INDIAN INSTITUTE OF INFORMATION TECHNOLOGY

Dharwad

ज्ञानेन विकासः

Introduction to Programming and Data Structures

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PDPM

Indian Institute of Information Technology, Design and Manufacturing, Jabalpur

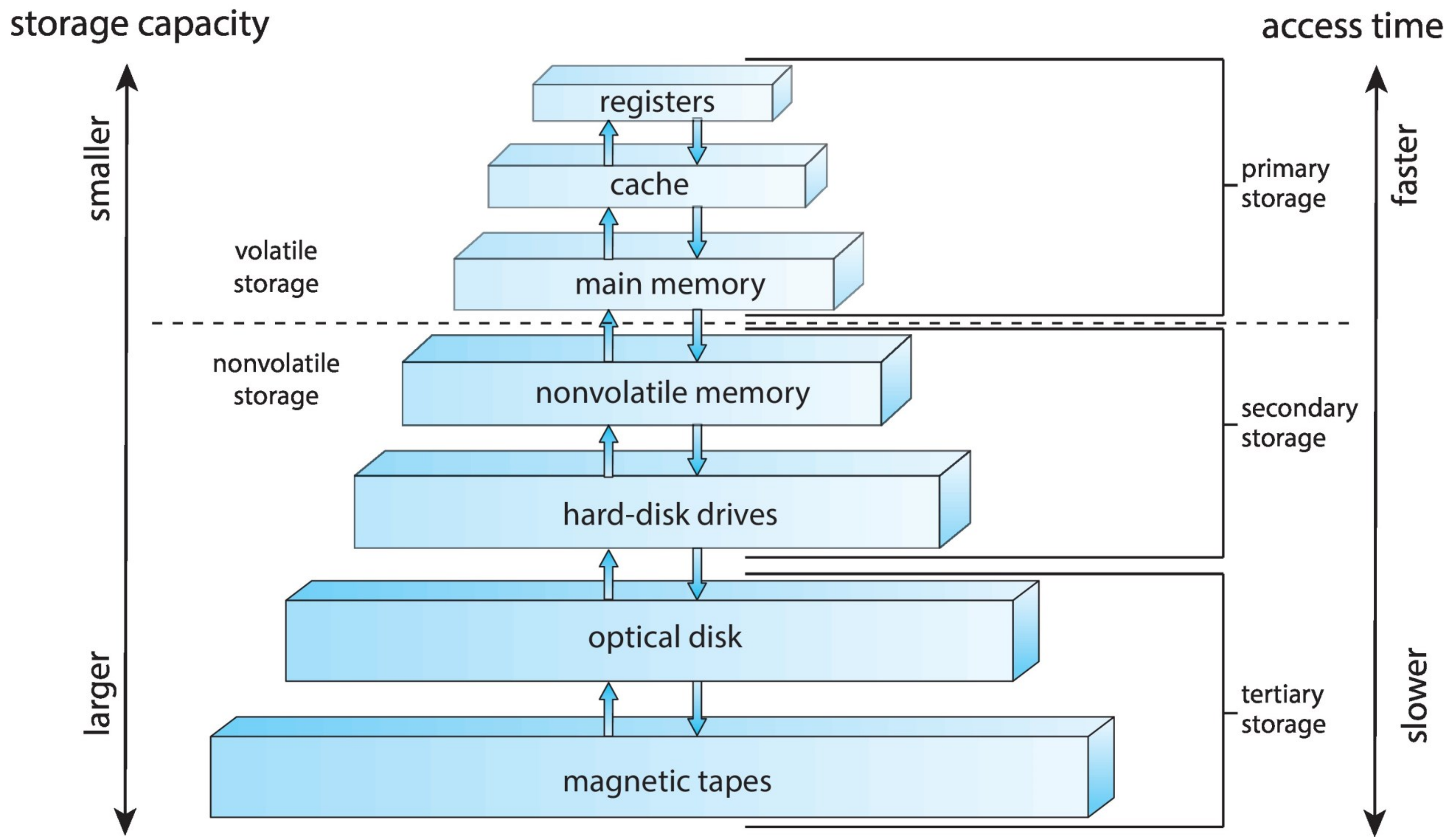
The Alan Turing Institute

Goals of the Course

- Become familiar with some of the fundamental data structures in computer science
- Improve ability to solve problems abstractly
  - data structures are the building blocks
- Improve ability to analyze your algorithms
  - prove correctness
  - gauge (and improve) time complexity
- Skill with the C, Java, and Data structures

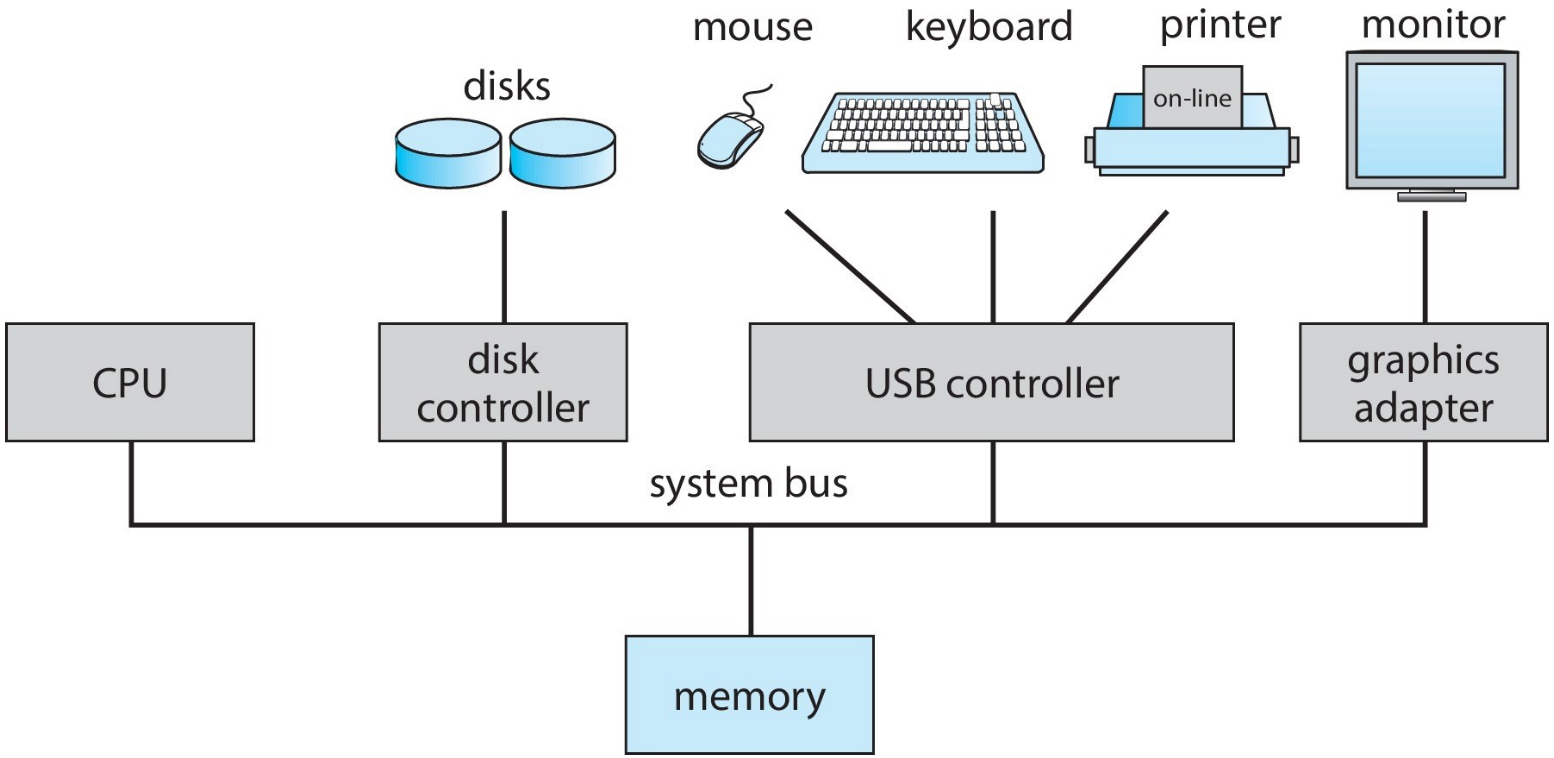
Basic Program Execution on CPU and Memory

