Introduction to Computing with Images

CSC 1040 – Algorithms and Data Structures I

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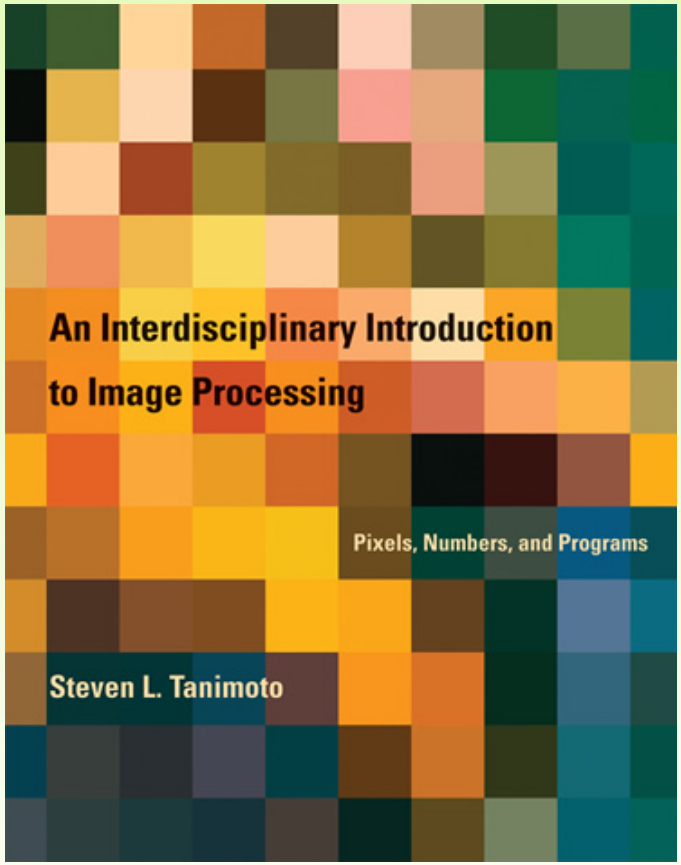
Course website:
www.csc.villanova.edu/~map/1040/

Some slides in this presentation are adapted from the slides accompanying Java Software Solutions by Lewis & Loftus

What is this course about?

- Computer Science
- Problem solving
- Algorithmic thinking
- Data representation
- Images and graphics
- Visual communication

Our textbook



An Interdisciplinary Introduction to Image Processing

Pixels, Numbers, and Programs

Steven L. Tanimoto

The MIT Press

Reverse History of computing

Examine what we already know, travel backwards…

1. What we see now all around us – a connected world of computing

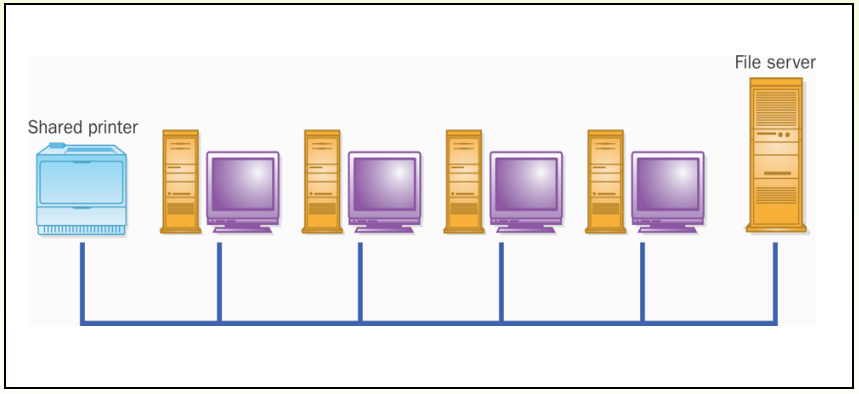
2. Focus on a single “traditional” computer

3. Dig deeper – data and processing

Networks

A *network* is two or more computers that are connected so that data and resources can be shared

A *Local-Area Network* (LAN) covers a small distance and a small number of computers



A *Wide-Area Network* (WAN) connects two or more LANs, often over long distances

The Internet

- **History:** Started as a United States government project, sponsored by the Advanced Research Projects Agency (ARPA) in late 1970's
  - 1980's: ***ARPANET***
    - the wide area network and Protocols for communication, including url's developed
  - 1990's: ***World Wide Web***
    - html and web browsers

IP and Internet Addresses

- Each computer on the Internet has a unique *IP address*, such as:

  `204.192.116.2`

- Most computers also have a unique Internet name, which also is referred to as an *Internet address*:

  `hector.vt.edu`

  `kant.gestalt-llc.com`

- The first part indicates a particular computer (`hector`)
- The rest is the *domain name*, indicating the organization (`vt.edu`)

Domain Names

- The last part of a domain name, called a *top-level domain* (TLD), supposedly indicates the type of organization:

edu	educational institution
com	commercial entity
org	non-profit organization
net	network-based organization

Sometimes the suffix indicates the country:

uk	United Kingdom
au	Australia
ca	Canada
se	Sweden

Additional TLDs have been added:

biz, info, tv, name

The World Wide Web

- The *World Wide Web* allows many different types of information to be accessed using a common interface
- A *browser* is a program which accesses network resources and presents them
  - Popular browsers: Internet Explorer, Safari, Firefox
- Resources presented include:
  - text, graphics, video, sound, audio, executable programs
- A Web document usually contains *links* to other Web documents, creating a *hypermedia* environment
- The term Web comes from the fact that information is not organized in a linear fashion

The World Wide Web

- Web documents are often defined using the *HyperText Markup Language* (HTML)
- Information on the Web is found using a *Uniform Resource Locator* (URL):

```
http://www.cnn.com

http://www.vt.edu/student_life/index.html

ftp://java.sun.com/applets/animation.zip
```

