EECS 10: Computational Methods in Electrical and Computer Engineering

Lecture 16

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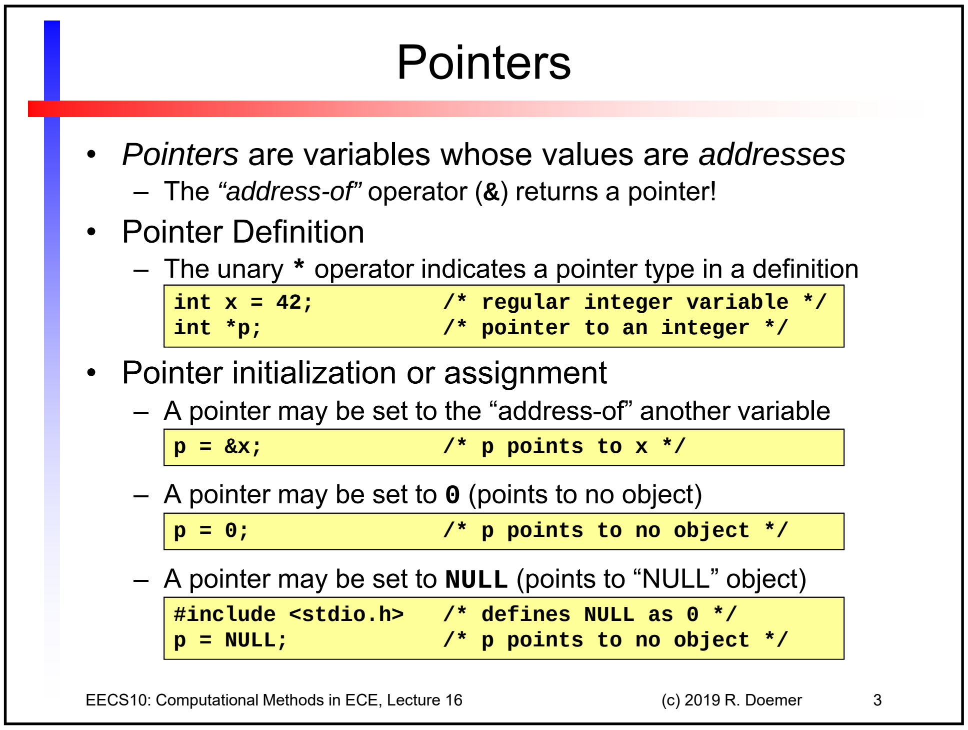
Lecture 16: Overview

- Data Structures
  - Pointers
    - Pointer definition
    - Pointer initialization, assignment
    - Pointer dereferencing
    - Pointer arithmetic, comparison
  - String operations using pointers
    - Pointer and array type equivalence
    - Passing pointers to functions
  - Standard library functions
    - String operations defined in **`string.h`**
  - Example
    - **`Bubblesort2.c`**



Pointers

- *Pointers* are variables whose values are *addresses*
  - The *“address-of”* operator (**&**) returns a pointer!
- Pointer Definition
  - The unary **`*`** operator indicates a pointer type in a definition

```
int x = 42;          /* regular integer variable */
int *p;              /* pointer to an integer */
```

- Pointer initialization or assignment
  - A pointer may be set to the “address-of” another variable

```
p = &x;              /* p points to x */
```

  - A pointer may be set to **`0`** (points to no object)

```
p = 0;               /* p points to no object */
```

  - A pointer may be set to **`NULL`** (points to “NULL” object)

```
#include <stdio.h>   /* defines NULL as 0 */
p = NULL;            /* p points to no object */
```

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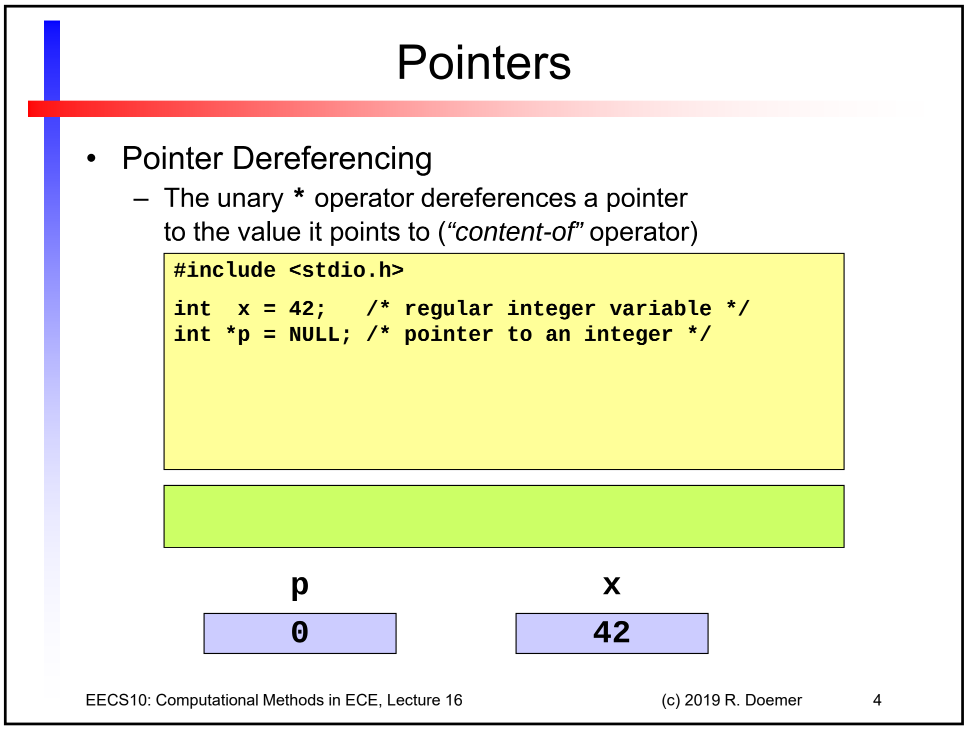