Data Storage Device Hierarchy



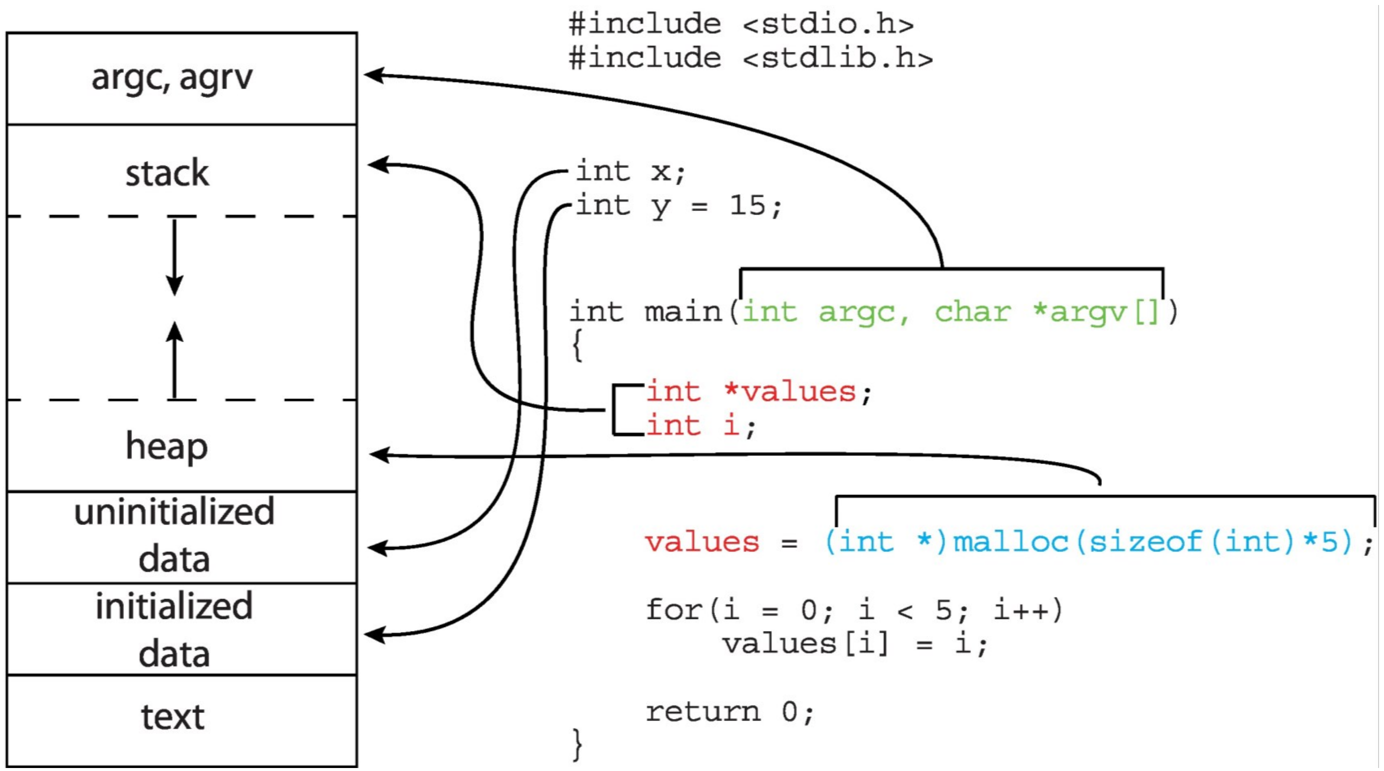
Computer System Organization

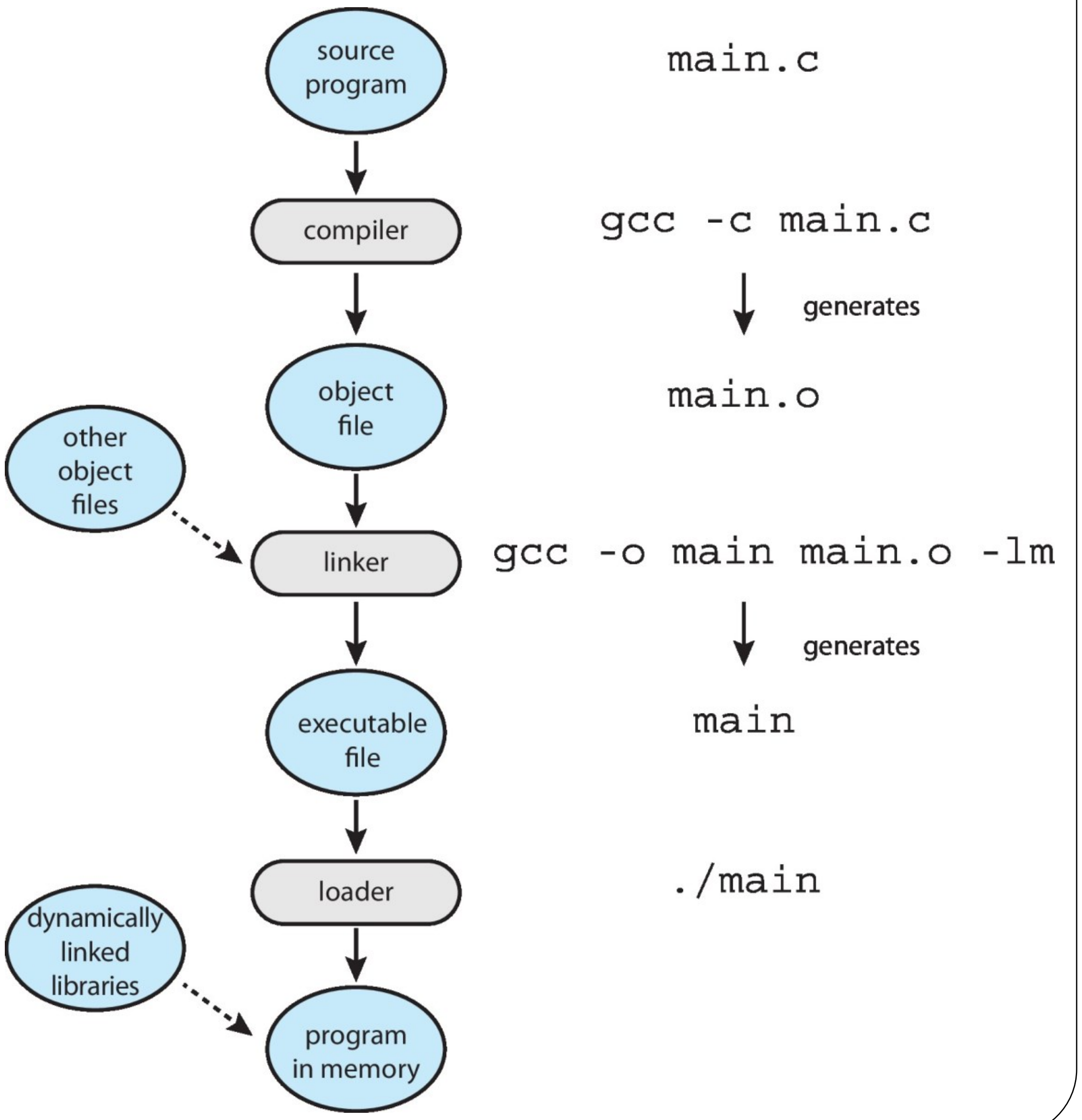
- Computer-system operation
  - One or more CPUs, device controllers connect through common **bus** providing access to shared memory
  - Concurrent execution of CPUs and devices competing for memory cycles