- A URL specifies a protocol (http), a domain, and possibly specific documents

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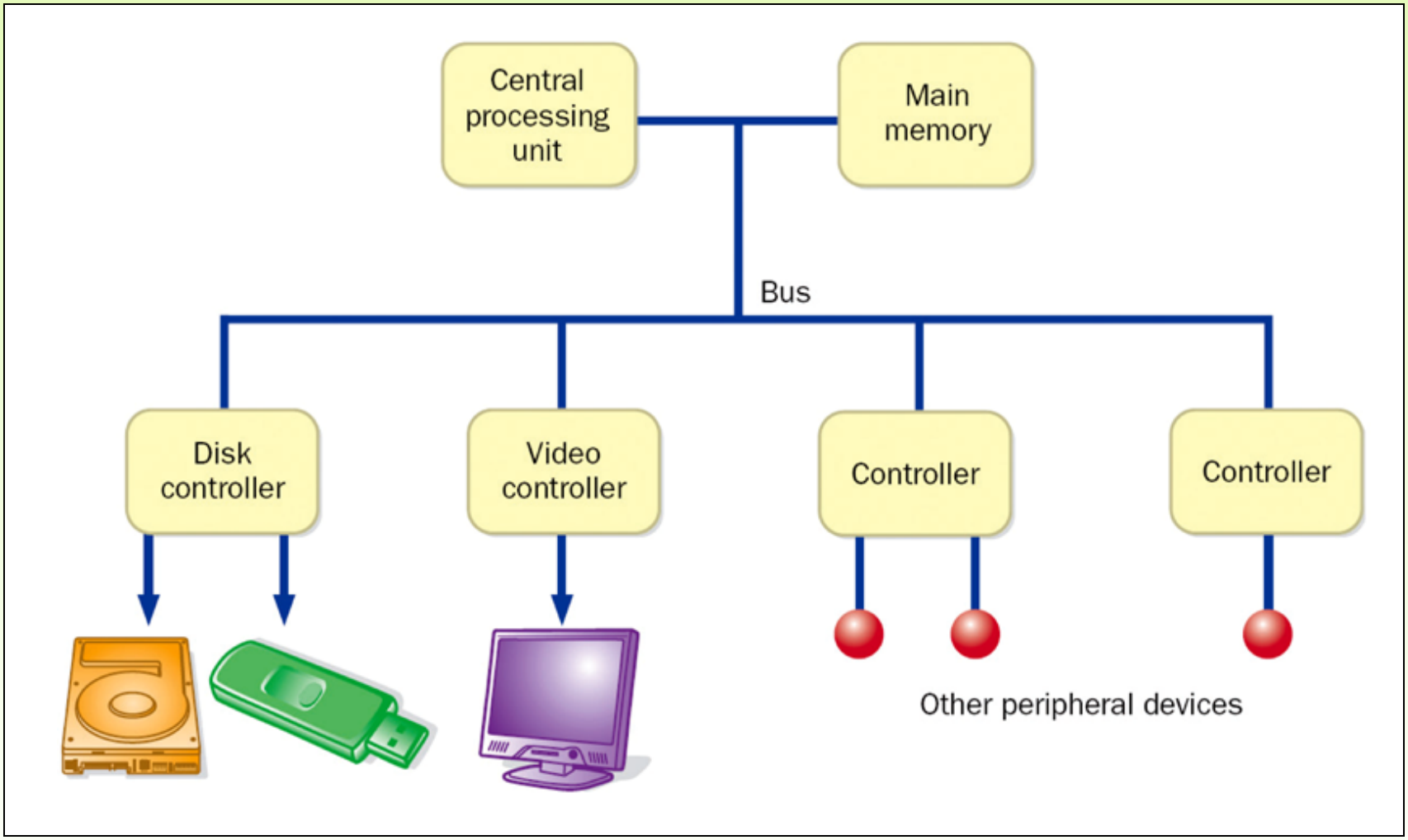
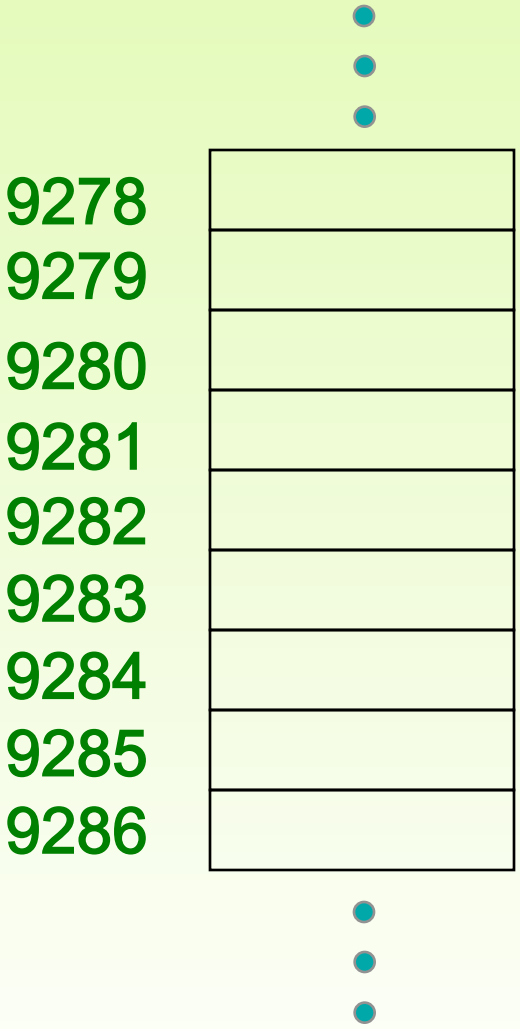
A Computer Specification

- Consider the following specification for a personal computer:
  - 3.07 GHz Intel Core i7 processor
  - 4 GB RAM
  - 750 GB Hard Disk
  - 16x Blu-ray / HD DVD-ROM & 16x DVD+R DVD Burner
  - 17” Flat Screen Video Display with 1280 x 1024 resolution
  - Network Card