Pointers

- Pointer Dereferencing
  - The unary **`*`** operator dereferences a pointer to the value it points to (*“content-of”* operator)

```
#include <stdio.h>

int  x = 42;   /* regular integer variable */
int *p = NULL; /* pointer to an integer */
```

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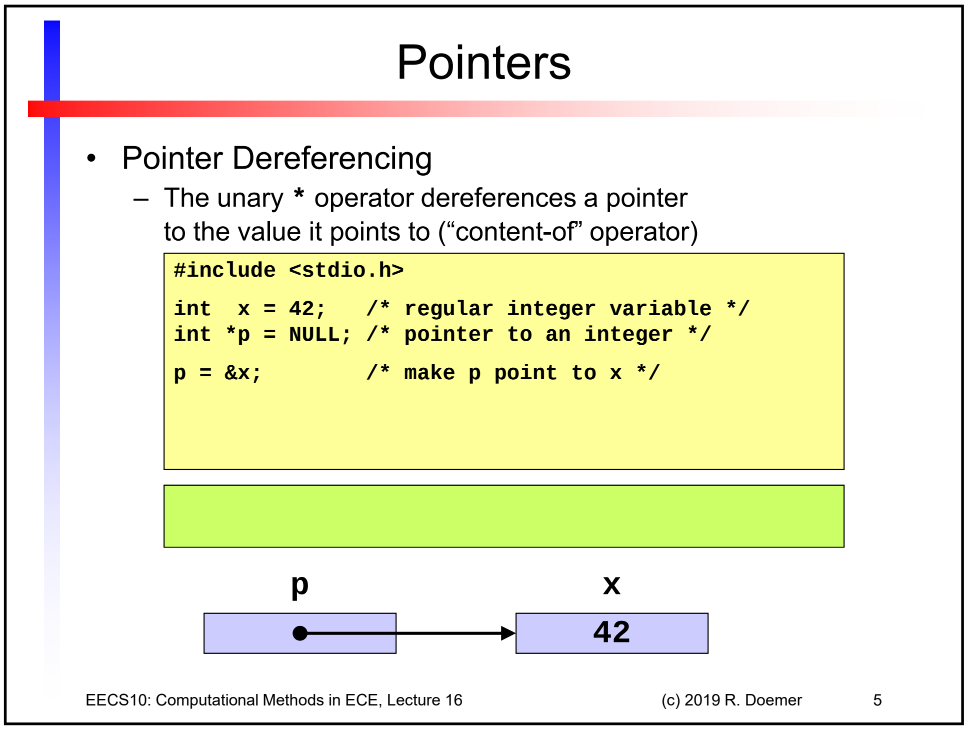
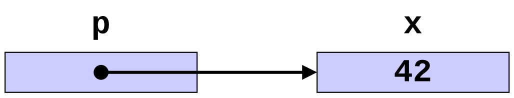
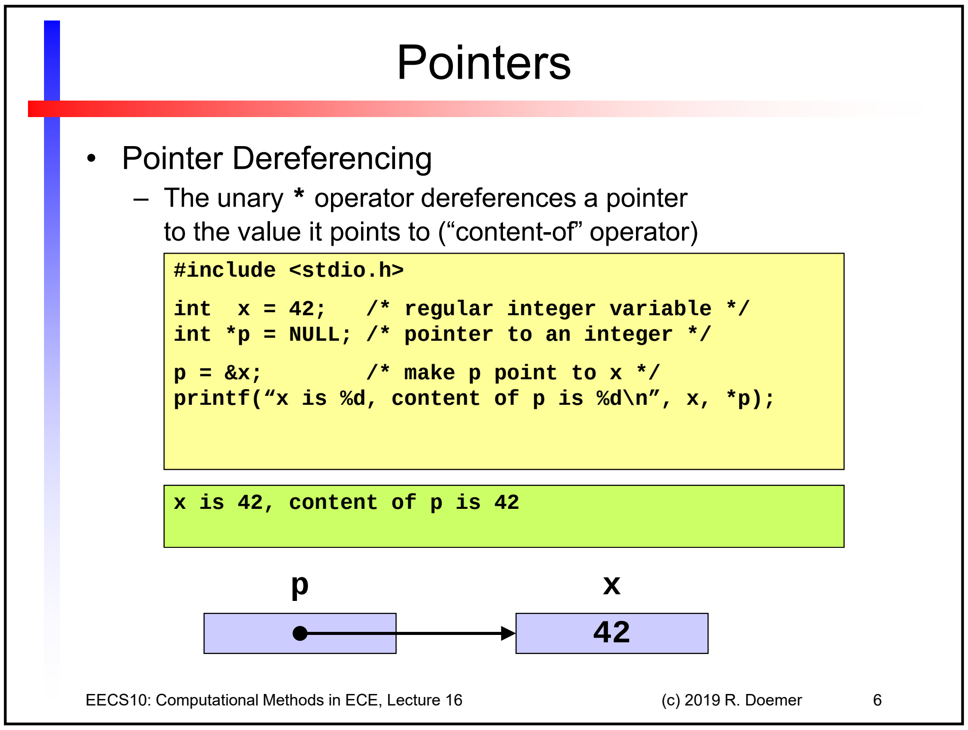


Pointers

- Pointer Dereferencing
  - The unary ***** operator dereferences a pointer to the value it points to ("content-of" operator)

```
#include <stdio.h>

int  x = 42;   /* regular integer variable */
int *p = NULL; /* pointer to an integer */

p = &x;        /* make p point to x */
```



