



CS11001: Programming & Data Structures

Dept. of Computer Science & Engineering



Course Materials

- Slides available at <http://cse.iitkgp.ac.in/~agupta/pds>
- More materials available at <http://cse.iitkgp.ac.in/~pds>

Books:

1. **Programming with C (Second Edition)**
Byron Gottfried, Third Edition, Schaum's Outlines Series,
2. **The C Programming Language**
Brian W Kernighan, Dennis M Ritchie
3. **Data structures**
S. Lipschutz, Schaum's Outline Series

About the Course

- Section 8, 9, 10
 - Mon, Thurs, Fri (4:30-5:30)
 - In classroom V-1 (in Vikramshila Complex)
 - Teacher: Prof. P. P. Chakraborty (PPC)
- Section 11, 12
 - Wed (11:30-12:25), Thurs (10:30-11:25), Fri (8:30-9:25)
 - In Classroom F-116 (in Main Building)
 - Teacher: Prof. Arobinda Gupta (AG)
- Section 13, 14
 - Wed (11:30-12:25), Thurs (10:30-11:25), Fri (8:30-9:25)
 - In Classroom F-142 (in Main Building)
 - Teacher: Prof. P. P. Das (PPD)

- Teachers' office hours (meeting time outside class):
 - PPC: Thursday, after class in V-1
 - AG: Tuesday (5:30-6:30), Room 302, CSE Dept.
 - PPD: Tuesday (5:30-6:30), Room 122, CSE Dept.

- Tutorial classes (one hour per week) will be conducted on a "per section" basis before Lab hours

- Evaluation in the theory course:

□ Mid-semester	30%
□ End-semester	50%
□ Two class tests and attendance	20%



Attendance REALLY matters

- Important for understanding the course
- Any student with low attendance may be deregistered from the course
- Leave due to medical reasons must be certified by the B.C. Roy Technology Hospital

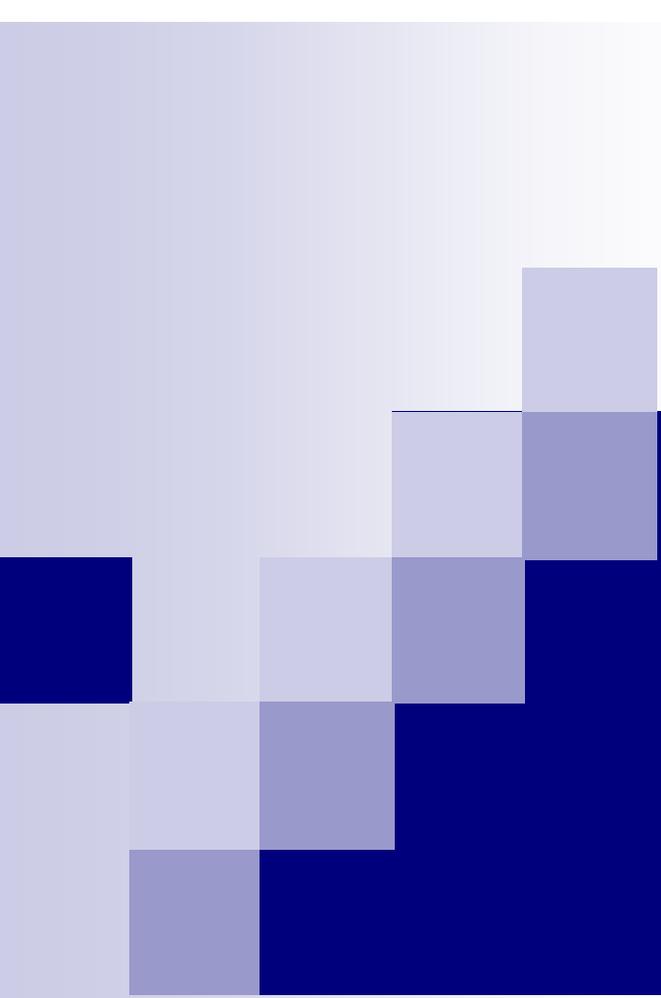


Important Dates

- Class Test 1: Sept. 2, 2013 (18:30 – 19:30)
- Class Test 2: Nov. 4, 2013 (18:30 – 19:30)

(Class test dates are tentative and may change. The exact dates will be announced in the class)

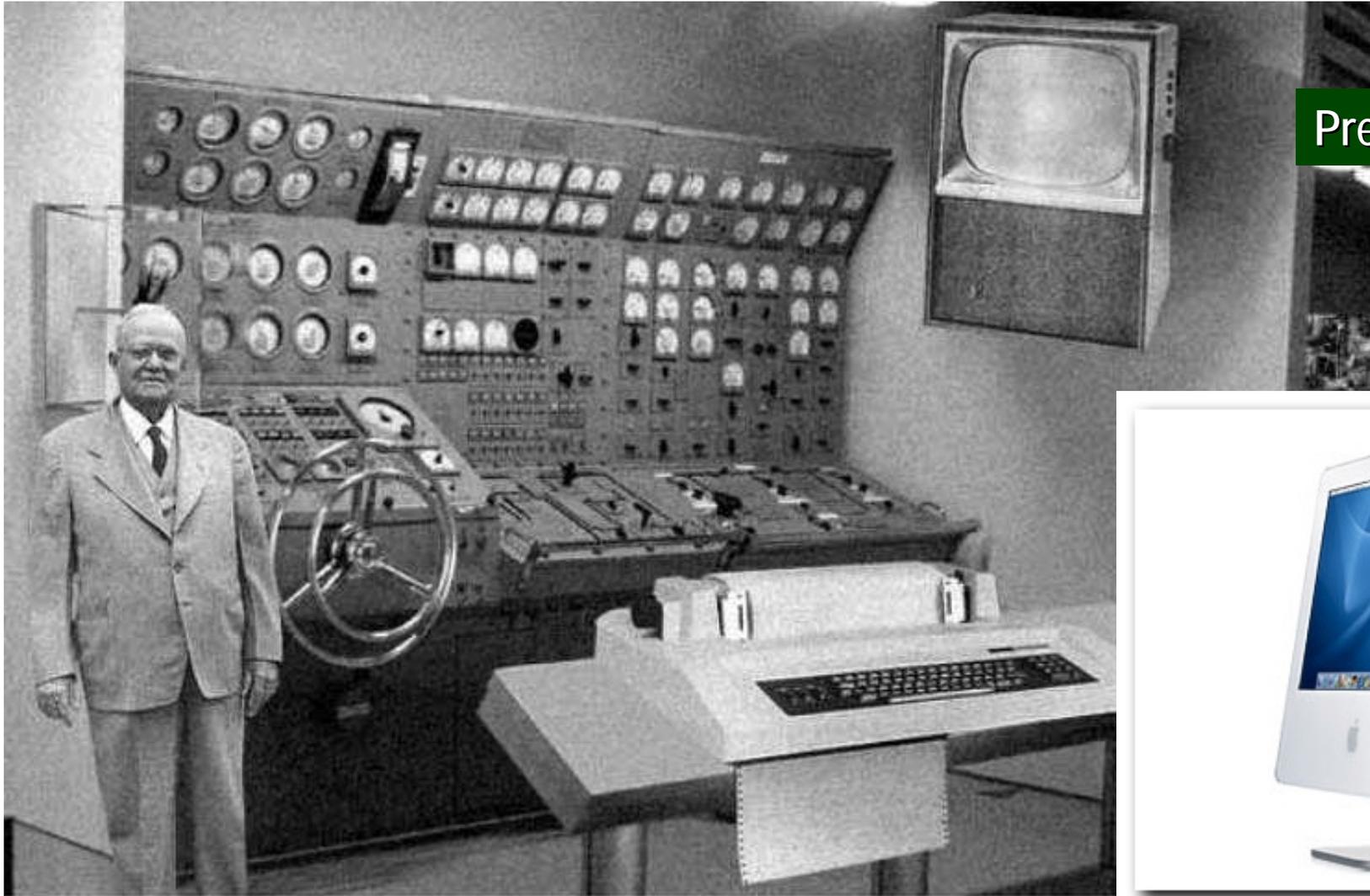
- Mid-semester: Sept 24 – Oct 1, 2013
- End-semester: Nov 18 – 26, 2013