Computer Architecture



Memory



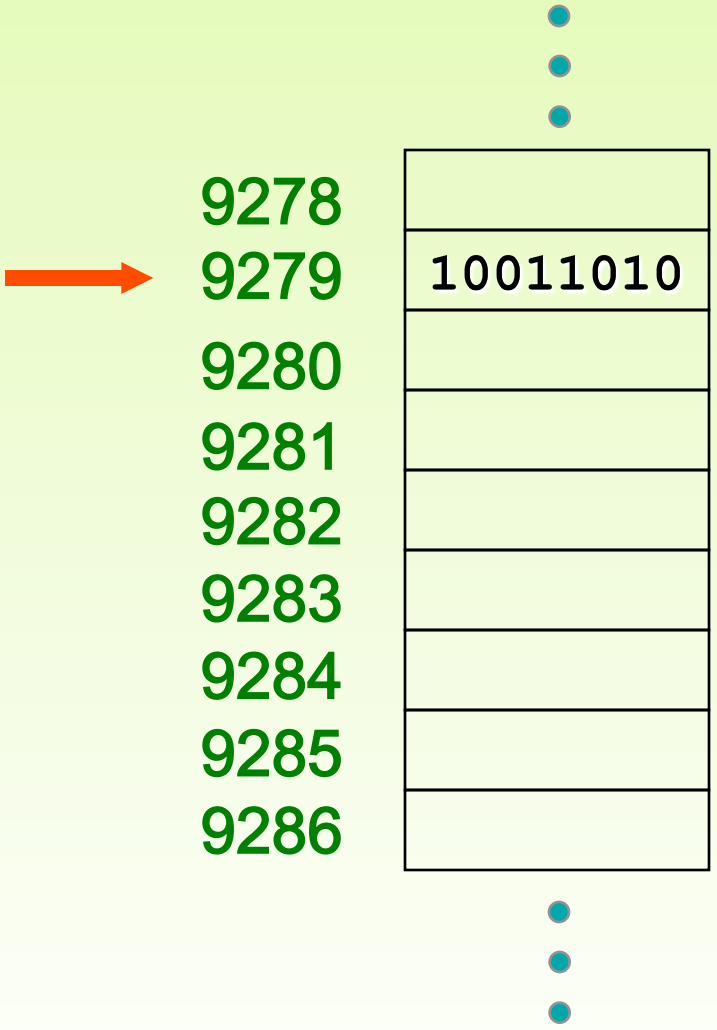
Main memory is divided into many memory locations (or *cells*)

Each memory cell has a numeric *address*, which uniquely identifies it

Why is main memory called “RAM”????

"Random Access Memory (RAM)"

You don't have to scan the memory sequentially – go to data directly using the address

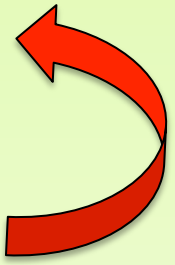


Memory characteristics

- ***Direct access*** or ***Random access*** – information can be reached directly (as opposed to sequentially as in the case of magnetic tape)
- ***Volatile*** - stored information is lost if the electric power is removed
- ***Read/Write*** – information can be overwritten (as opposed to read-only devices – ROM)

What is “ROM”? is it the opposite of “RAM”????

Read Only Memory



What is “ROM”?

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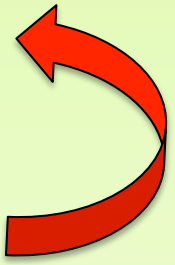
Read Only Memory



What is “ROM”?

is it the opposite of “RAM”????

NO!

ROM is also random access

RAM vs. ROM

- *RAM* - Random Access Memory
  - synonymous with main memory:
    - fast
    - read/write
    - volatile
    - random access
- *ROM* - Read-Only Memory
  - ROM typically holds the firmware, eg BIOS
    - fast (except in CD-ROM)
    - read only
    - non-volatile
    - random access

Random Access Memory Devices

	Volatile	Non-volatile
fastest	CPU registers Cache memory	ROM chip
fast	main memory (Also called Random Access Memory -- RAM)	ROM chip
slow		USB flash drive Hard disks CD-ROM DVD

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magnetic

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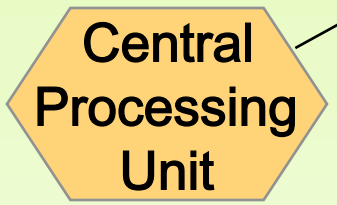
optical

Storage Capacity

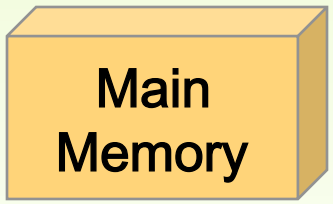
- Every memory device has a *storage capacity*, indicating the number of bytes it can hold
- Capacities are expressed in various units:

Unit	Symbol	Number of Bytes
kilobyte	KB	2^{10} = 1024
megabyte	MB	2^{20} (over one million)
gigabyte	GB	2^{30} (over one billion)
terabyte	TB	2^{40} (over one trillion)
petabyte	PB	2^{50} (a whole bunch)