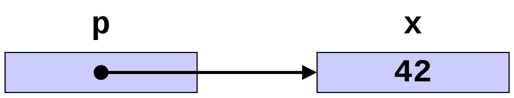


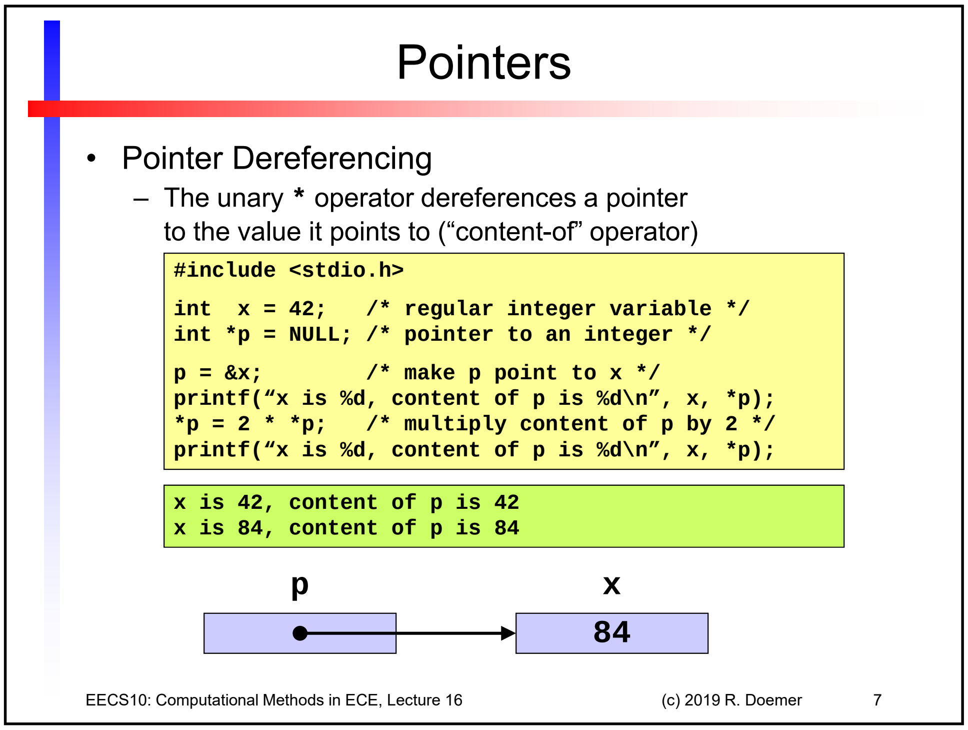
Pointers

- Pointer Dereferencing
  - The unary ***** operator dereferences a pointer to the value it points to ("content-of" operator)

```
#include <stdio.h>

int  x = 42;   /* regular integer variable */
int *p = NULL; /* pointer to an integer */

p = &x;        /* make p point to x */
printf("x is %d, content of p is %d\n", x, *p);
```

```
x is 42, content of p is 42
```



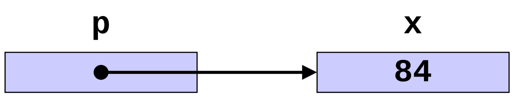


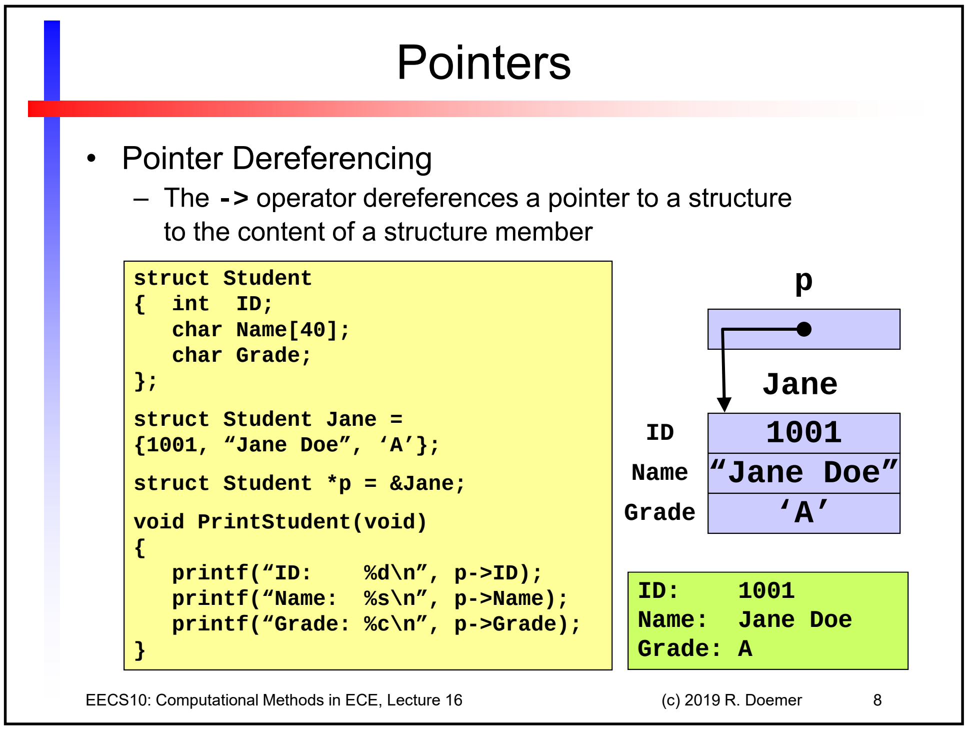
Pointers

- Pointer Dereferencing
  - The unary ***** operator dereferences a pointer to the value it points to (“content-of” operator)

```
#include <stdio.h>

int  x = 42;   /* regular integer variable */
int *p = NULL; /* pointer to an integer */

p = &x;        /* make p point to x */
printf(“x is %d, content of p is %d\n”, x, *p);
*p = 2 * *p;   /* multiply content of p by 2 */
printf(“x is %d, content of p is %d\n”, x, *p);
```

```
x is 42, content of p is 42
x is 84, content of p is 84
```