Program to Process

- When you run an exe file, the OS creates a process = a running program

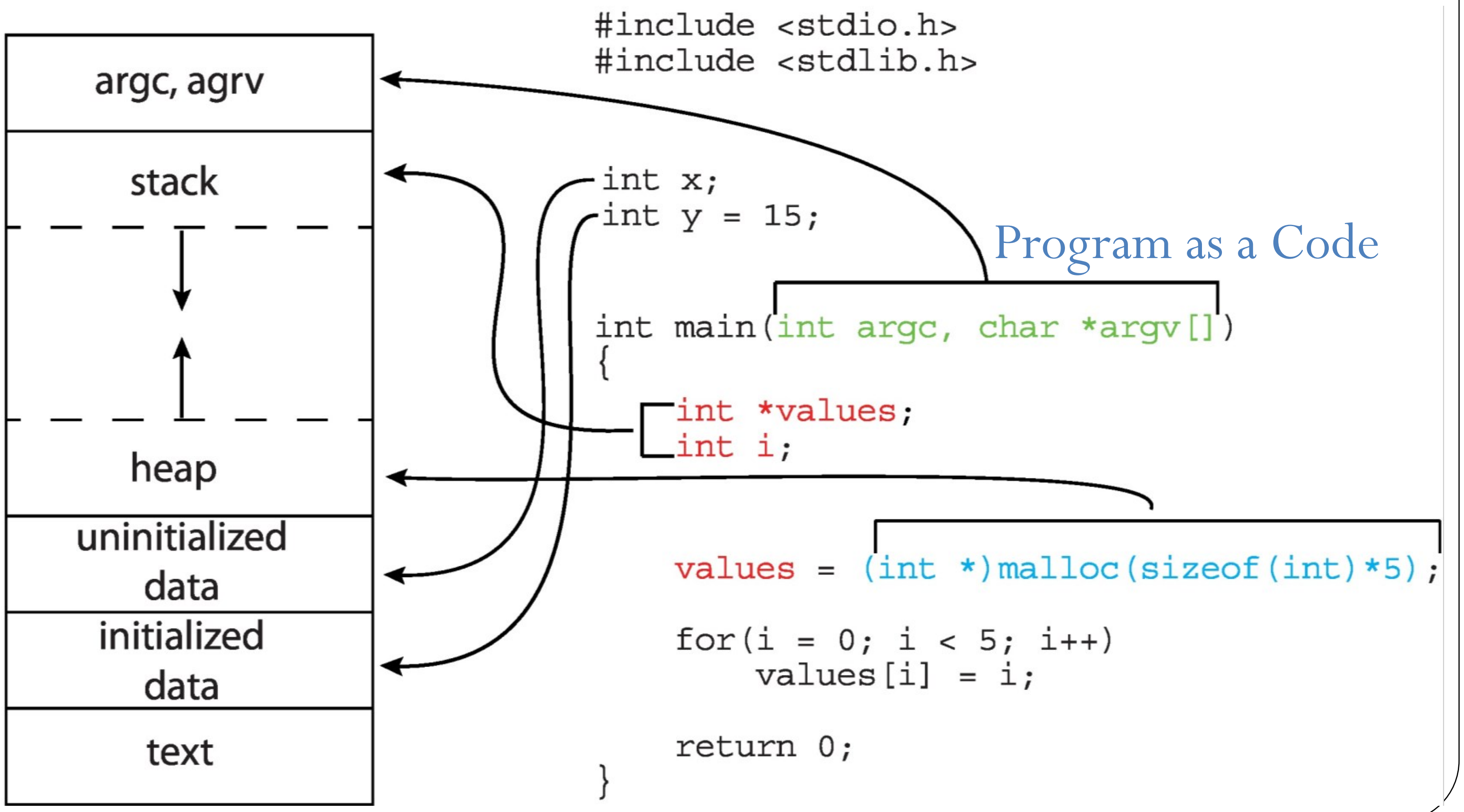




Motivation: Program Code to Memory

- **Abstraction** of complex usage Program as a Memory (RAM or Cache).
- Conversion of **High level language to Low level language**
- Static/global variables are allocated in the executable
  - Local variables of a function on Stack
  - Dynamic allocation with malloc on the heap