Introduction

Home Computer@2004:

Predicted versus Real



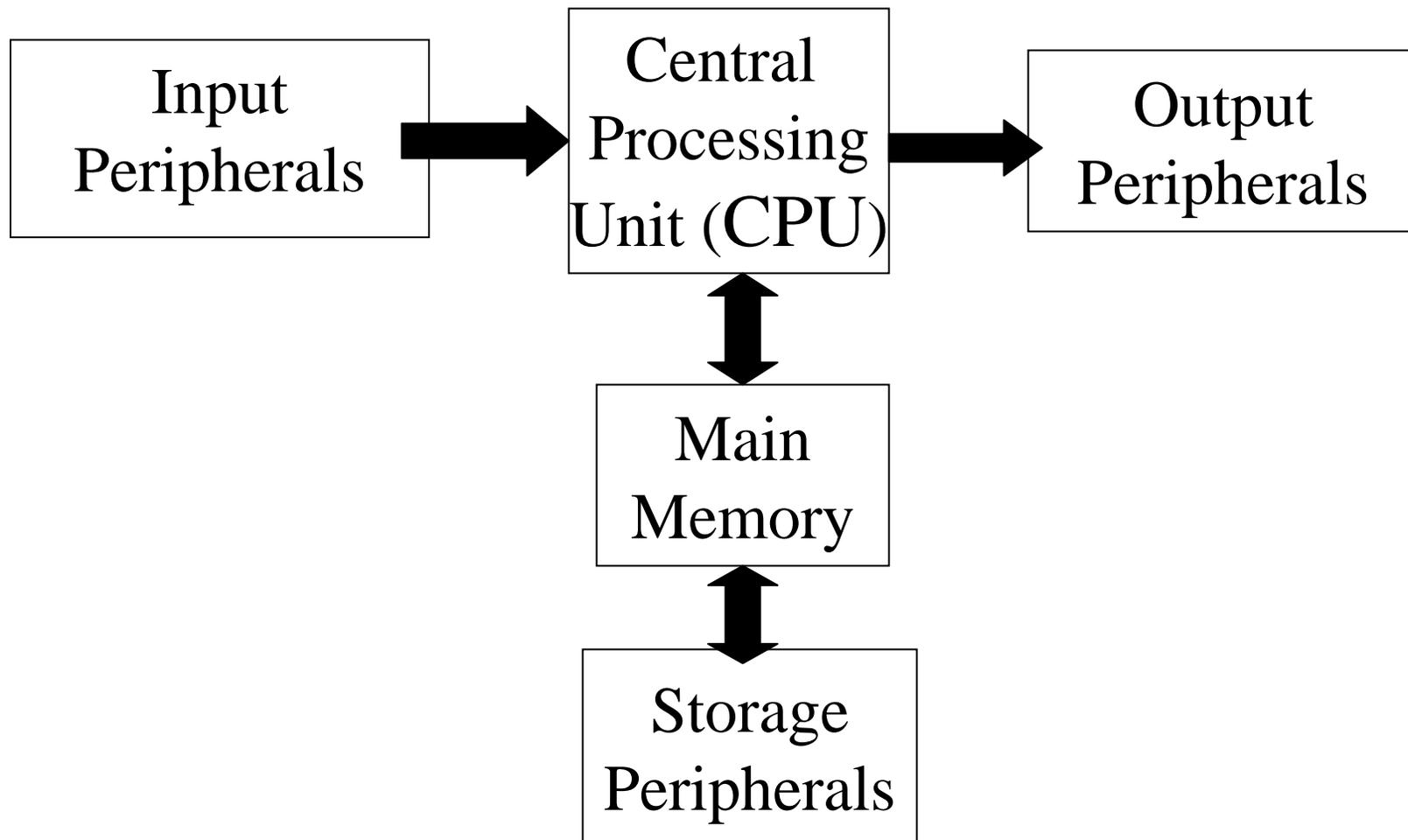
Predicted in 1954

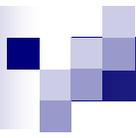


Reality

Scientists from the RAND Corporation have created this model to illustrate how a "home computer" could look like in the year 2004. However the needed technology will not be economically feasible for the average home. Also the scientists readily admit that the computer will require not yet invented technology to actually work, but 50 years from now scientific progress is expected to solve these problems. With teletype interface and the Fortran language, the computer will be easy to use.

A Computer (Level 0 Version)