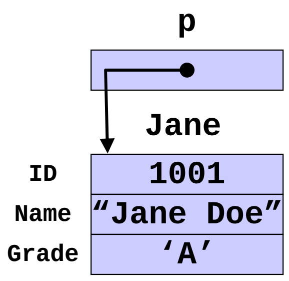




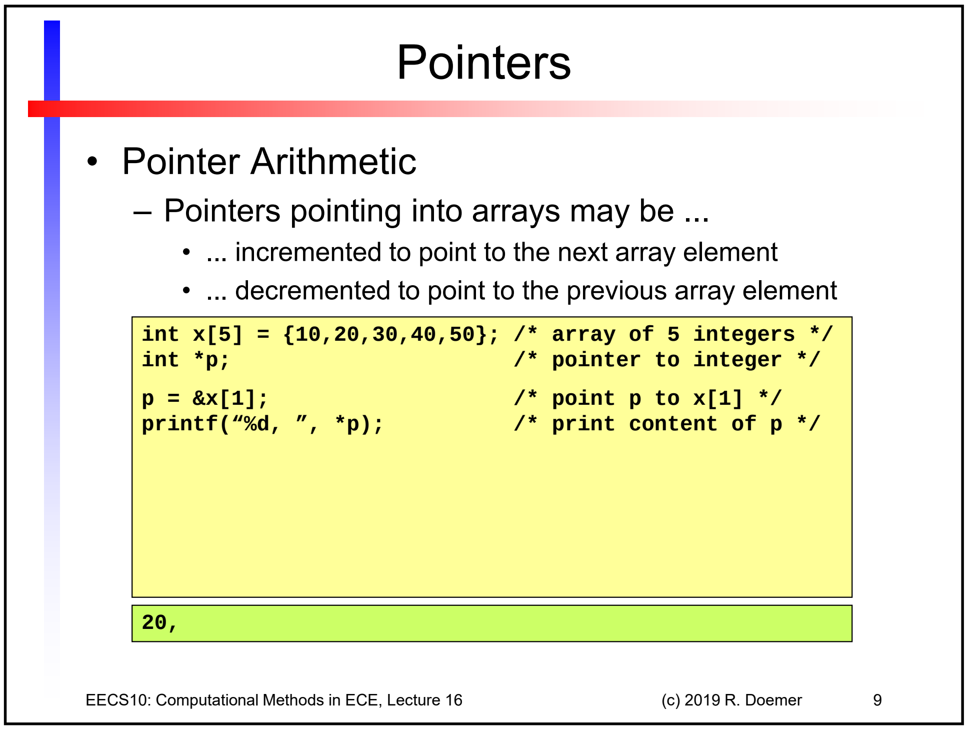
Pointers

- Pointer Dereferencing
  - The **->** operator dereferences a pointer to a structure to the content of a structure member

```
struct Student
{  int  ID;
   char Name[40];
   char Grade;
};

struct Student Jane =
{1001, “Jane Doe”, ‘A’};

struct Student *p = &Jane;

void PrintStudent(void)
{
   printf(“ID:    %d\n”, p->ID);
   printf(“Name:  %s\n”, p->Name);
   printf(“Grade: %c\n”, p->Grade);
}
```



```
ID:    1001
Name:  Jane Doe
Grade: A
```

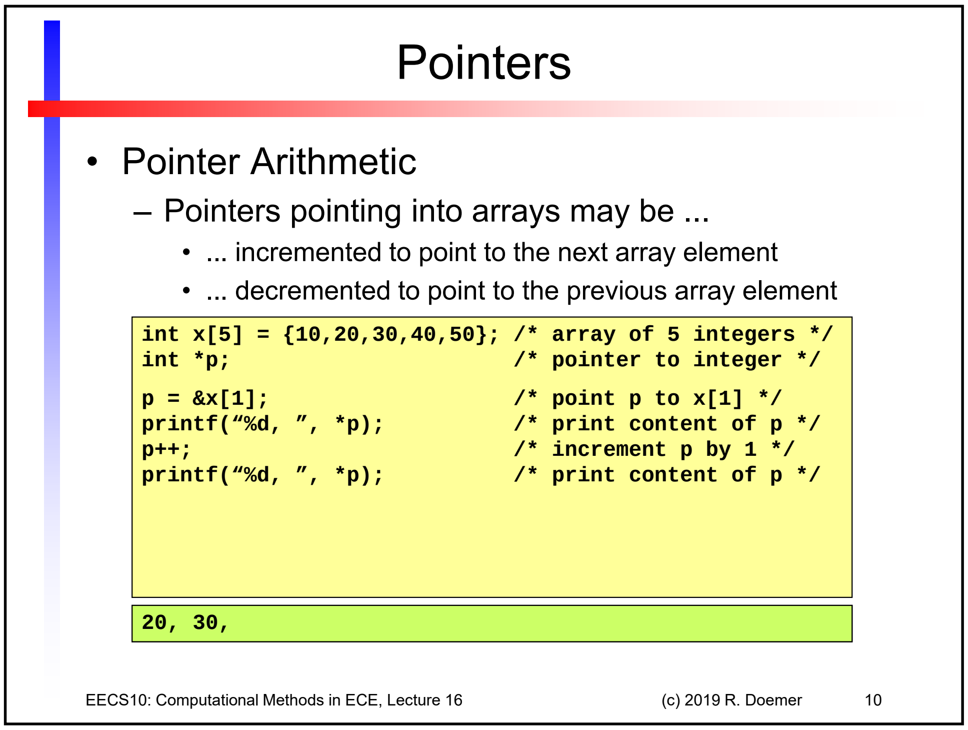


Pointers

- Pointer Arithmetic
  - Pointers pointing into arrays may be ...
    - ... incremented to point to the next array element
    - ... decremented to point to the previous array element

```
int x[5] = {10,20,30,40,50}; /* array of 5 integers */
int *p;                      /* pointer to integer */

p = &x[1];                   /* point p to x[1] */
printf(“%d, ”, *p);          /* print content of p */
```

```
20,
```