CPU and Main Memory



Chip that executes program commands



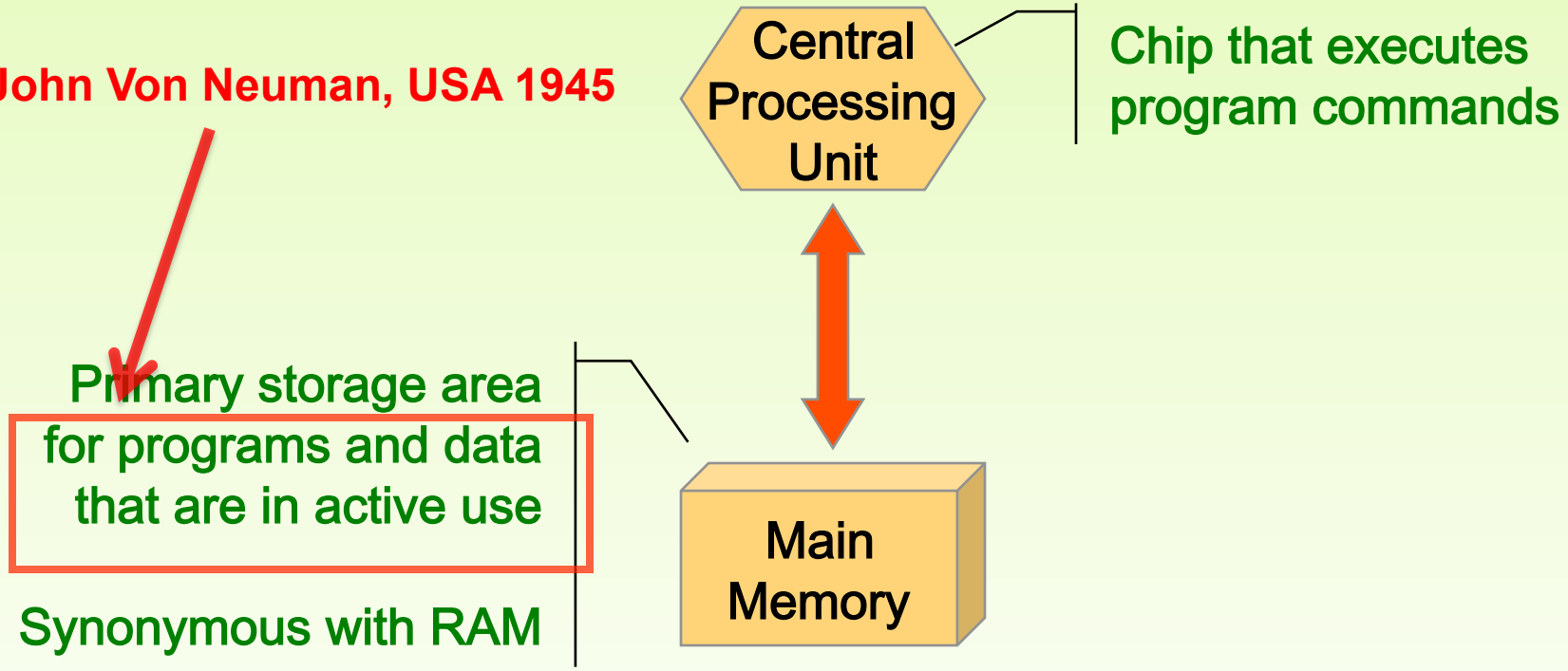
Primary storage area for programs and data that are in active use

Synonymous with RAM

CPU and Main Memory

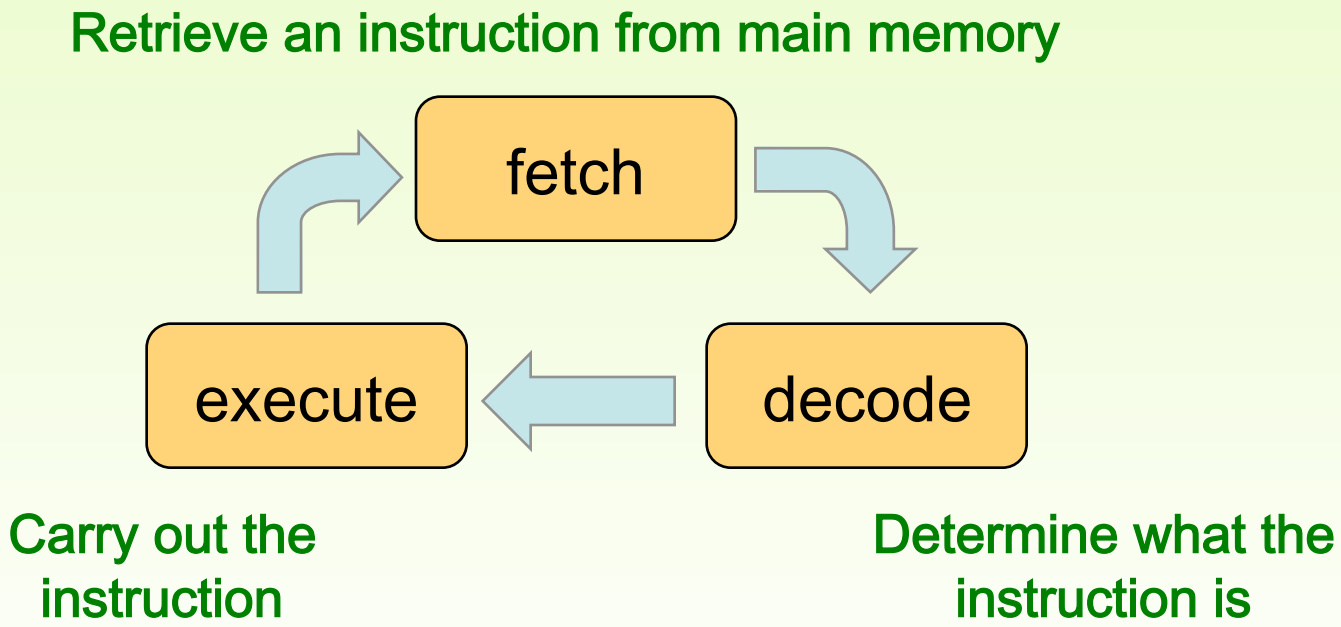
Historic note:
Von Neuman architecture

John Von Neuman, USA 1945



The Central Processing Unit

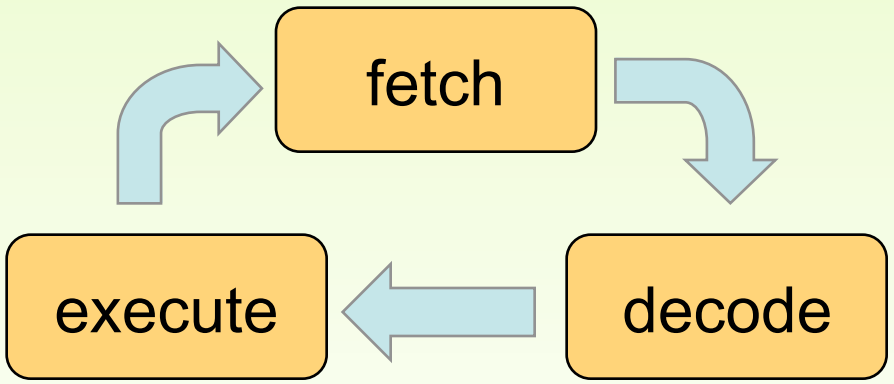
- A CPU is on a chip called a *microprocessor*
- It continuously follows the *fetch-decode-execute cycle:*