I/O and Peripherals: Examples

- Input Devices

- Keyboard, Mouse, Digital Camera

- Output Devices

- Monitor, Printer, Speaker

- Storage Peripherals

- Magnetic Disks: hard disk

- Optical Disks: CDROM, CD-RW, DVD

- Flash Memory: pen drives

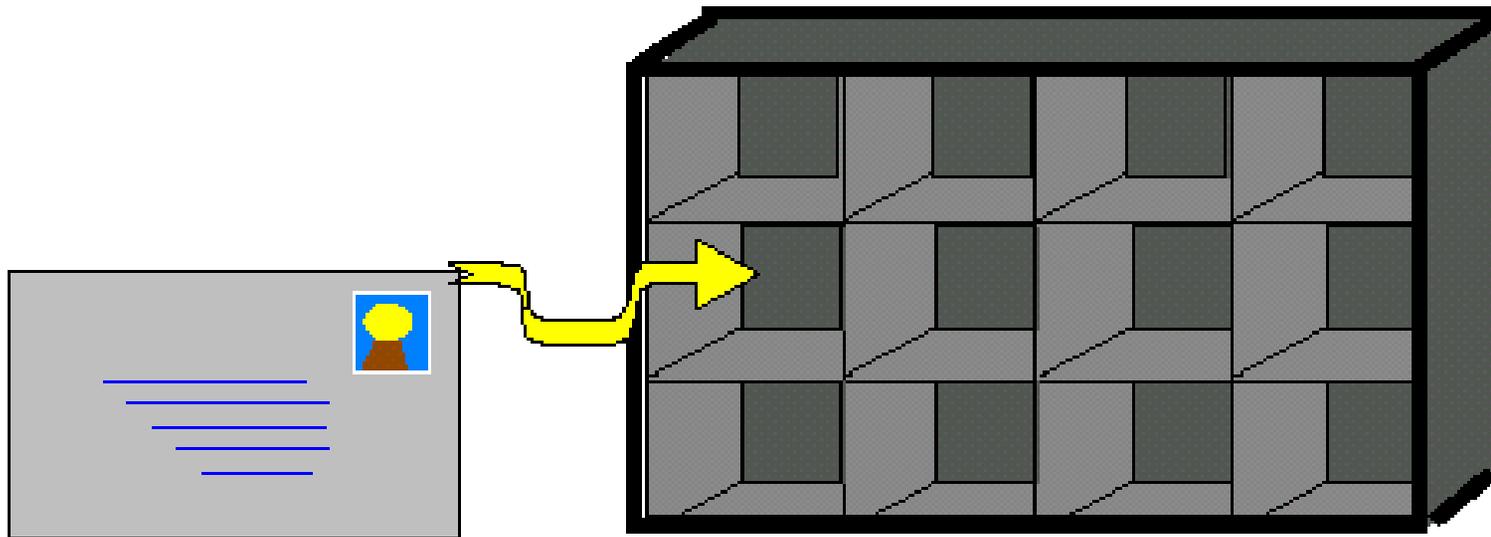
Memory: Address and Values

Every memory location has a **unique** address

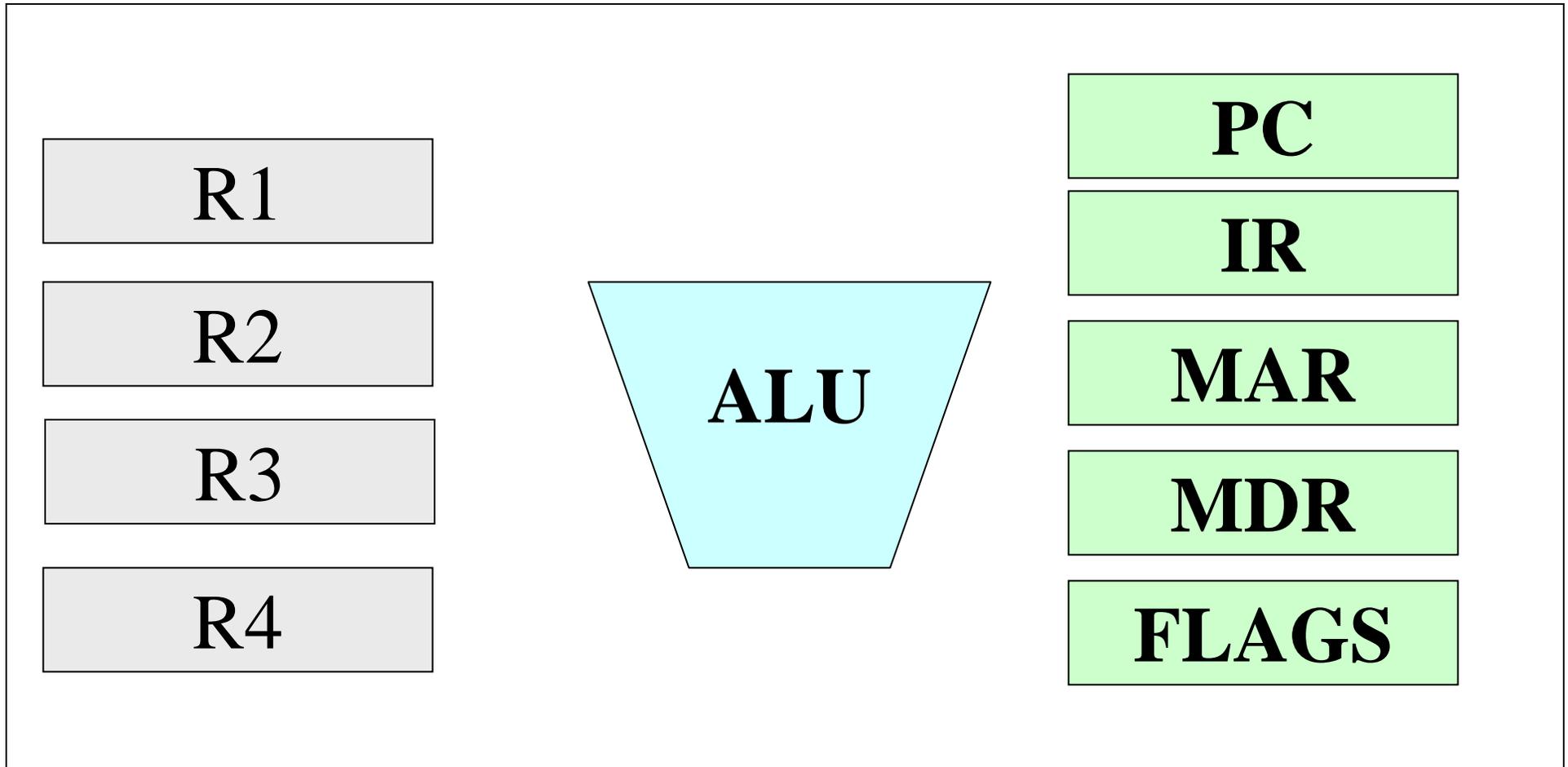
0	0
1	11
2	5
3	23
4	12
5	62

Address of byte

Value of byte (0...255)



CPU: A first cut





What can a computer do

- Determining if a given integer is a prime number
- A Palindrome recognizer
- Read in airline route information as a matrix and determine the shortest time journey between two airports
- Telephone pole placement problem
- Patriot Missile Control
- Finger-print recognition
- Chess Player
- Speech Recognition
- Language Recognition
- Discovering New Laws in Mathematics
- Automatic drug discovery
-



Programming and Software

Computer needs to be **programmed** to do such tasks

Programming is the process of writing instructions in a **language** that can be understood by the computer so that a desired task can be performed by it

Program: sequence of instructions to do a task, computer processes the instructions sequentially one after the other

Software: programs for doing tasks on computers



Contd.