Pointers

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  - Pointers pointing into arrays may be ...
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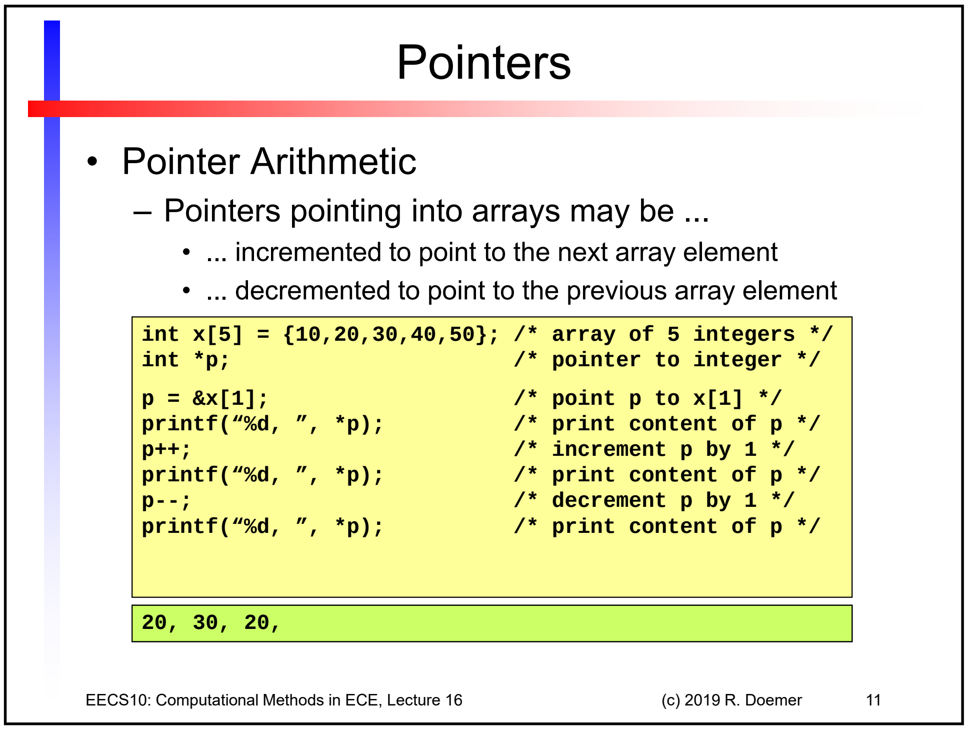
```
int x[5] = {10,20,30,40,50}; /* array of 5 integers */
int *p;                      /* pointer to integer */

p = &x[1];                   /* point p to x[1] */
printf(“%d, ”, *p);          /* print content of p */
p++;                         /* increment p by 1 */
printf(“%d, ”, *p);          /* print content of p */
```

```
20, 30,
```



Pointers

- Pointer Arithmetic
  - Pointers pointing into arrays may be ...
    - ... incremented to point to the next array element
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```
int x[5] = {10,20,30,40,50}; /* array of 5 integers */
int *p;                      /* pointer to integer */

p = &x[1];                   /* point p to x[1] */
printf(“%d, ”, *p);          /* print content of p */
p++;                         /* increment p by 1 */
printf(“%d, ”, *p);          /* print content of p */
p--;                         /* decrement p by 1 */
printf(“%d, ”, *p);          /* print content of p */
```

```
20, 30, 20,
```

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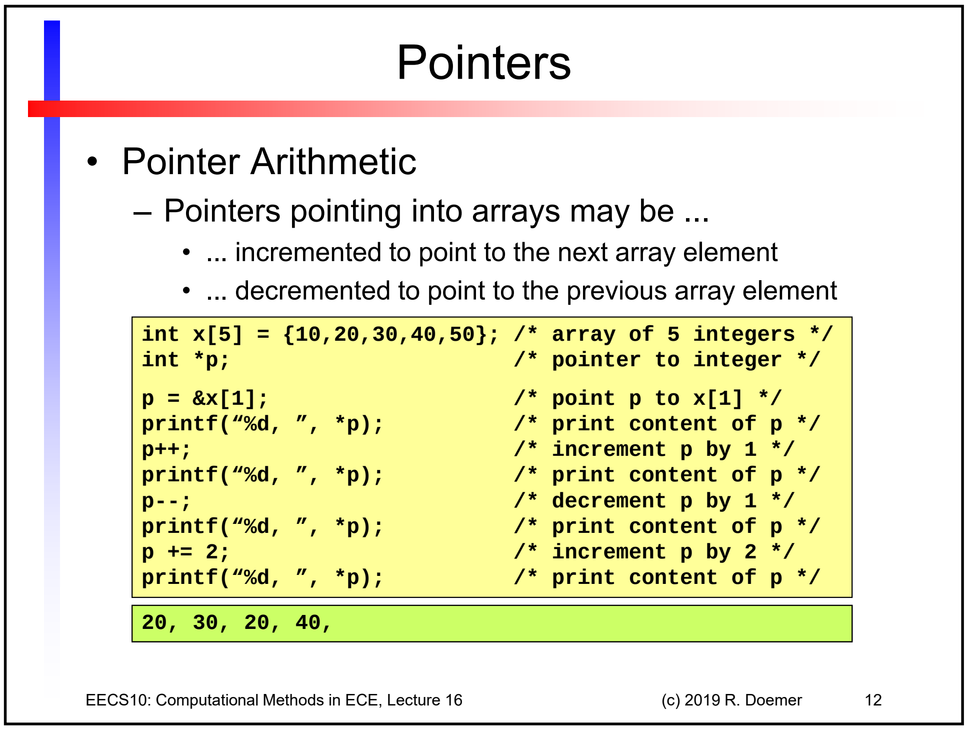

Pointers

- Pointer Arithmetic
  - Pointers pointing into arrays may be ...
    - ... incremented to point to the next array element
    - ... decremented to point to the previous array element

```
int x[5] = {10,20,30,40,50}; /* array of 5 integers */
int *p;                      /* pointer to integer */

p = &x[1];                   /* point p to x[1] */
printf(“%d, ”, *p);          /* print content of p */
p++;                         /* increment p by 1 */
printf(“%d, ”, *p);          /* print content of p */
p--;                         /* decrement p by 1 */
printf(“%d, ”, *p);          /* print content of p */
p += 2;                      /* increment p by 2 */
printf(“%d, ”, *p);          /* print content of p */
```