The Central Processing Unit

- A CPU is on a chip called a *microprocessor*
- It continuously follows the *fetch-decode-execute cycle:*

Retrieve an instruction from main memory

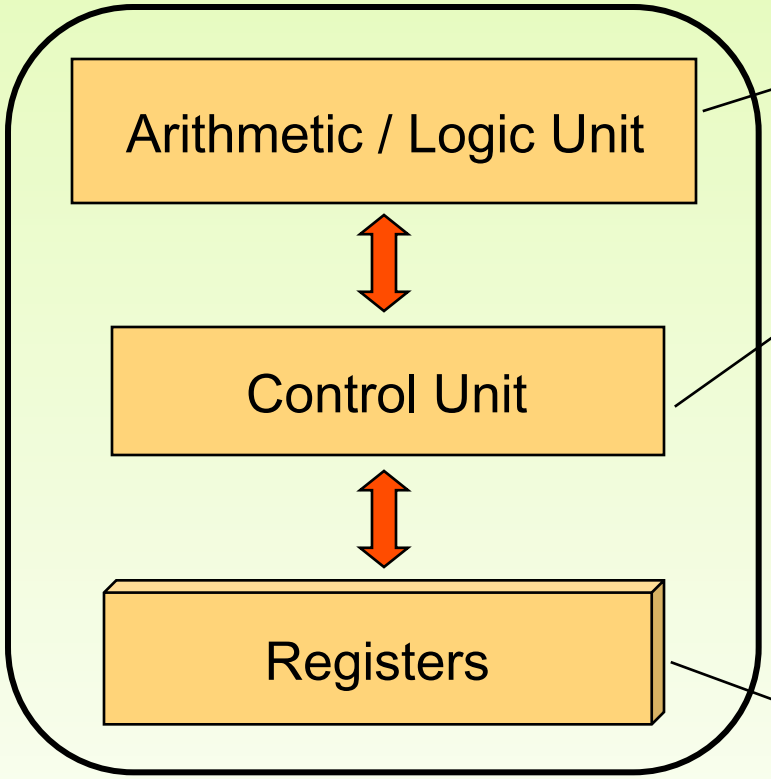


system clock *controls speed,* measured in *gigahertz* (GHz)

Carry out the instruction

Determine what the instruction is

The Central Processing Unit



Performs calculations and makes decisions

Coordinates processing (system clock, decoding, etc)

Small, very fast memory

Historic Note: Automatic control of computation

- The concept of a machine that can follow a series of steps - a "***program***"
- Some early steps:
  - Jacquard loom (1801)
  - Babbage's Difference engine and Analytical engine (1822)
  - Holerith's census machine (1890)
- Stored program and the fetch/decode/execute cycle (John von Neumann, 1945)
- ENIAC - first fully electronic digital computer (Eckert and Mauchley, 1946)
-

Reverse History of computing

Examine what we already know, travel backwards…

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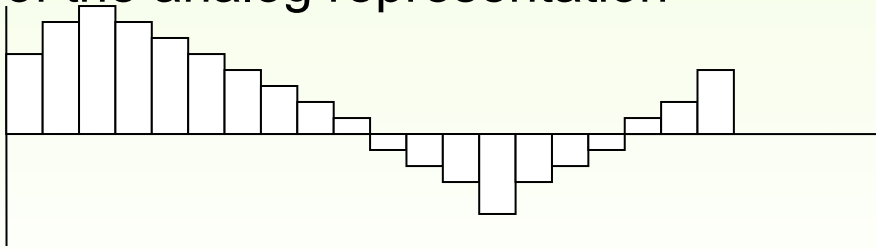
Data Representation

- Computers store all information ***digitally***, using ***binary*** codes:
  - numbers
  - text
  - images
  - audio
  - video
  - program instructions

Analog vs. Digital Data

- *Analog*
  - continuous, in direct proportion to the data represented
  - music on a record album - a needle rides on ridges in the grooves that are directly proportional to the voltages sent to the speaker

- *Digital*
  - information is broken down into pieces, and each piece is represented separately
  - *sampling* – record discrete values of the analog representation



Binary Numbers

- Number system consisting of 1's & 0's
- Simplest way to represent digital information
- modern computers use binary numbers internally

A binary digit is called a ***bit*** - ***bi***nary digi***t***

A ***byte*** is a group of eight bits

Representing and processing bits

- Electronic circuits: high/low voltage
- Magnetic devices (eg hard drive): positive/negative
- Optical devices (eg DVD): light reflected/not reflected due to microscopic grooves

Bit Permutations

1 bit	2 bits	3 bits	4 bits	
0	00	000	0000	1000
1	01	001	0001	1001
	10	010	0010	1010
	11	011	0011	1011
		100	0100	1100
		101	0101	1101
		110	0110	1110
		111	0111	1111