Process as a Memory



Program to Process

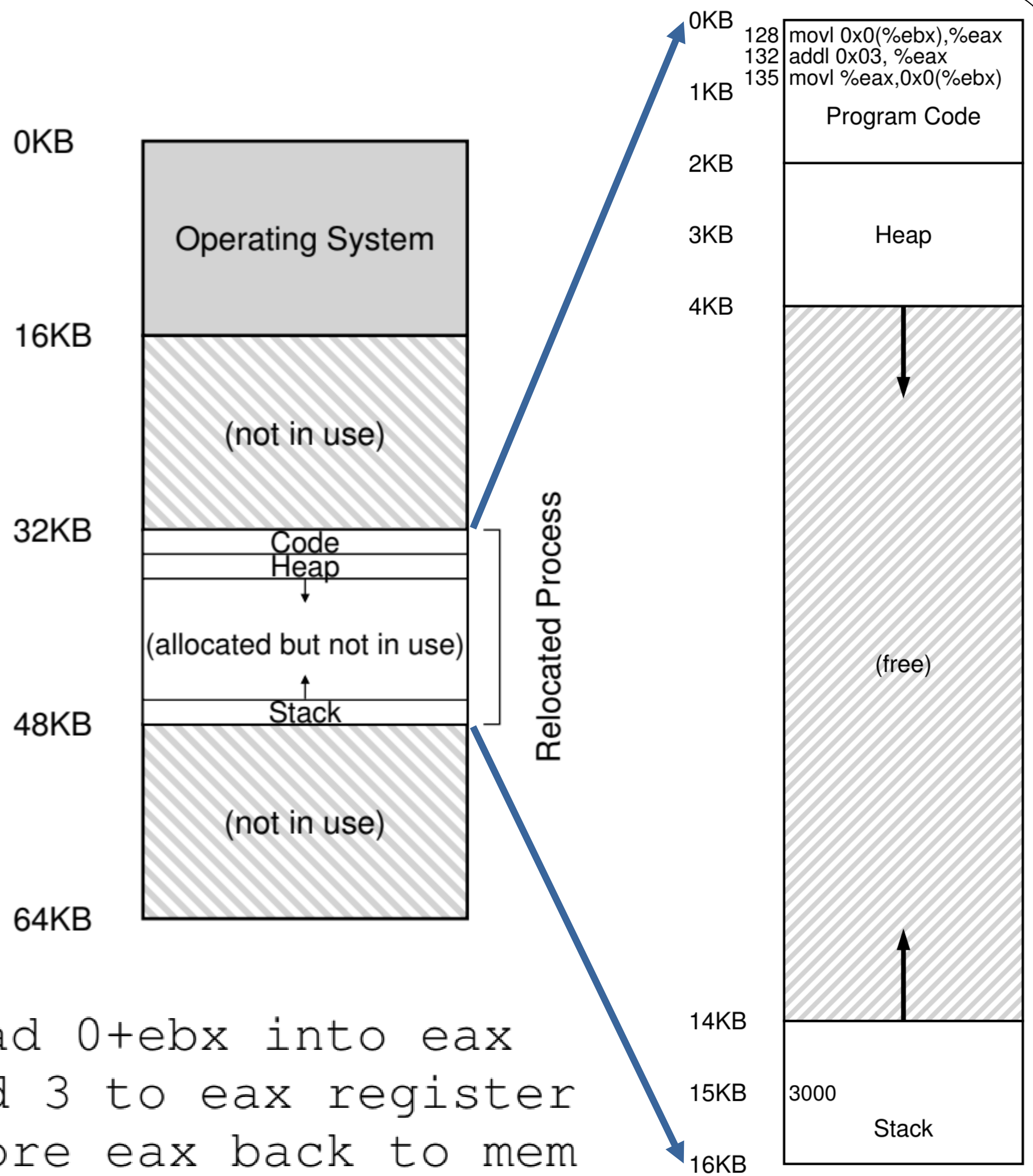
- Virtual address space is setup by OS during process creation

Simplified OS: places entire memory image in one chunk

```
void func() {
    int x = 3000;
    x = x + 3;
    ...
```

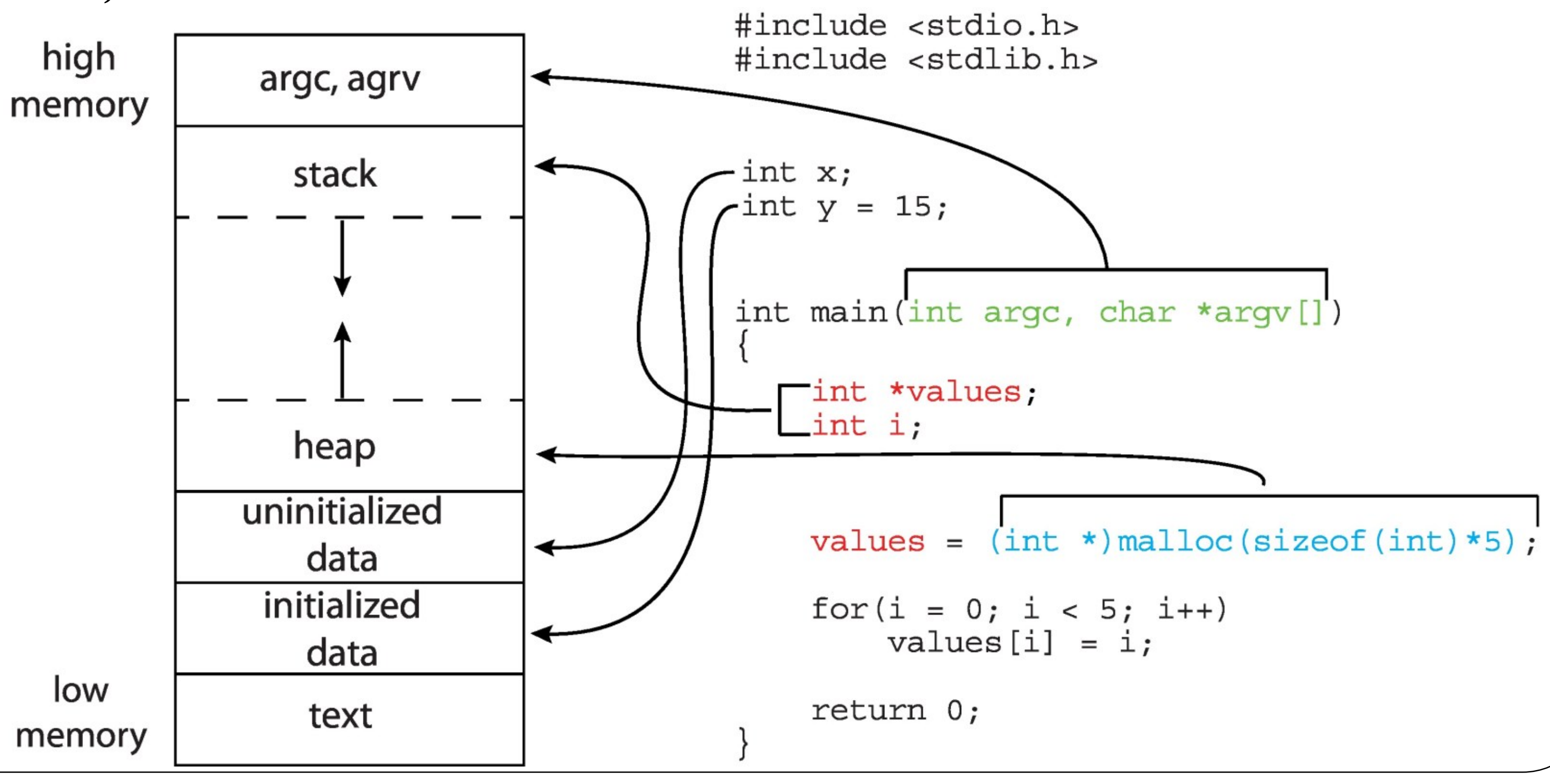
Compiler

```
128: movl 0x0(%ebx), %eax      ;load 0+ebx into eax
132: addl $0x03, %eax          ;add 3 to eax register
135: movl %eax, 0x0(%ebx)      ;store eax back to mem
```