```
20, 30, 20, 40,
```

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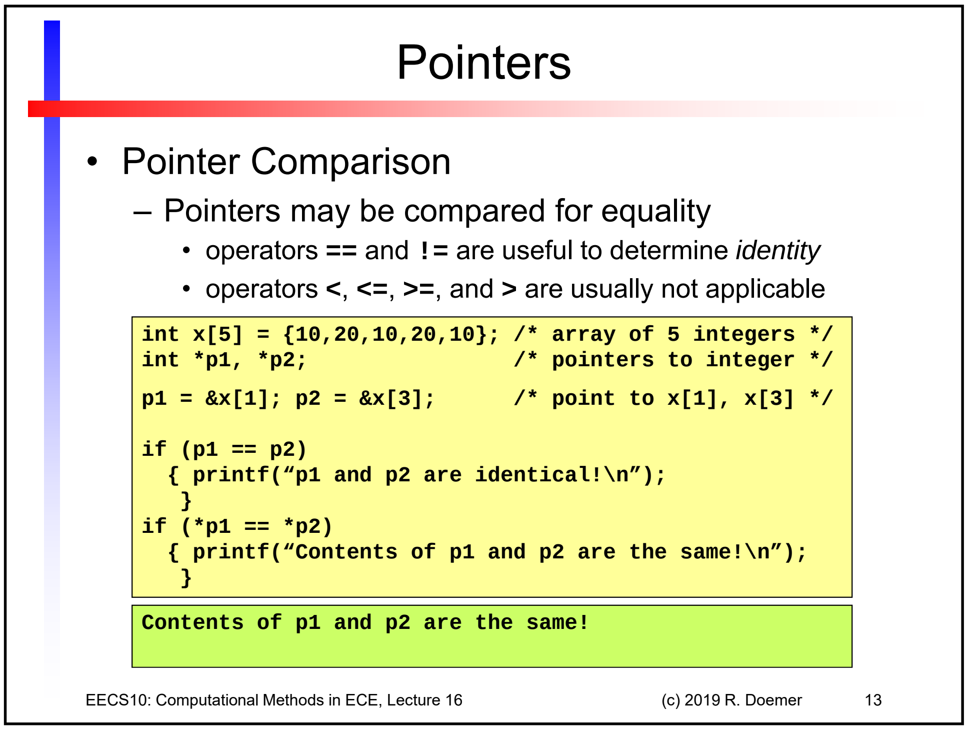

Pointers

- Pointer Comparison
  - Pointers may be compared for equality
    - operators **==** and **!=** are useful to determine *identity*
    - operators **<**, **<=**, **>=**, and **>** are usually not applicable

```
int x[5] = {10,20,10,20,10}; /* array of 5 integers */
int *p1, *p2;                /* pointers to integer */
p1 = &x[1]; p2 = &x[3];      /* point to x[1], x[3] */

if (p1 == p2)
  { printf("p1 and p2 are identical!\n");
   }
if (*p1 == *p2)
  { printf("Contents of p1 and p2 are the same!\n");
   }
```

```
Contents of p1 and p2 are the same!
```

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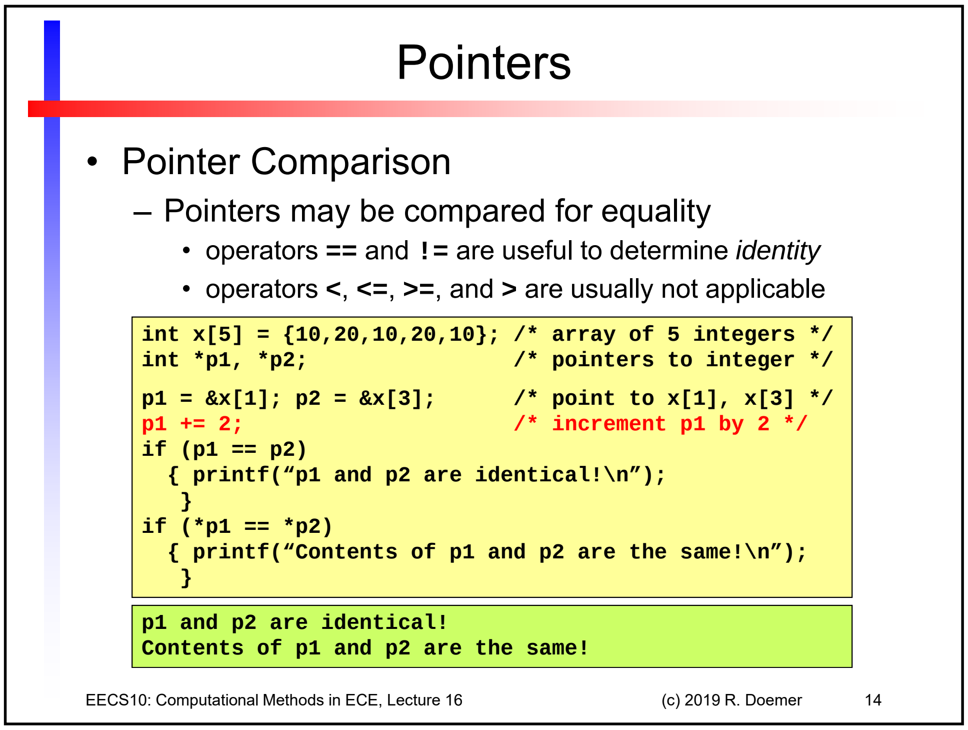

Pointers

- Pointer Comparison
  - Pointers may be compared for equality
    - operators **==** and **!=** are useful to determine *identity*
    - operators **<**, **<=**, **>=**, and **>** are usually not applicable

```
int x[5] = {10,20,10,20,10}; /* array of 5 integers */
int *p1, *p2;                /* pointers to integer */
p1 = &x[1]; p2 = &x[3];      /* point to x[1], x[3] */
p1 += 2;                     /* increment p1 by 2 */
if (p1 == p2)
  { printf("p1 and p2 are identical!\n");
   }
if (*p1 == *p2)
  { printf("Contents of p1 and p2 are the same!\n");
   }
```