- CPU understands **machine language**
 - Different strings of 0's and 1's only!!
 - Hard to remember and use
- **Instruction set** of a CPU
 - Mnemonic names for this strings

Instruction Set

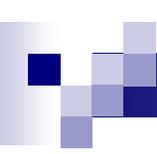
- ◆ **Start**
- ◆ **Read M**
- ◆ **Write M**
- ◆ **Load Data, M**
- ◆ **Copy M1, M2**
- ◆ **Add M1, M2, M3**
- ◆ **Sub M1, M2, M3**
- ◆ **Compare M1, M2, M3**
- ◆ **Jump L**
- ◆ **J_Zero M, L**
- ◆ **Halt**

Instruction Set

- ◆ Start
- ◆ Read M
- ◆ Write M
- ◆ Load Data, M
- ◆ Copy M1, M2
- ◆ Add M1, M2, M3
- ◆ Sub M1, M2, M3
- ◆ Compare M1, M2, M3
- ◆ Jump L
- ◆ J_Zero M, L
- ◆ Halt

Program

0: Start
1: Read 10
2: Read 11
3: Add 10, 11, 12
4: Write 12
5: Halt



Problems with programming using instruction sets directly

- Instruction sets of different types of CPUs different
 - Need to write different programs for computers with different types of CPUs even to do the same thing
- Still hard to remember
- Solution: High level languages (C, C++, Java,...)
 - CPU neutral, one program for many
 - **Compiler** to convert from high-level program to low level program that CPU understands



High-Level Program

```
Variables x, y;  
Begin  
Read (x);  
Read (y);  
If (x > y) then Write (x)  
           else Write (y);  
End.
```

High-Level Program

```
Variables x, y;  
Begin  
Read (x);  
Read (y);  
If (x > y) then Write (x)  
                else Write (y);  
End.
```

Low-Level Program

```
0: Start  
1: Read 20  
2: Read 21  
3: Compare 20, 21, 22  
4: J_Zero 22, 7  
5: Write 20  
6: Jump 8  
7: Write 21  
8: Halt
```



Three steps in writing programs

Step 1: Write the program in a high-level language (in your case, C)

Step 2: Compile the program using a C compiler

Step 3: Run the program (as the computer to execute it)

Binary Representation

- Numbers are represented inside computers in the base-2 system (Binary Numbers)
 - Only two symbols/digits 0 and 1
 - Positional weights of digits: $2^0, 2^1, 2^2, \dots$ from right to left for integers
- Decimal number system we use is base-10
 - 10 digits, from 0 to 9, Positional weights $10^0, 10^1, 10^2, \dots$ from right to left for integers
 - Example: $723 = 3 \times 10^0 + 2 \times 10^1 + 7 \times 10^2$

Binary Numbers

Dec	Binary
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000

Binary Numbers

Dec	Binary
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000

Binary to Decimal Conversion

$$101011 \rightarrow 1x2^5 + 0x2^4 + 1x2^3 + 0x2^2 + 1x2^1 + 1x2^0 = 43$$

$$(101011)_2 = (43)_{10}$$

$$111001 \rightarrow 1x2^5 + 1x2^4 + 1x2^3 + 0x2^2 + 0x2^1 + 1x2^0 = 57$$

$$(111001)_2 = (57)_{10}$$

$$10100 \rightarrow 1x2^4 + 0x2^3 + 1x2^2 + 0x2^1 + 0x2^0 = 20$$

$$(10100)_2 = (20)_{10}$$

Bits and Bytes

- Bit – a single 1 or 0
- Byte – 8 consecutive bits
 - 2 bytes = 16 bits
 - 4 bytes = 32 bits
- Max. integer that can be represented
 - in 1 byte = 255 (=11111111)
 - In 4 bytes = 4294967295 (= 32 1's)
- No. of integers that can be represented in 1 byte = 256 (the integers 0, 1, 2, 3,.....255)



Fundamentals of C



First C program – print on screen

```
#include <stdio.h>
void main()
{
    printf ("Hello, World! \n") ;
}
```



More print

```
#include <stdio.h>
```

```
void main()
```

```
{
```

```
    printf ("Hello, World! ");
```

```
    printf ("Hello \n World! \n");
```

```
}
```



Some more print

```
#include <stdio.h>
void main()
{
    printf ("Hello, World! \n") ;
    printf ("Hello \n World! \n") ;
    printf ("Hell\no \t World! \n") ;
}
```

Reading values from keyboard

```
#include <stdio.h>
void main()
{
    int num ;
    scanf ("%d", &num) ;
    printf ("No. of students is %d\n", num) ;
}
```

Centigrade to Fahrenheit

```
#include <stdio.h>
void main()
{
    float cent, fahr;
    scanf("%f",&cent);
    fahr = cent*(9.0/5.0) + 32;
    printf( "%f C equals %f F\n", cent, fahr);
}
```

Largest of two numbers

```
#include <stdio.h>
void main()
{
    int x, y;
    scanf("%d%d",&x,&y);
    if (x>y) printf("Largest is %d\n",x);
    else printf("Largest is %d\n",y);
}
```

What does this do?

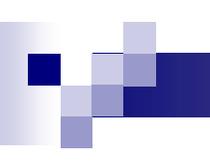
```
#include <stdio.h>
void main()
{
    int x, y;
    scanf("%d%d",&x,&y);
    if (x>y) printf("Largest is %d\n",x);
    printf("Largest is %d\n",y);
}
```

The C Character Set

- The C language alphabet
 - Uppercase letters 'A' to 'Z'
 - Lowercase letters 'a' to 'z'
 - Digits '0' to '9'
 - Certain special characters:

!	#	%	^	&	*	()
-	_	+	=	~	[]	\
	;	:	'	"	{	}	,
.	<	>	/	?	blank		

A C program should not contain anything else



Structure of a C program

- A collection of **functions** (we will see what they are later)
- Exactly one special function named **main** must be present. Program always starts from there
- Each function has statements (instructions) for declaration, assignment, condition check, looping etc.
- Statements are executed one by one



Variables

- Very important concept for programming
- An entity that has a value and is known to the program by a name
- Can store any temporary result while executing a program
- Can have only one value assigned to it at any given time during the execution of the program
- The value of a variable can be changed during the execution of the program