Each additional bit doubles the number of possible permutations

Bit Permutations

How many items can be represented by

- **1 bit ?**
- **2 bits ?**
- **3 bits ?**
- **4 bits ?**
- **5 bits ?**

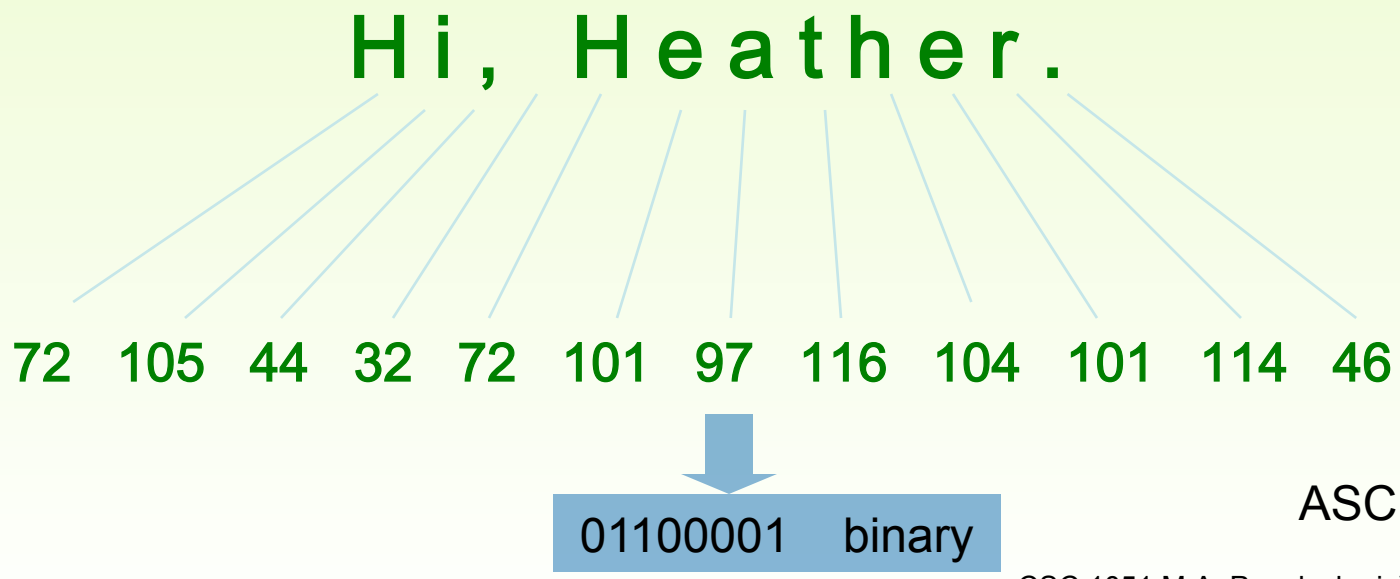
- How many permutations of N bits?
- How many bits are needed to represent 64 items?
- How many bits are needed to represent 100 items?

Binary Representation of Information

- Computers store all information ***digitally***, using ***binary*** codes:
  - numbers
  - text
  - images
  - audio
  - video
  - program instructions

Representing Text Digitally

- For example, every character is stored as a number, including spaces, digits, and punctuation
- Corresponding upper and lower case letters are separate characters