```
p1 and p2 are identical!
Contents of p1 and p2 are the same!
```

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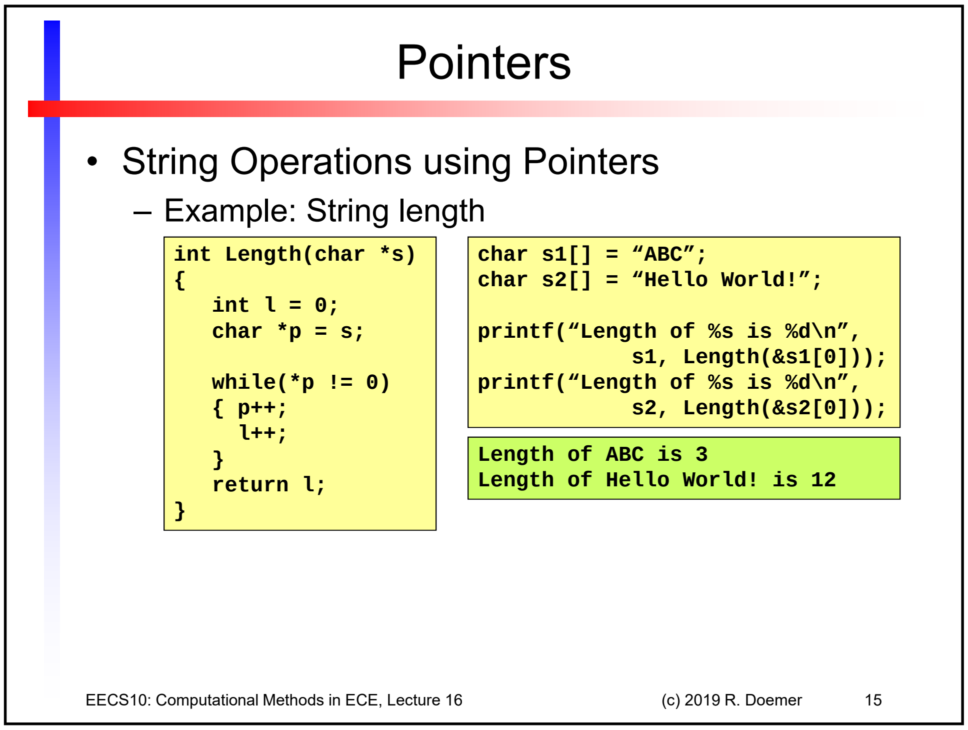


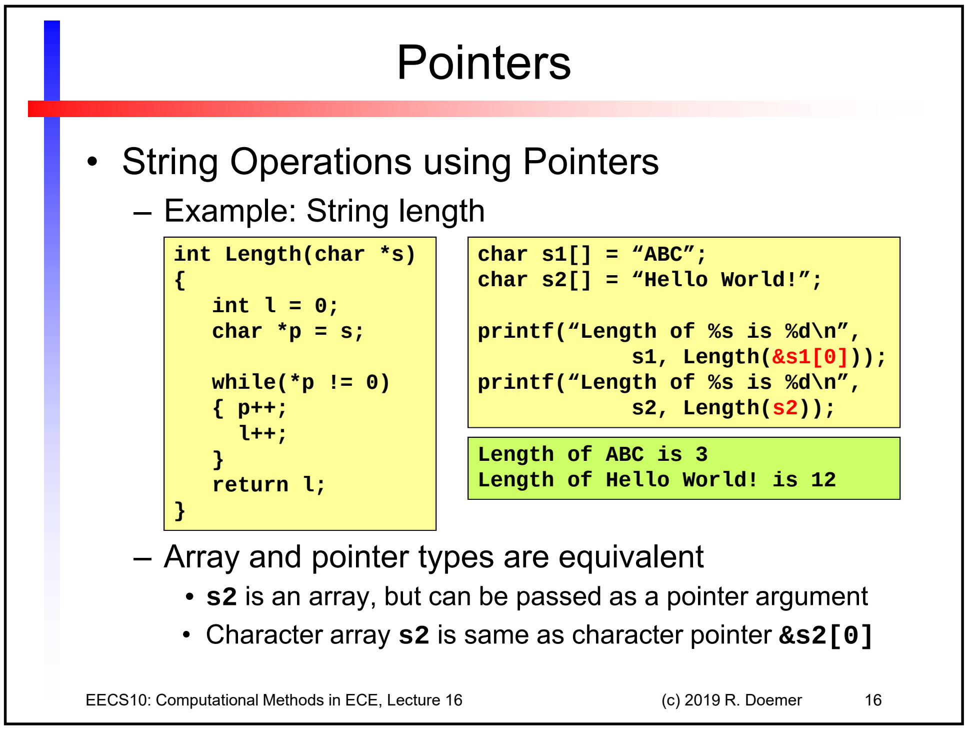
Pointers

- String Operations using Pointers
  - Example: String length

```
int Length(char *s)
{
   int l = 0;
   char *p = s;

   while(*p != 0)
   { p++;
     l++;
   }
   return l;
}
```

```
char s1[] = “ABC”;
char s2[] = “Hello World!”;

printf(“Length of %s is %d\n”,
            s1, Length(&s1[0]));
printf(“Length of %s is %d\n”,
            s2, Length(&s2[0]));
```

