York, NY 10017**
**$22.95 plus %15 postage and handling**

This guide offers suggestions on how to boost female interest in computers. Some examples include going out of your way to ask girls to participate in computer activities or to demonstrate new techniques, producing the school newspaper with the aid of computers or conducting a computer art show. The guide's more than 50 pilot-tested activities can help significantly increase female participation in computer courses.

# Glossary

**arithmetic logic unit:** a part of the computer that performs arithmetic operations such as adding numbers and logical operations such as comparisons.

**artificial intelligence:** a field concerned with developing computer systems that simulate human thought. Artificially intelligent devices may understand language, learn, reason, and exhibit other human-like thought processes.

**bit:** the smallest unit of information in a computer, equivalent to a single zero or one. The word "bit" is a contraction of "binary digit".

**byte:** a sequence of eight bits, treated as a unit for computation or storage in memory.

**central processing unit (CPU):** a part of the computer that interprets and executes instructions. It is composed of an arithmetic logic unit, a control unit, and a small amount of memory. In most personal computers, the entire CPU is contained in one microprocessor chip.

**computer:** a programmable machine that processes information.

**control unit:** a part of the central processing unit of the computer that interprets instructions and carries them out.

**disk drive:** a mechanism that rotates an information storage disk, and reads or records data.

**hard disk:** an information storage device often built into personal computers that typically hold twenty to forty megabytes of information. A hard disk consists of a metal (usually aluminum) platter with a highly polished coating of magnetic particles

**hardware:** the physical equipment that makes up a computer system.

**input device:** a part a computer system that conveys information from outside the system into the computer. Common examples include keyboards, joyticks and mice.

**integrated circuit (IC):** an electronic circuit with all of its components etched on a single piece of a semiconductor material, usually silicon.

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**memory:** a part of the computer that stores information internally.

**microprocessor:** a single integrated circuit (or chip) containing all the parts of a computer's central processing unit.

**modem:** a device used by a computer to communicate with other computers via a telephone line.

**monitor:** a display console similar to a television that shows a computer's output.

**output device:** a part a computer system that displays information from inside the the computer. Common examples include printers and monitors.

**program:** a specific, detailed set of instructions for accomplishing a specific purpose.

**punch card**: an early form of permanent storage for computers. A punch card consists of a stiff paper card through which small holes can be punched to represent information.

**RAM chip:** temporary computer memory that can be read from and written to by the user. RAM is usually erased when the computer is reset or turned off.

**ROM chip:** permanent computer memory that can be read from by the user, but cannot be re-written. ROM retains its information even when the power to the computer is turned off.

**software:** instructions for a computer, such as a program or set of programs, that can be loaded into a computer and executed. Software does not have a physical form, but is pure information stored in a computer or as magnetic data on a disk.

**stored-program computer**: a computer with memory into which programs can be loaded, as opposed to a computer in which switches or wires must be physically moved to perform different tasks.

**transistor:** an early semiconductor device that can be used as a switch or amplifier.

**vacuum tube:** the earliest form of electronic switching and storage device. The vacuum tube consists of large electronic parts sealed in a glass bulb.