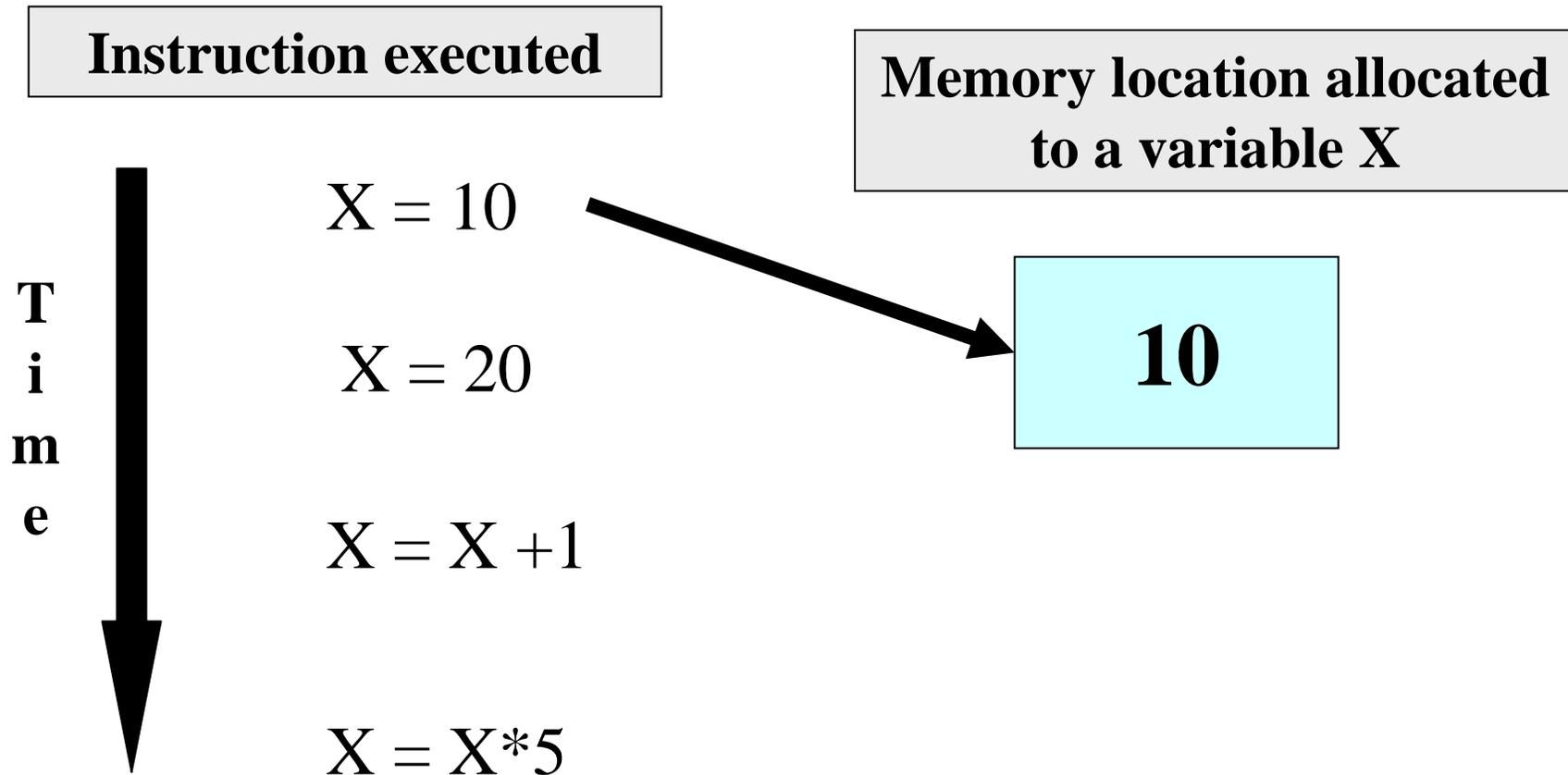
Contd.

- Variables stored in memory
- Remember that memory is a list of storage locations, each having a unique address
- A variable is like a **bin**
 - The contents of the bin is the **value** of the variable
 - The variable name is used to refer to the value of the variable
 - A variable is mapped to a location of the memory, called its **address**

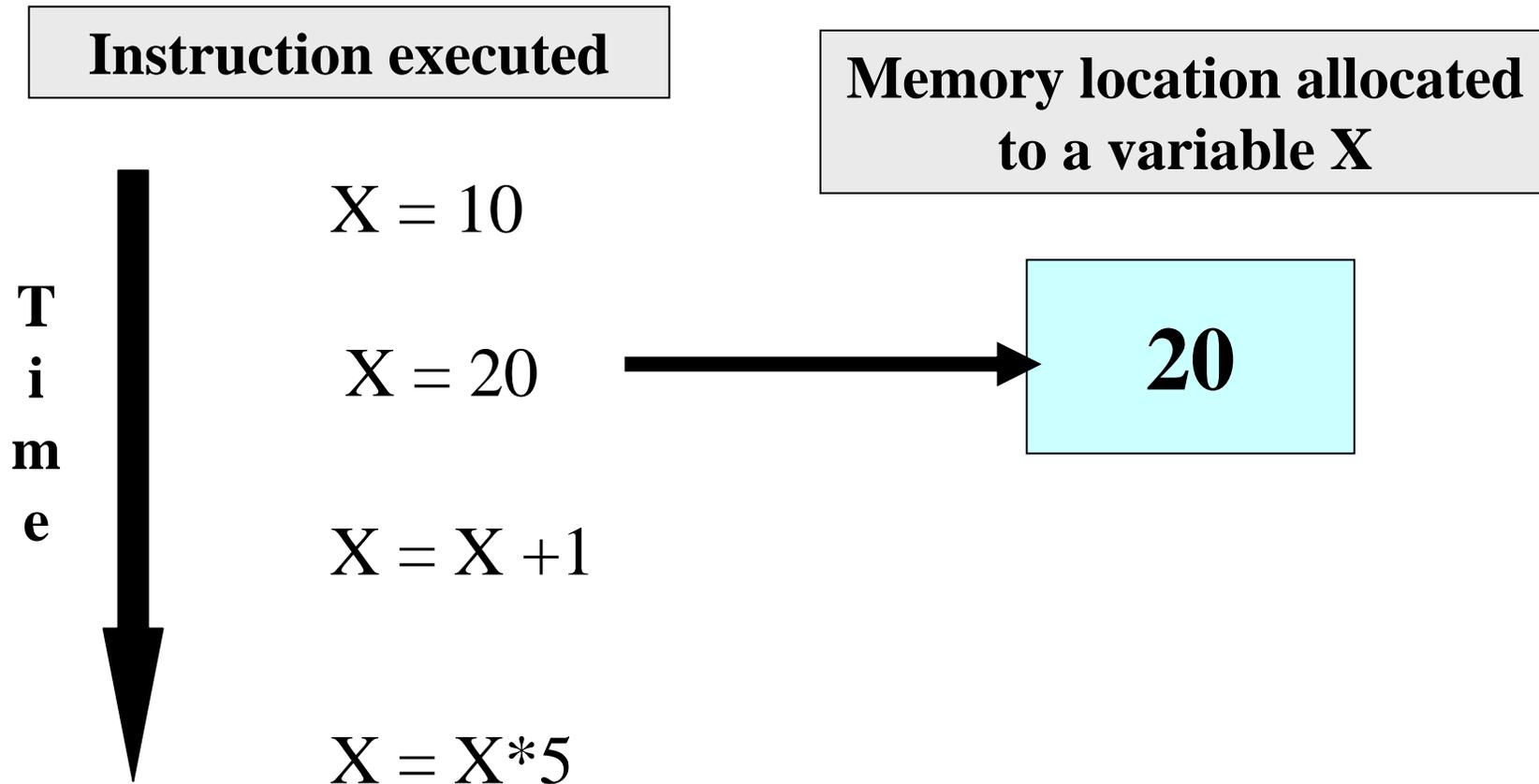
Example

```
#include <stdio.h>
void main( )
{
    int x;
    int y;
    x=1;
    y=3;
    printf("x = %d, y= %d\n", x, y);
}
```