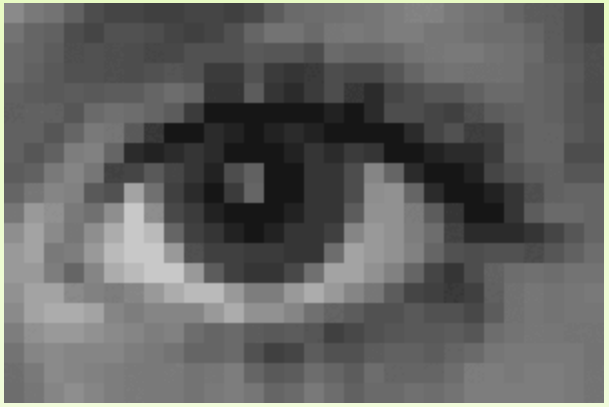


ASCII / UNICODE

Representing Images

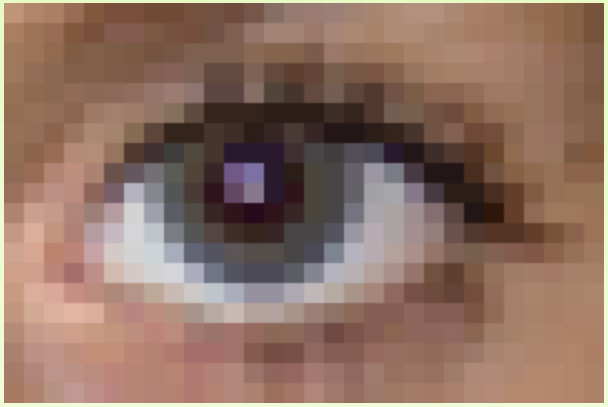
Bitmap

1 bit



Grayscale

8 bits



RGB Color

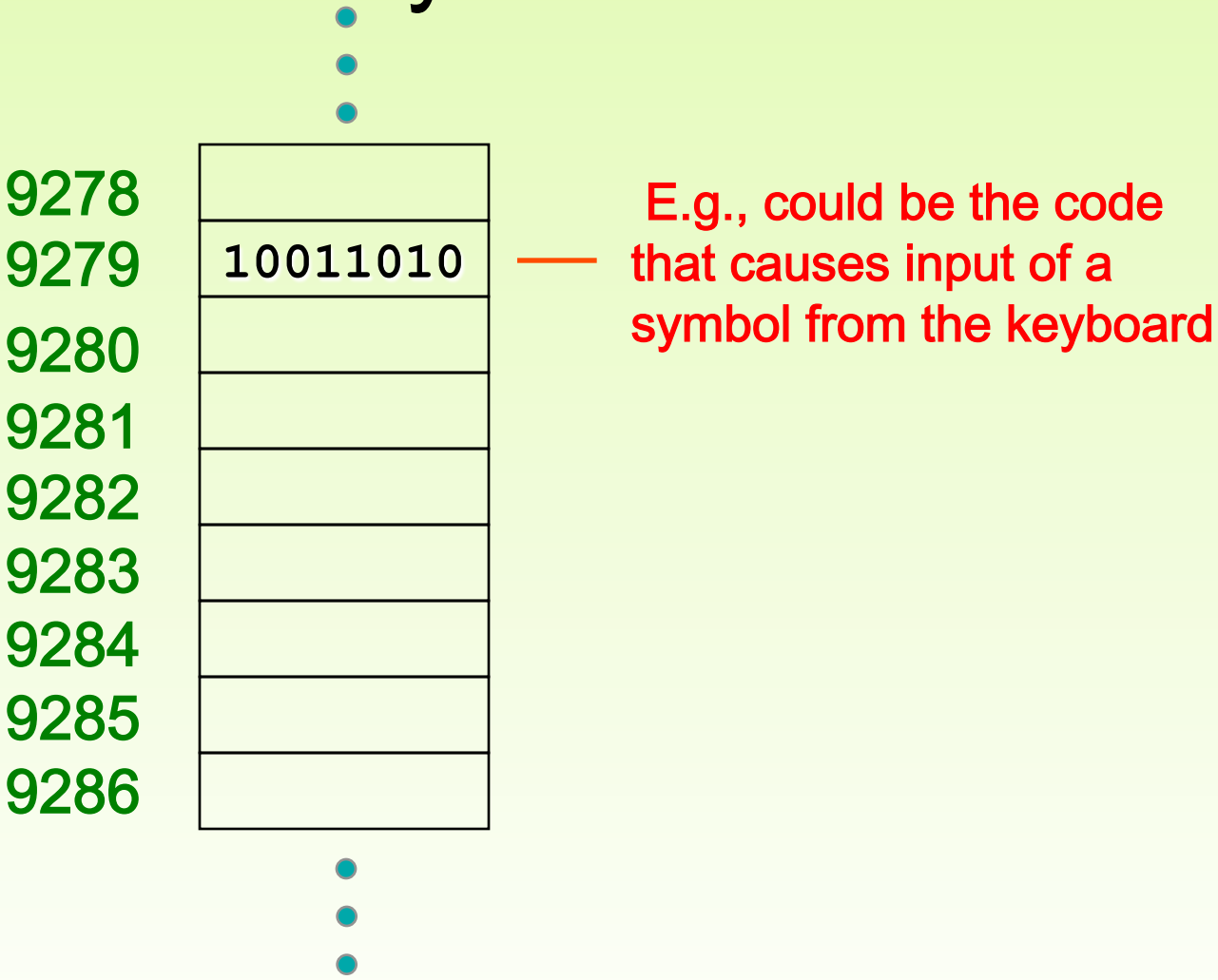
3 colors: red, green, blue

8 bits/color

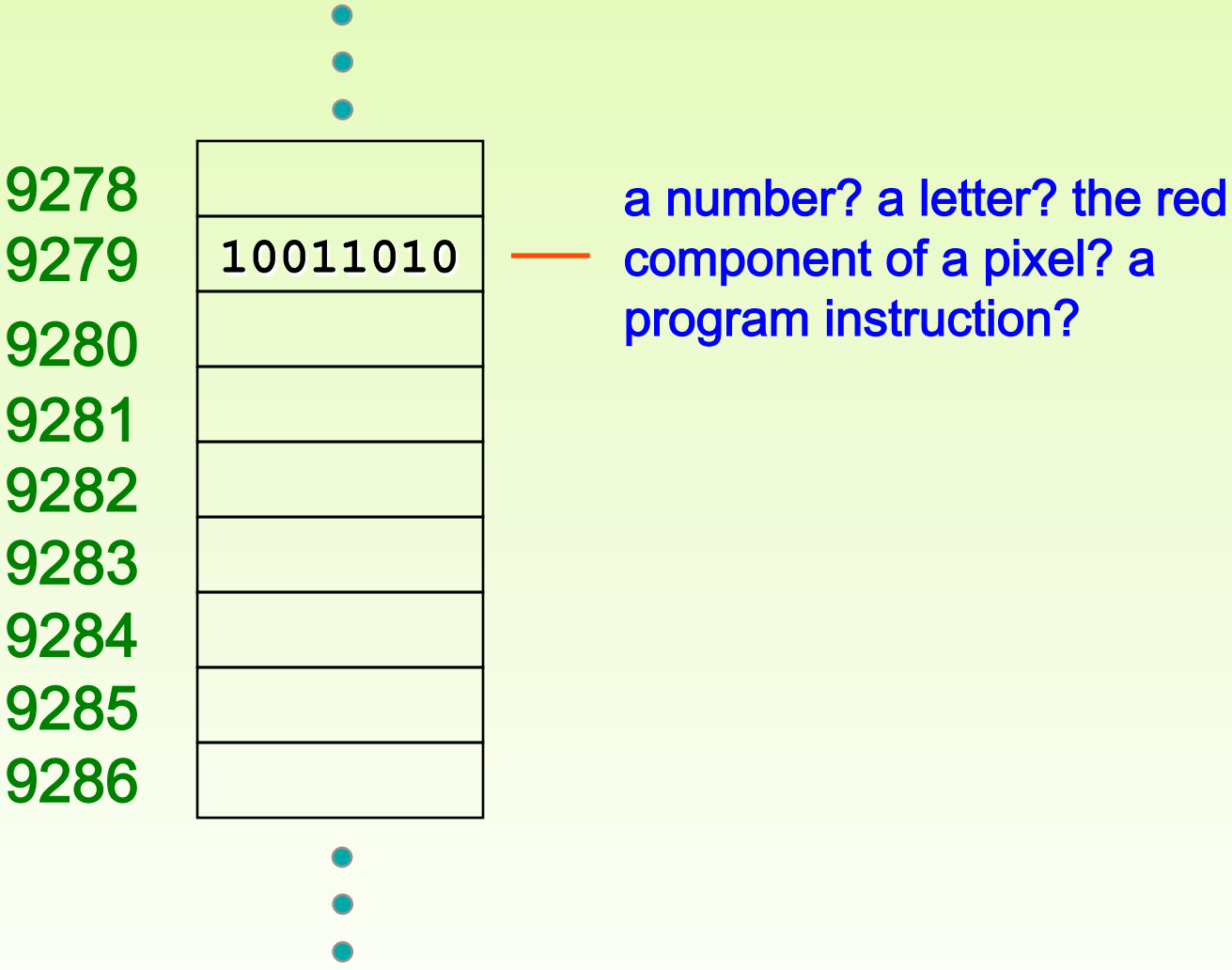
24 bits


y = 9
x = 12
red=108
green=86
blue
Color:(108,86,142)
Position: (12,9)