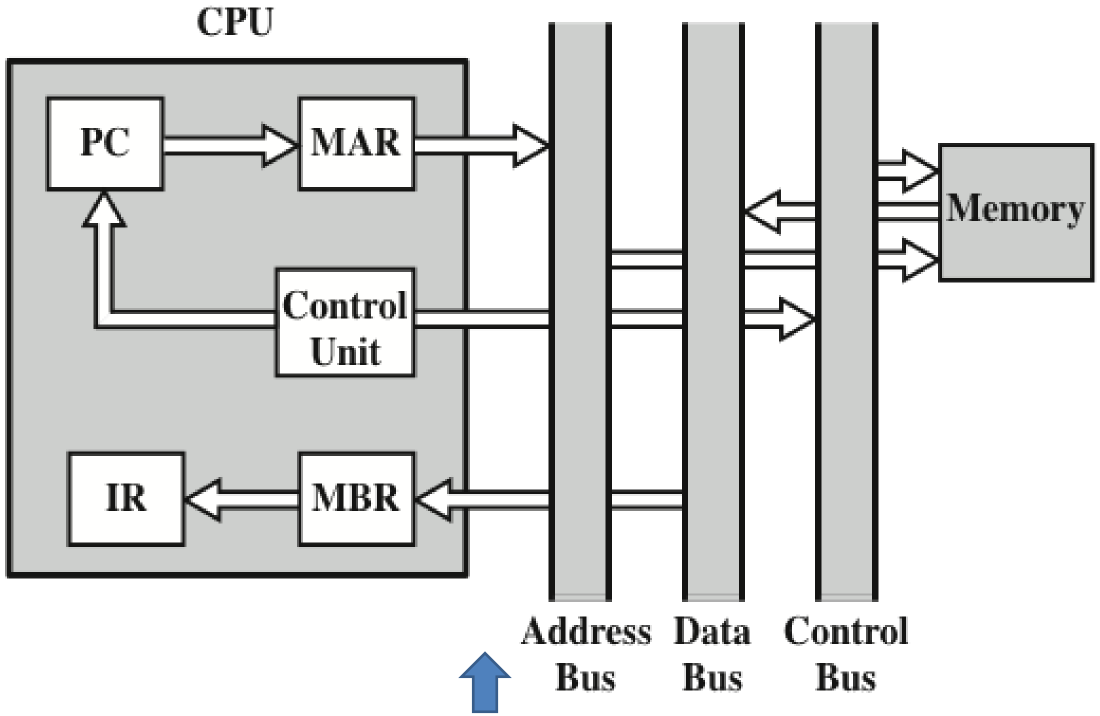


Program and Process

- A unique identifier
- Points CPU program counter to current instruction – Other registers may store operands, return values etc.
- CPU context: registers
  - Program counter
  - Current operands
  - Stack pointer