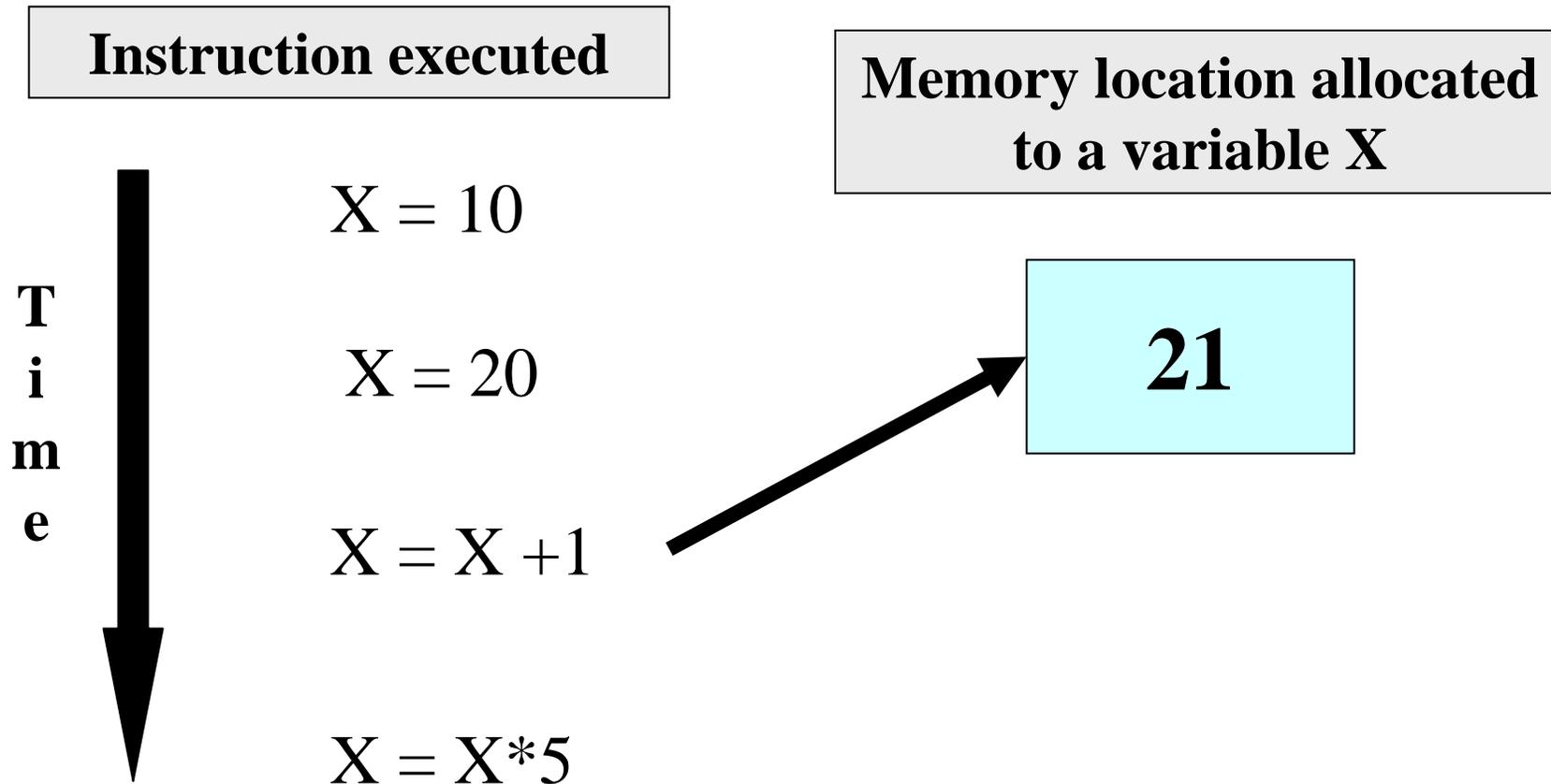
Variables in Memory



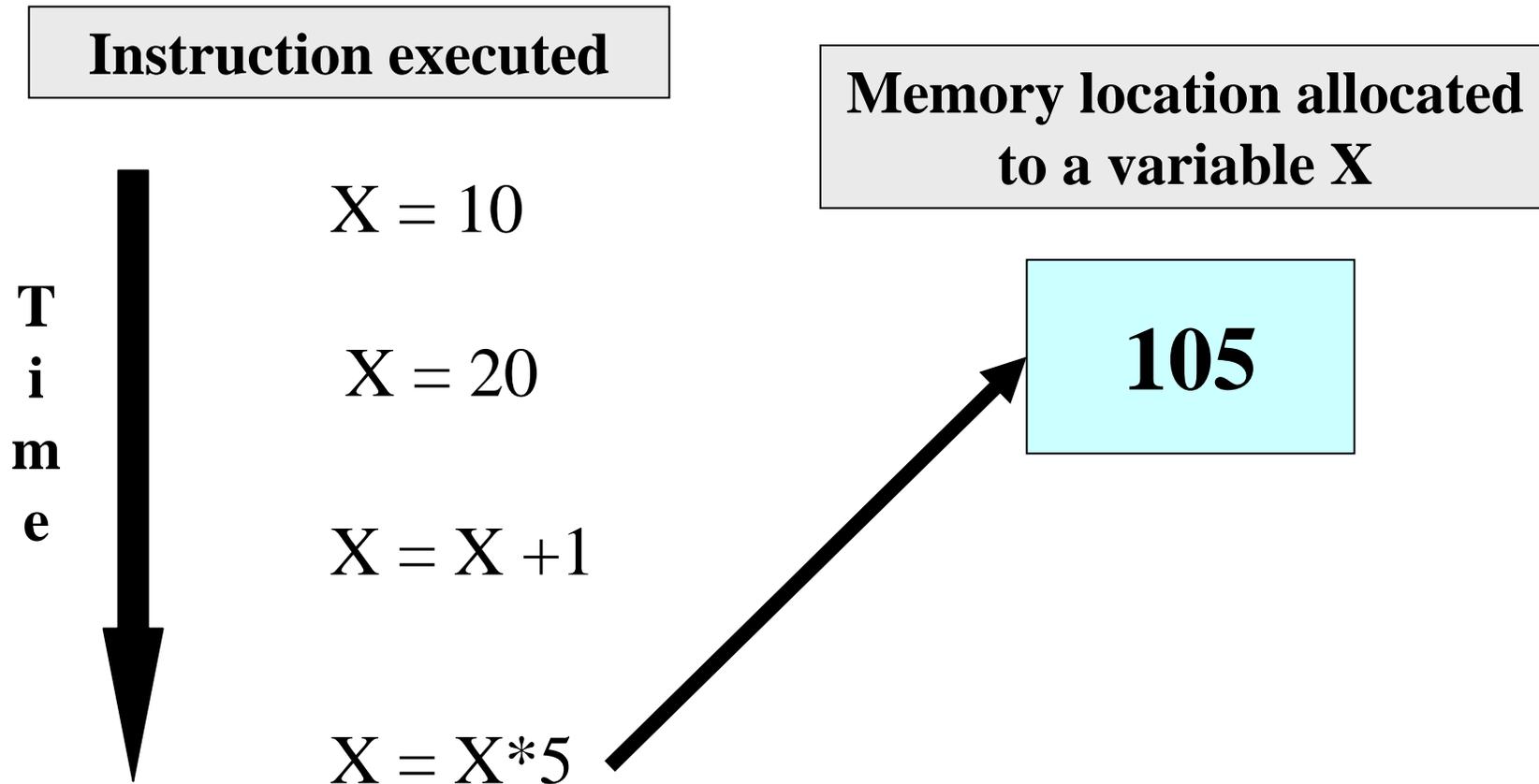
Variables in Memory



Variables in Memory



Variables in Memory



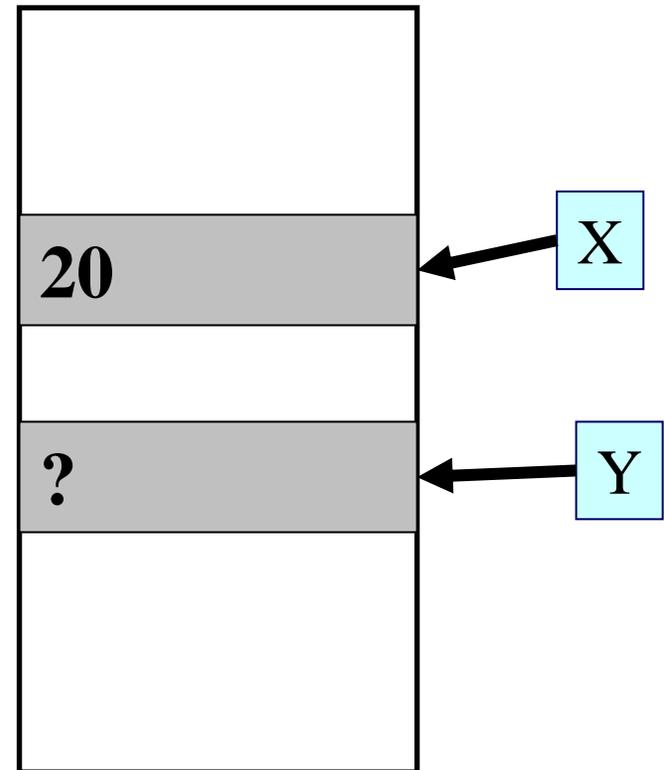
Variables (contd.)

X = 20

Y=15

X = Y+3

Y=X/6