Program instructions are also encoded in binary



Memory devices store data of ***all kinds***



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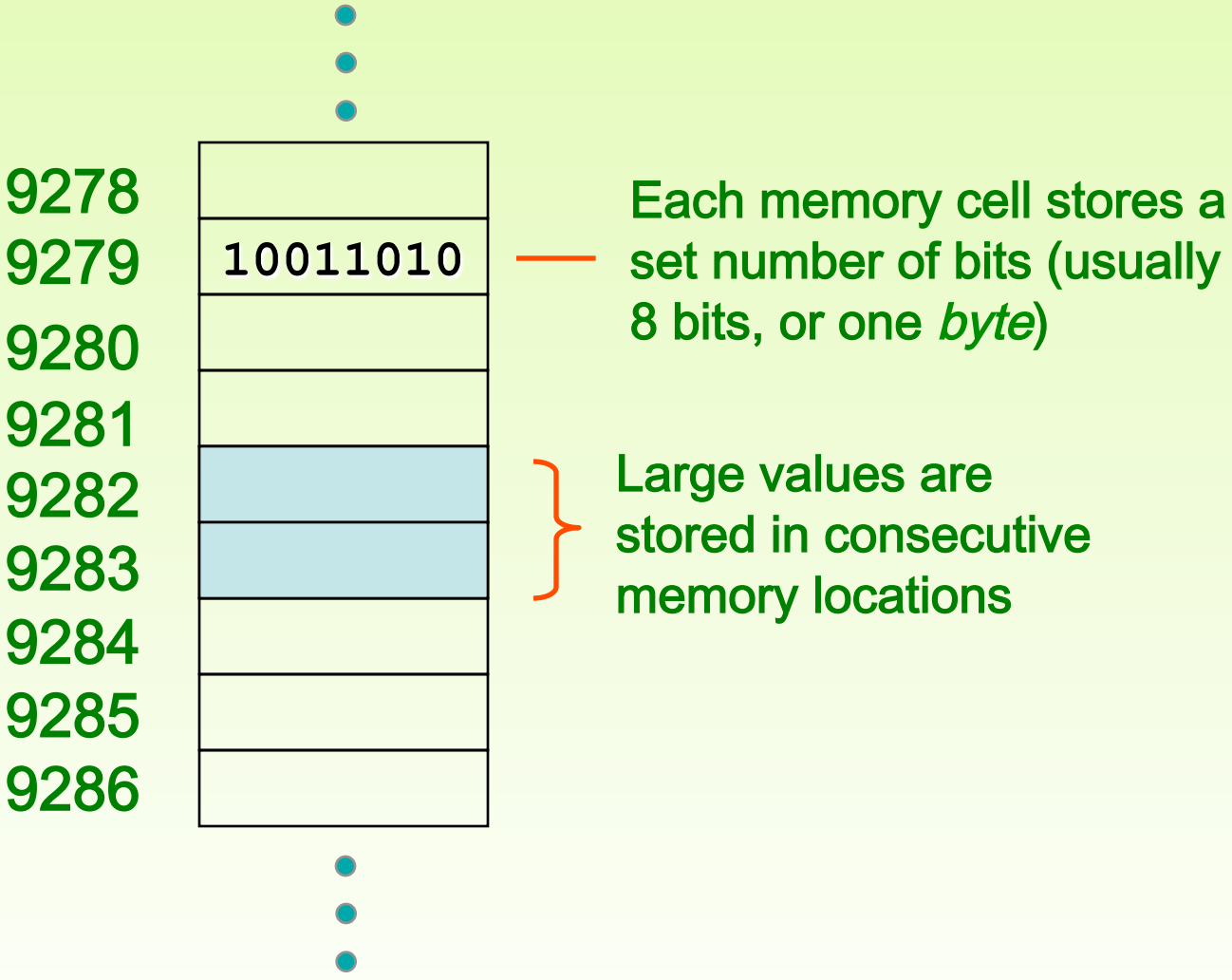

Historic note: Great human developments that gave rise to the modern computer

- Mechanization of arithmetic – the concepts of numbers, symbols, algorithms, and computation
- Automatic control of computation – a “program” to control operations (fetch/decode/execute cycle and the stored program concept)

Historic Note: Mechanization of arithmetic

- Development of number systems
  - Abacus (2400 BC)
  - Number systems (Babylonian, Greek, Roman, Arabic 1000 BC - 800 AD)
- The notion of an algorithm
  - Euclid (300 BC)
  - al-Khwārizmī (780 AD)
- Creation of special purpose calculators
  - Stonehenge (1900-1600 BC)
  - Napier's bones (1600, a precursor of the slide rule)
  - Pascal's adder (1642)
  - Leibniz's calculator (1670s)
  - modern calculators

Mechanization of Arithmetic

+

Automatic Control of Computation

= Modern Computer

Computer Science

Can be viewed as a culmination of humanity's search for understanding of:

- Problem solving
- Mechanization
- Computation
- Representation & encoding
- Abstraction

Just like Physics and other sciences branched off from philosophy during the renaissance, so CS emerged in the 20th century from the work of philosophers and mathematicians (with the help of dedicated, visionary practitioners, experimental scientists and engineers).