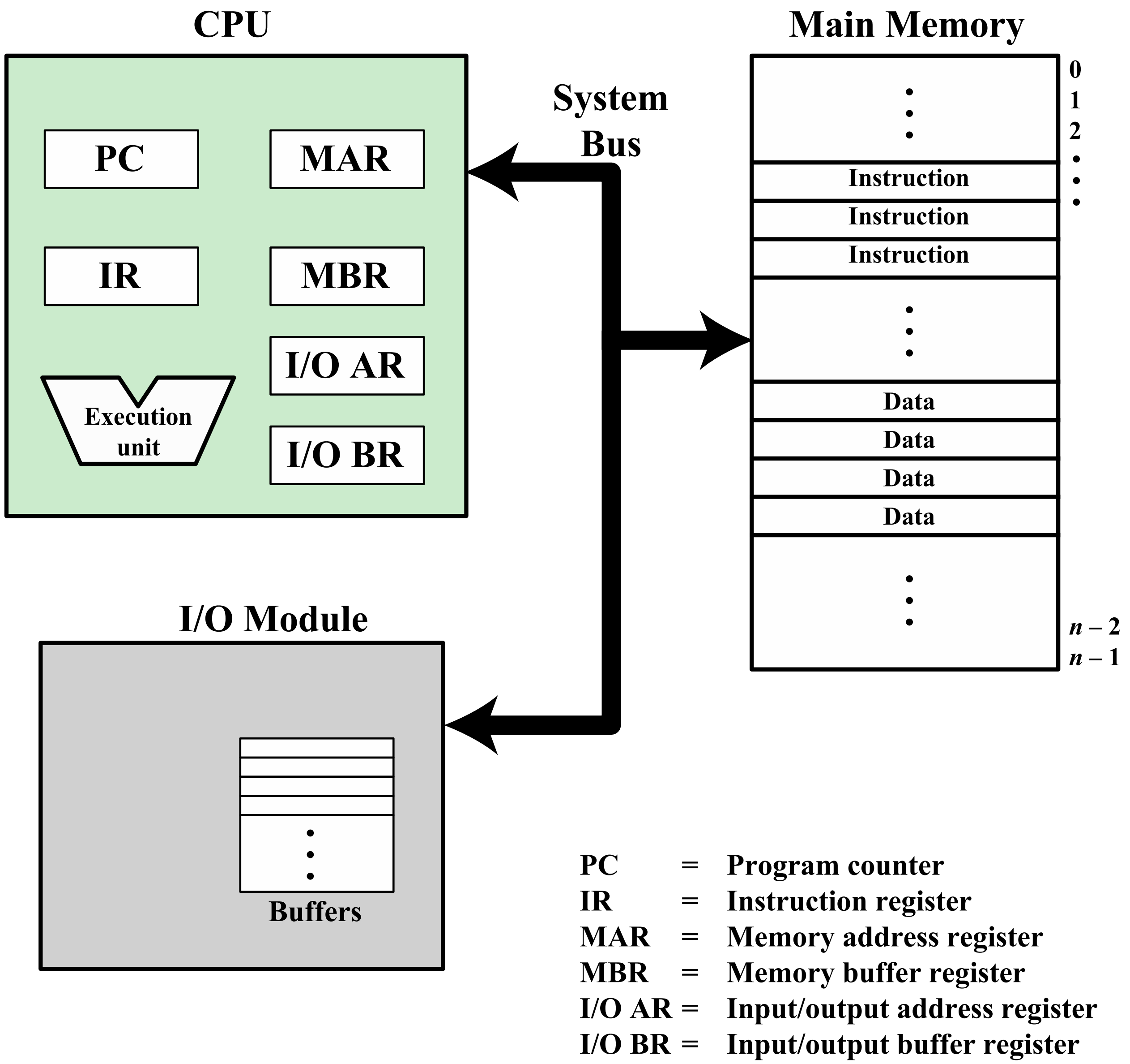


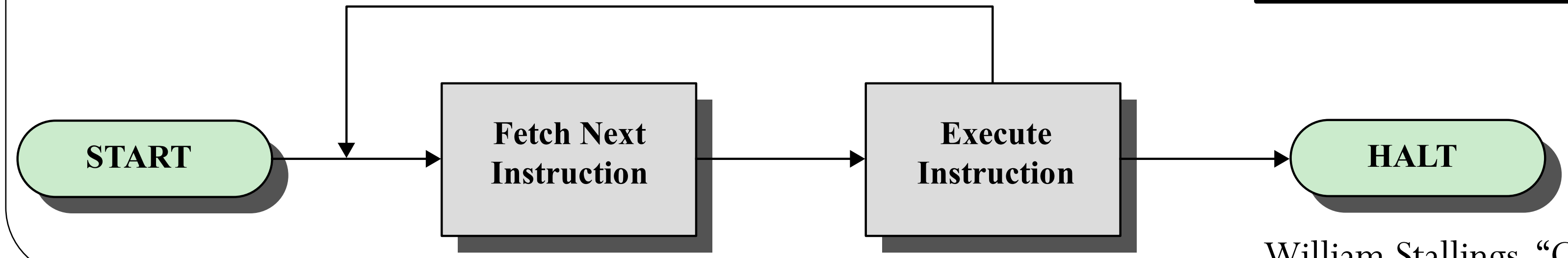
CPU and Memory



Fetch Cycle

Execute Cycle





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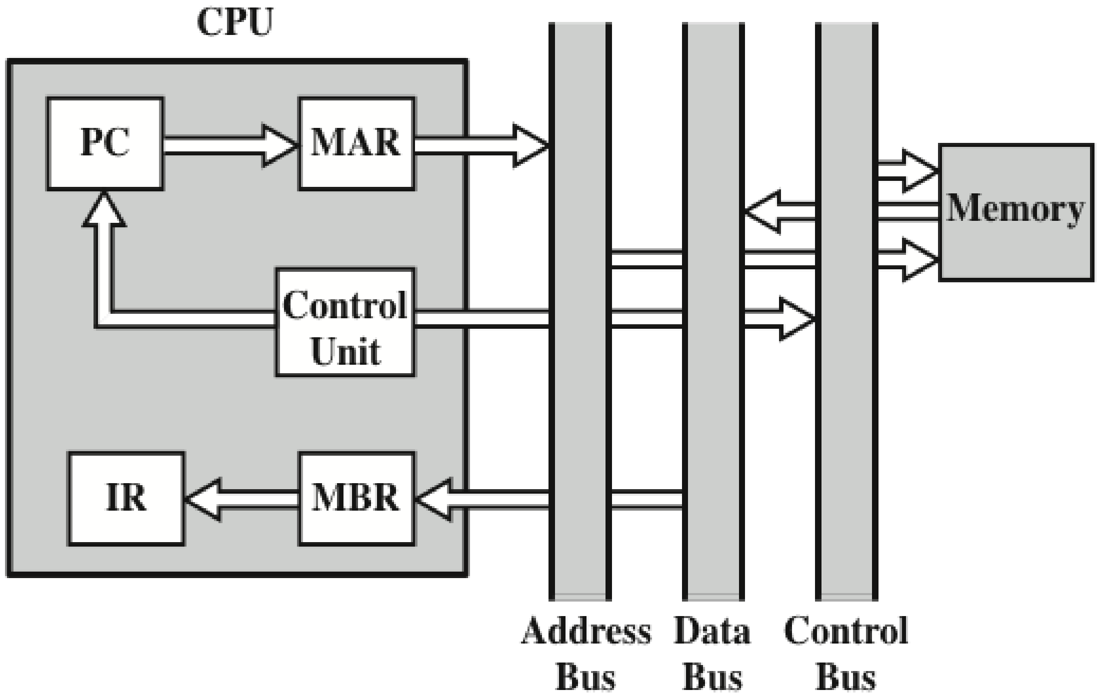
CPU and Memory

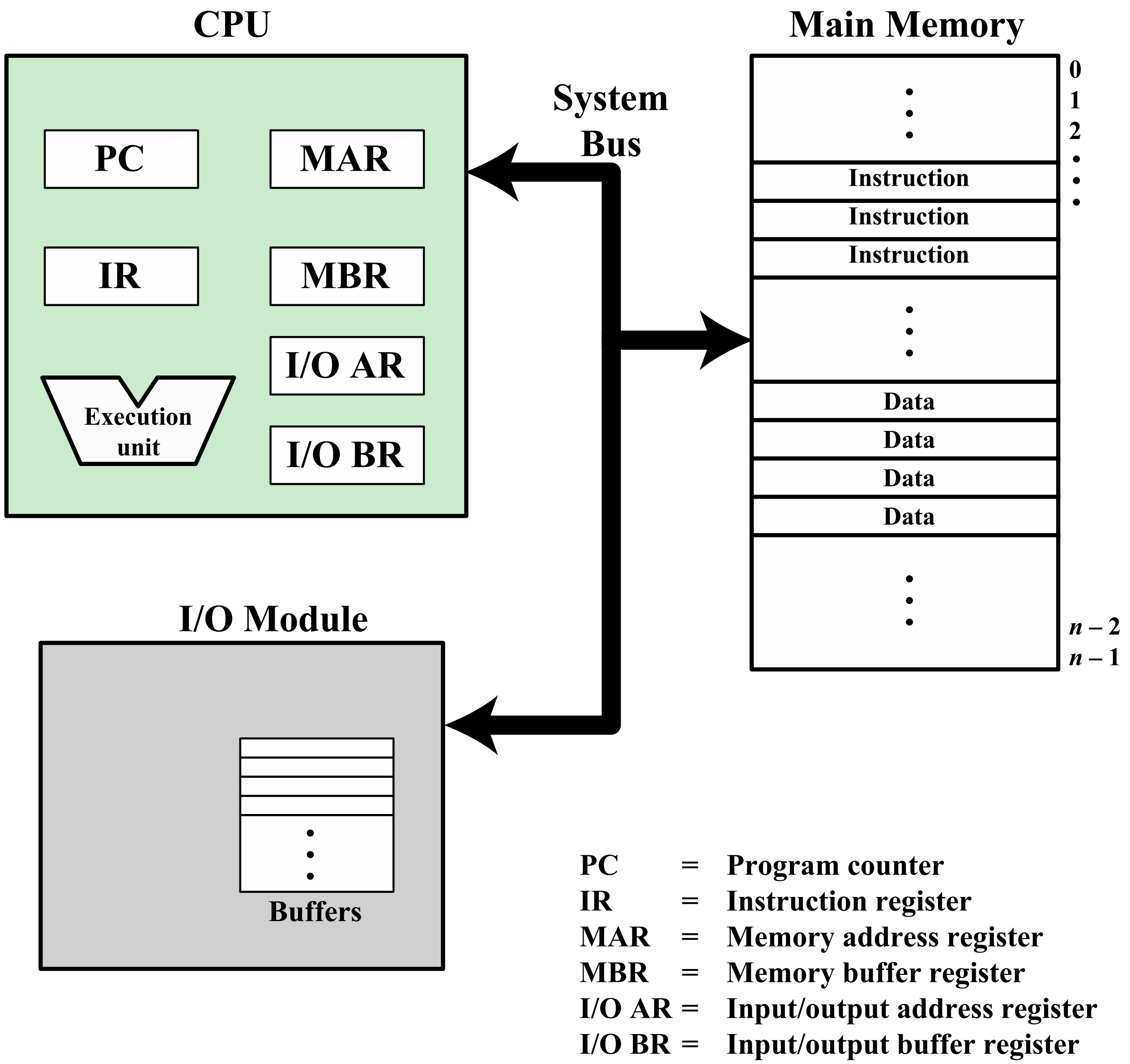


t1 : MAR ← PC

t2 : MBR ← MEMORY

PC ← (PC) + I

t3 : IR ← (MBR)