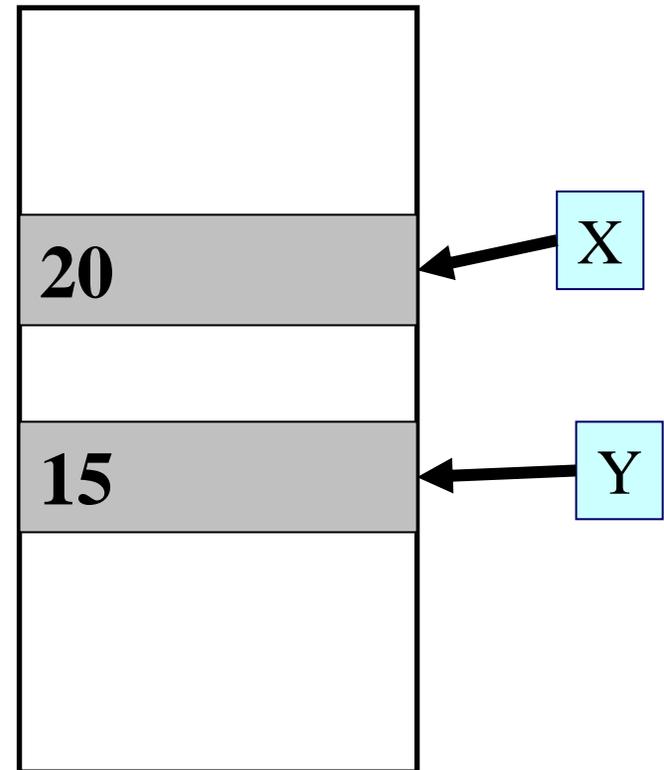
Variables (contd.)

$X = 20$

$Y = 15$

$X = Y + 3$

$Y = X / 6$



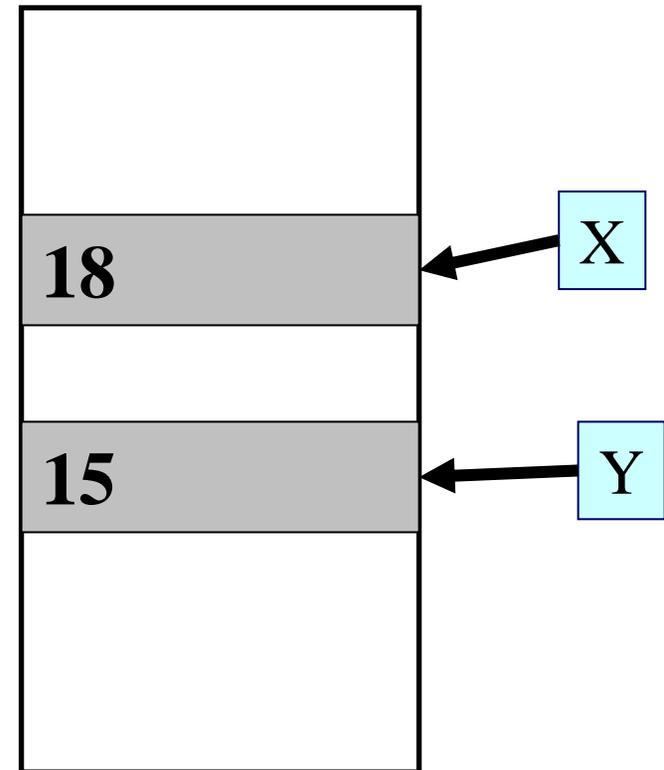
Variables (contd.)

$$X = 20$$

$$Y = 15$$

$$X = Y + 3$$

$$Y = X / 6$$



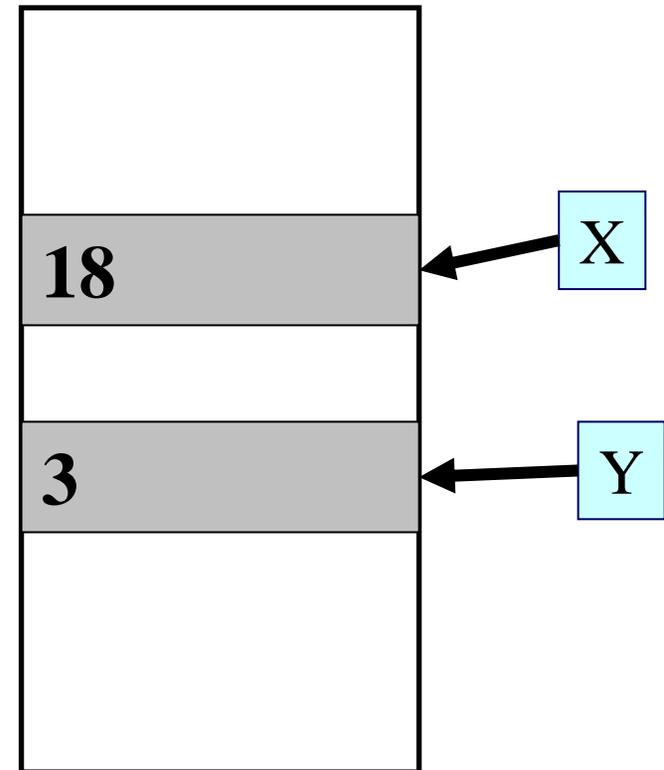
Variables (contd.)

$$X = 20$$

$$Y = 15$$

$$X = Y + 3$$

$$Y = X / 6$$



Data Types

- Each variable has a **type**, indicates what type of values the variable can hold
- Four common data types in C
 - **int** - can store integers (usually 4 bytes)
 - **float** - can store single-precision floating point numbers (usually 4 bytes)
 - **double** - can store double-precision floating point numbers (usually 8 bytes)
 - **char** - can store a character (1 byte)

Contd.

- Must declare a variable (specify its **type** and **name**) before using it anywhere in your program
- All variable declarations should be at the beginning of the `main()` or other functions
- A value can also be assigned to a variable at the time the variable is declared.

```
int speed = 30;
```

```
char flag = 'y';
```

Variable Names

- Sequence of letters and digits
- First character must be a letter or ‘_’
- No special characters other than ‘_’
- No blank in between
- Names are **case-sensitive** (**max** and **Max** are two different names)
- Examples of valid names:
 - **i rank1 MAX max Min class_rank**
- Examples of invalid names:
 - **a's fact rec 2sqroot class,rank**

More Valid and Invalid Identifiers

■ Valid identifiers

X

abc

simple_interest

a123

LIST

stud_name

Empl_1

Empl_2

avg_empl_salary

■ Invalid identifiers

10abc

my-name

“hello”

simple interest

(area)

%rate



C Keywords

- Used by the C language, cannot be used as variable names
- Examples:
 - int, float, char, double, main, if else, for, while. do, struct, union, typedef, enum, void, return, signed, unsigned, case, break, sizeof,.....
 - There are others, see textbook...

Example 1

```
#include <stdio.h>
```

```
void main()
```

```
{
```

```
    int x, y, sum;
```

```
    scanf(“%d%d”, &x, &y);
```

```
    sum = x + y;
```

```
    printf( “%d plus %d is %d\n”, x, y, sum );
```

```
}
```

Three int type variables declared

Values assigned

Example - 2

```
#include <stdio.h>
void main()
```

```
{
```

```
    float x, y;
```

```
    int d1, d2 = 10;
```

```
    scanf("%f%f%d",&x, &y, &d1);
```

```
    printf( "%f plus %f is %f\n", x, y, x+y);
```

```
    printf( "%d minus %d is %d\n", d1, d2, d1-d2);
```

```
}
```

**Assigns an initial value to d2,
can be changed later**





Read-only variables

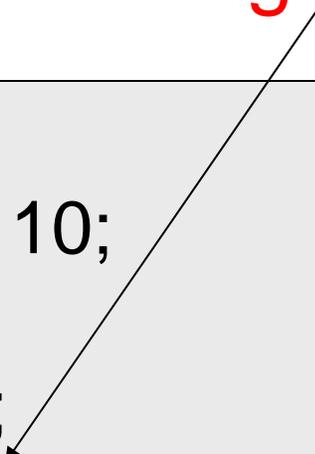
- Variables whose values can be initialized during declaration, but cannot be changed after that
- Declared by putting the `const` keyword in front of the declaration
- Storage allocated just like any variable
- Used for variables whose values need not be changed
 - Prevents accidental change of the value

Correct

```
void main() {
    const int LIMIT = 10;
    int n;
    scanf("%d", &n);
    if (n > LIMIT)
        printf("Out of limit");
}
```

Incorrect: **Limit changed**

```
void main() {
    const int Limit = 10;
    int n;
    scanf("%d", &n);
    Limit = Limit + n;
    printf("New limit is %d",
    Limit);
}
```



Constants

- Integer constants

- Consists of a sequence of digits, with possibly a plus or a minus sign before it
- Embedded spaces, commas and non-digit characters are not permitted between digits

- Floating point constants

- Two different notations:

- Decimal notation: 25.0, 0.0034, .84, -2.234
- Exponential (scientific) notation
3.45e23, 0.123e-12, 123e2

e means “10 to the power of”

Contd.

- Character constants

- Contains a single character enclosed within a pair of single quote marks.

- Examples :: '2', '+', 'Z'

- Some special backslash characters

- '\n' new line

- '\t' horizontal tab

- '\"' single quote

- '\"' double quote

- '\\' backslash

- '\0' null

Input: **scanf** function

- Performs input from keyboard
- It requires a format string and a list of variables into which the value received from the keyboard will be stored
- format string = individual groups of characters (usually ‘%’ sign, followed by a conversion character), with one character group for each variable in the list

```
int a, b;
float c;
scanf("%d %d %f", &a, &b, &c);
```

Variable list (note the & before a variable name)

Format string



- Commonly used conversion characters

- c** for char type variable

- d** for int type variable

- f** for float type variable

- lf** for double type variable

- Examples

- `scanf ("%d", &size) ;`

- `scanf ("%c", &nextchar) ;`

- `scanf ("%f", &length) ;`

- `scanf ("%d%d", &a, &b);`

Reading a single character

- A single character can be read using `scanf` with `%c`
- It can also be read using the `getchar()` function

```
char c;  
c = getchar();
```

- Program waits at the `getchar()` line until a character is typed, and then reads it and stores it in `c`

Output: `printf` function

- Performs output to the standard output device (typically defined to be the screen)
- It requires a format string in which we can specify:
 - The text to be printed out
 - Specifications on how to print the values
`printf ("The number is %d\n", num);`
 - The format specification `%d` causes the value listed after the format string to be embedded in the output as a decimal number in place of `%d`
 - Output will appear as: `The number is 125`

Contd.

- General syntax:

 - `printf (format string, arg1, arg2, ..., argn);`

 - format string refers to a string containing formatting information and data types of the arguments to be output
 - the arguments `arg1, arg2, ...` represent list of variables/expressions whose values are to be printed

- The conversion characters are the same as in `scanf`



- **Examples:**

```
printf ("Average of %d and %d is %f", a, b, avg);
```

```
printf ("Hello \nGood \nMorning \n");
```

```
printf ("%3d %3d %5d", a, b, a*b+2);
```

```
printf ("%7.2f %5.1f", x, y);
```

- **Many more options are available for both printf and scanf**

- Read from the book

- Practice them in the lab