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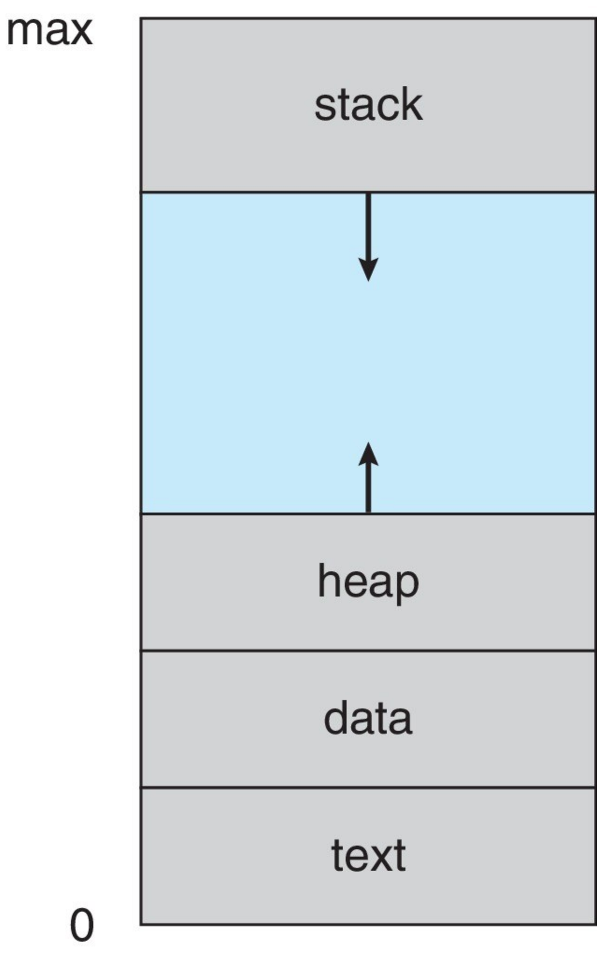
Program and Process

- OS allocates memory and creates memory image
  - Loads code, data from disk exe
  - Creates runtime stack, heap
  - Opens basic files – STD IN, OUT, ERR
  - Initializes CPU registers – PC points to first instruction
- Memory image
  - Code & data (static)
  - Stack and heap (dynamic)



Basic Data Structures

Observation

- All programs manipulate data
  - programs *process, store, display, gather*
  - data can be *information, numbers, images, sound*
- Each program must decide how to store data
- Choice influences program at every level
  - execution speed
  - memory requirements
  - maintenance (debugging, extending, etc.)

What is an Abstract Data Type?

Abstract Data Type (ADT) -

1) An opportunity for an acronym

2) Mathematical description of an object and the set of operations on the object

Data Structures : Algorithms

- Algorithm
  - A high level language independent description of a step-by-step process for solving a problem
- Data Structure
  - A set of algorithms which implement an ADT

Why so many data structures?

Ideal data structure:

fast, elegant, memory efficient

Generates tensions:

- time *vs.* space
- performance *vs.* elegance
- generality *vs.* simplicity
- one operation's performance *vs.* another's

Dictionary ADT

- list
- binary search tree
- AVL tree
- Splay tree
- Red-Black tree
- hash table

Code Implementation

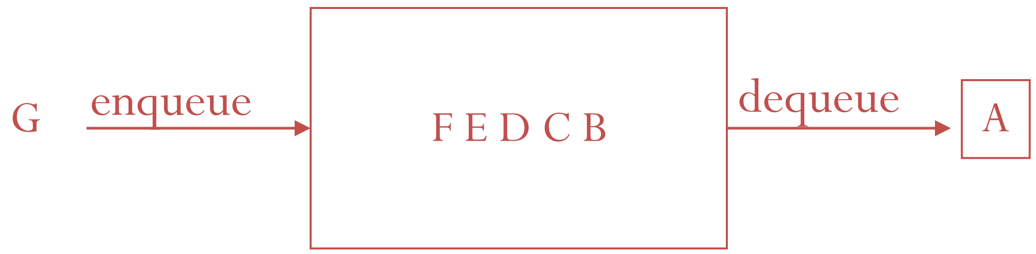
- Theoretically
  - abstract base class describes ADT
  - inherited implementations implement data structures
  - can change data structures transparently (to client code)
- Practice
  - different implementations sometimes suggest different interfaces (generality *vs*. simplicity)
  - performance of a data structure may influence form of client code (time *vs*. space, one operation *vs*. another)

ADT Presentation Algorithm

- Present an ADT
- Motivate with some applications
- Repeat until browned entirely through
  - develop a data structure for the ADT
  - analyze its properties
    - efficiency
    - correctness
    - limitations
    - ease of programming
- Contrast data structure's strengths and weaknesses
  - understand when to use each one

Queue ADT

- Queue operations
  - create
  - destroy
  - enqueue
  - dequeue
  - is_empty



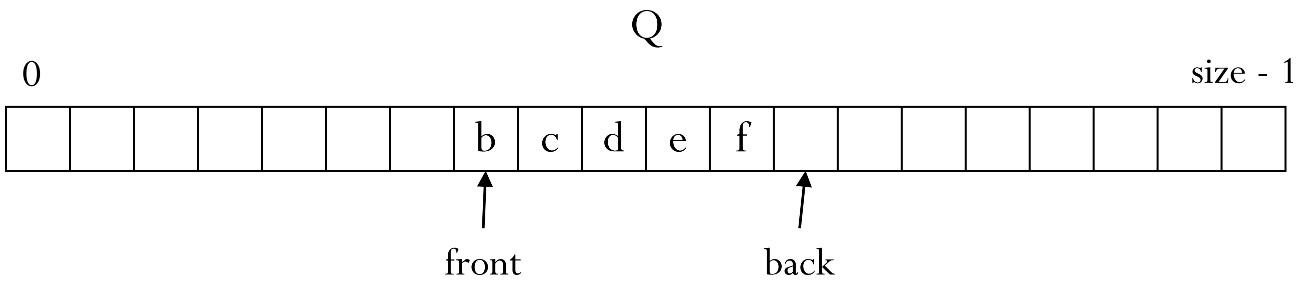
- Queue property: if x is enQed before y is enQed, then x will be deQed before y is deQed

  FIFO: First In First Out

Applications of the Q

- Hold jobs for a printer
- Store packets on network routers
- Hold memory “freelists”
- Make waitlists fair
- Breadth first search

Circular Array Q Data Structure




```
void enqueue(Object x) {
  Q[back] = x
  back = (back + 1) % size
}
Object dequeue() {
  x = Q[front]
  front = (front + 1) % size
  return x
}
```

When is the Q empty?

Are there error situations this code will not catch?

What are some limitations of this structure?

This is *pseudocode*. Do not correct my semicolons.

Q Example

enqueue R

enqueue O

dequeue

enqueue T

enqueue A

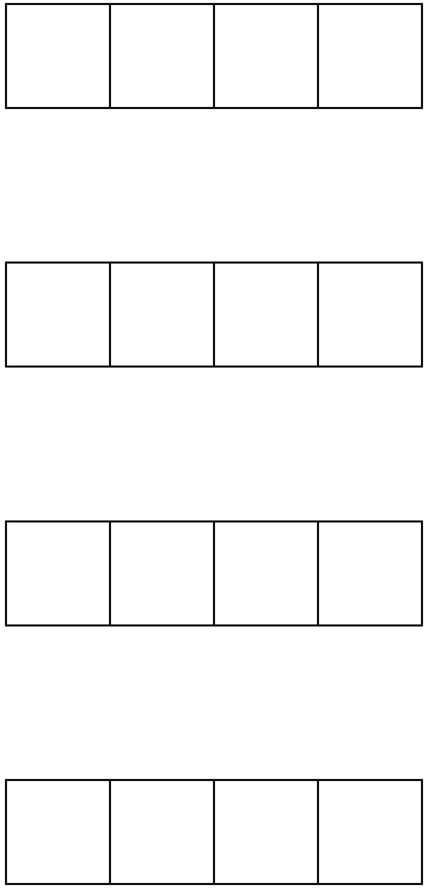
enqueue T

dequeue

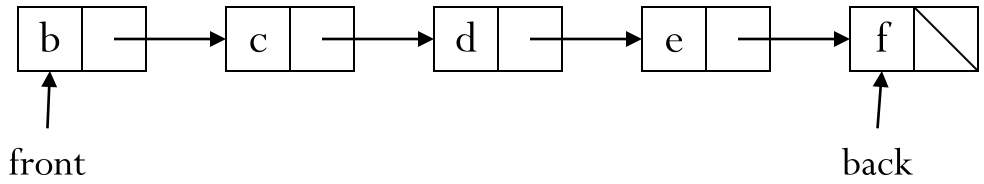
dequeue

enqueue E

dequeue



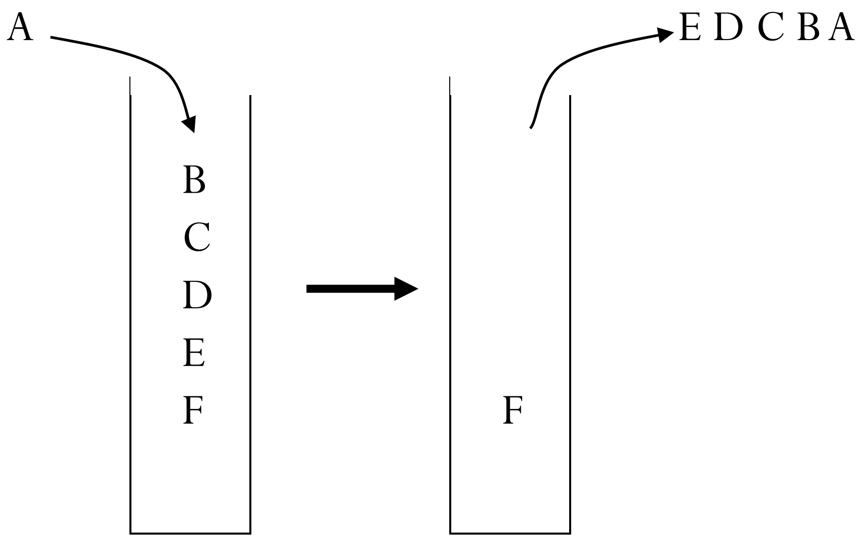
Linked List Q Data Structure




```
void enqueue(Object x) {
   if (is_empty())
       front = back = new Node(x)
   else
       back->next = new Node(x)
       back = back->next
}
```

```
Object dequeue() {
   assert(!is_empty)
   return_data = front->data
   temp = front
   front = front->next
   delete temp
   return temp->data
}
```

LIFO Stack ADT



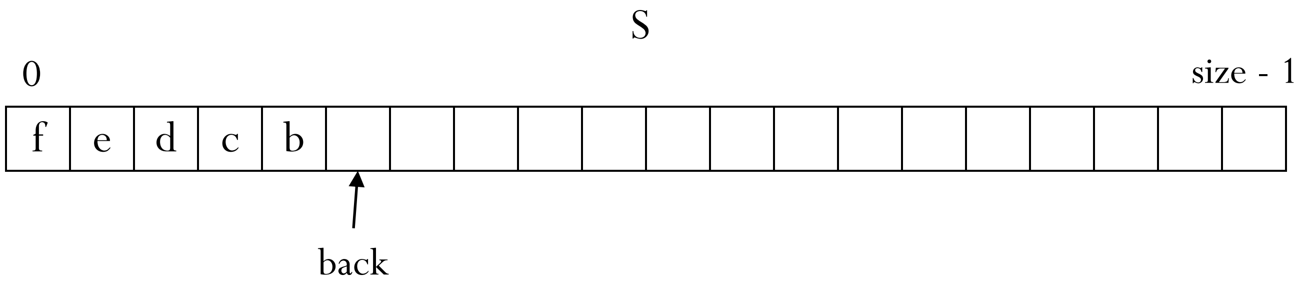
- Stack operations
  - create
  - destroy
  - push
  - pop
  - top
  - is_empty
- Stack property: if x is on the stack before y is pushed, then x will be popped after y is popped

  LIFO: Last In First Out

Stacks in Practice

- Function call stack
- Removing recursion
- Balancing symbols (parentheses)
- Evaluating Reverse Polish Notation
- Depth first search

Array Stack Data Structure

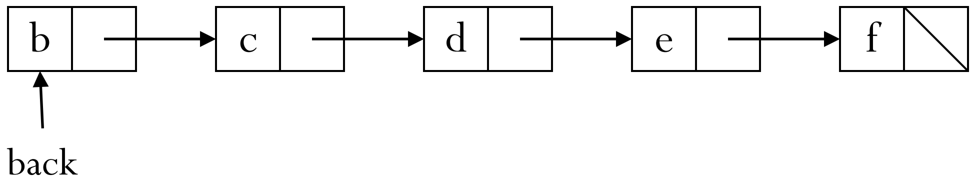



```
void push(Object x) {
  assert(!is_full())
  S[back] = x
  back++
}
Object top() {
  assert(!is_empty())
  return S[back - 1]
}
```

```
Object pop() {
  back--
  return S[back]
}

bool is_full() {
  return back == size
}
```

Linked List Stack Data Structure




```
void push(Object x) {
   temp = back
   back = new Node(x)
   back->next = temp
}
Object top() {
   assert(!is_empty())
   return back->data
}
```

```
Object pop() {
   assert(!is_empty())
   return_data = back->data
   temp = back
   back = back->next
   return return_data
}
```

Data structures you should already know

- Arrays
- Linked lists
- Trees
- Queues
- Stacks

ขอบคุณ

Thai

Grazie

Italian

תודה רבה

Hebrew

धन्यवादः

Sanskrit

ಧನ್ಯವಾದಗಳು

Kannada

Ευχαριστώ

Greek

Thank You

English

Gracias

Spanish

Спасибо

Russian

Obrigado

Portuguese

شكراً

Arabic

https://sites.google.com/site/animeshchaturvedi07

Merci

French

多謝

Traditional Chinese

धन्यवाद

Hindi

Danke

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多谢

Simplified Chinese

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Tamil

Tamil

ありがとうございました

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