```
Length of ABC is 3
Length of Hello World! is 12
```



Pointers

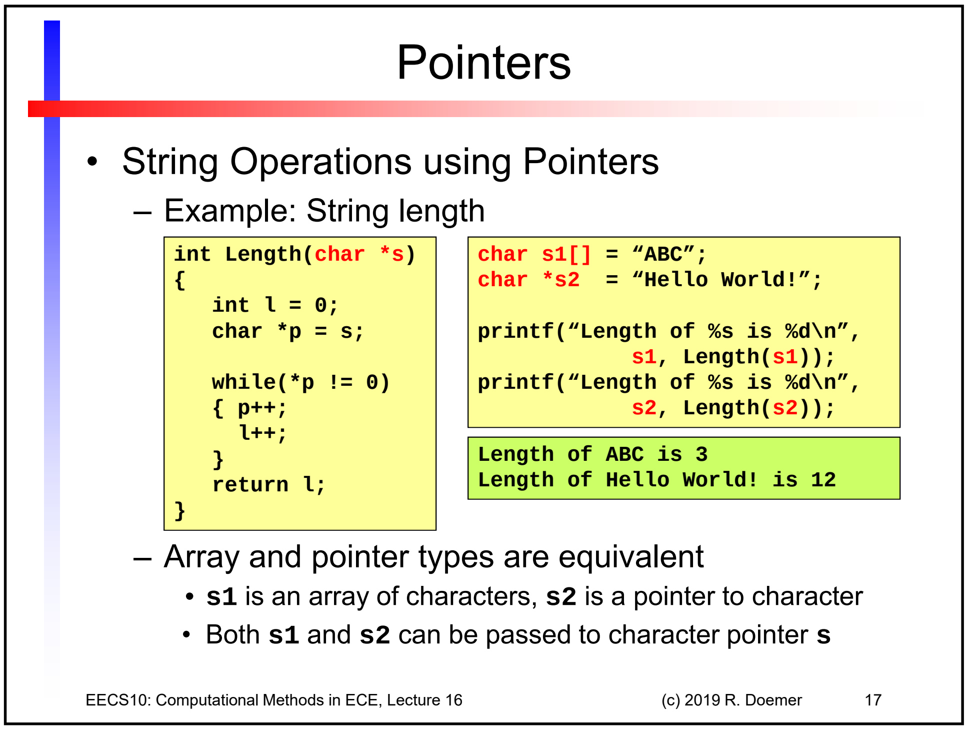
- String Operations using Pointers
  - Example: String length

```
int Length(char *s)
{
   int l = 0;
   char *p = s;

   while(*p != 0)
   { p++;
     l++;
   }
   return l;
}
```

```
char s1[] = “ABC”;
char s2[] = “Hello World!”;

printf(“Length of %s is %d\n”,
            s1, Length(&s1[0]));
printf(“Length of %s is %d\n”,
            s2, Length(s2));
```

```
Length of ABC is 3
Length of Hello World! is 12
```

  - Array and pointer types are equivalent
    - **`s2`** is an array, but can be passed as a pointer argument
    - Character array **`s2`** is same as character pointer **`&s2[0]`**



Pointers

- String Operations using Pointers
  - Example: String length

```
int Length(char *s)
{
   int l = 0;
   char *p = s;

   while(*p != 0)
   { p++;
     l++;
   }
   return l;
}
```

```
char s1[] = “ABC”;
char *s2  = “Hello World!”;

printf(“Length of %s is %d\n”,
            s1, Length(s1));
printf(“Length of %s is %d\n”,
            s2, Length(s2));
```

```
Length of ABC is 3
Length of Hello World! is 12
```

  - Array and pointer types are equivalent
    - **s1** is an array of characters, **s2** is a pointer to character
    - Both **s1** and **s2** can be passed to character pointer **s**

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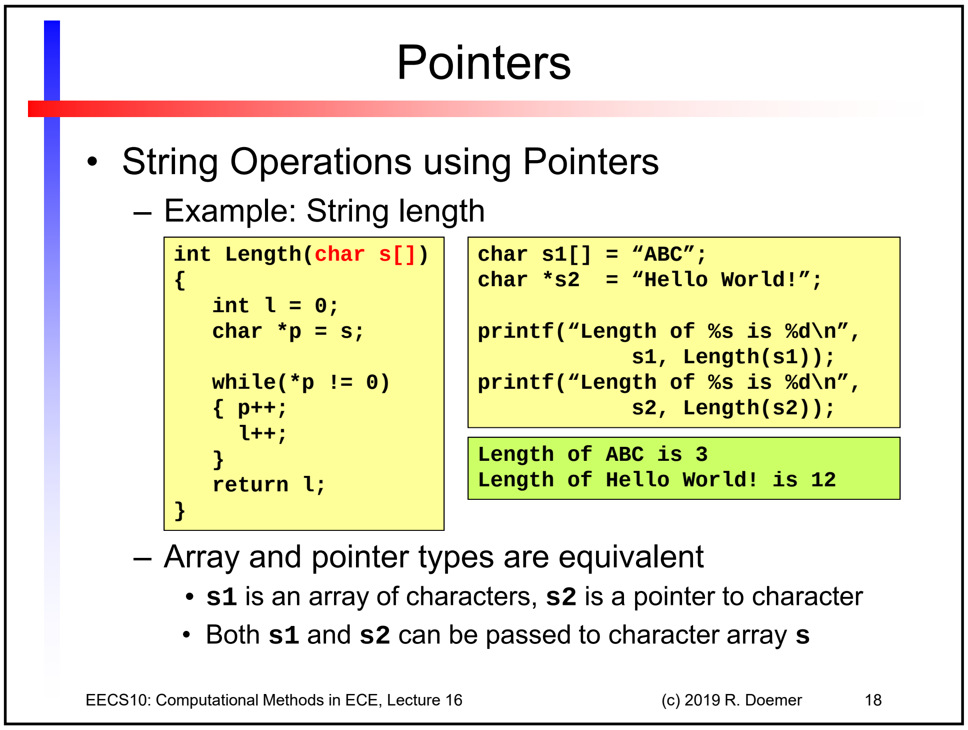

Pointers

- String Operations using Pointers
  - Example: String length

```
int Length(char s[])
{
   int l = 0;
   char *p = s;

   while(*p != 0)
   { p++;
     l++;
   }
   return l;
}
```

```
char s1[] = “ABC”;
char *s2  = “Hello World!”;

printf(“Length of %s is %d\n”,
            s1, Length(s1));
printf(“Length of %s is %d\n”,
            s2, Length(s2));
```

```
Length of ABC is 3
Length of Hello World! is 12
```

  - Array and pointer types are equivalent
    - **s1** is an array of characters, **s2** is a pointer to character
    - Both **s1** and **s2** can be passed to character array **s**

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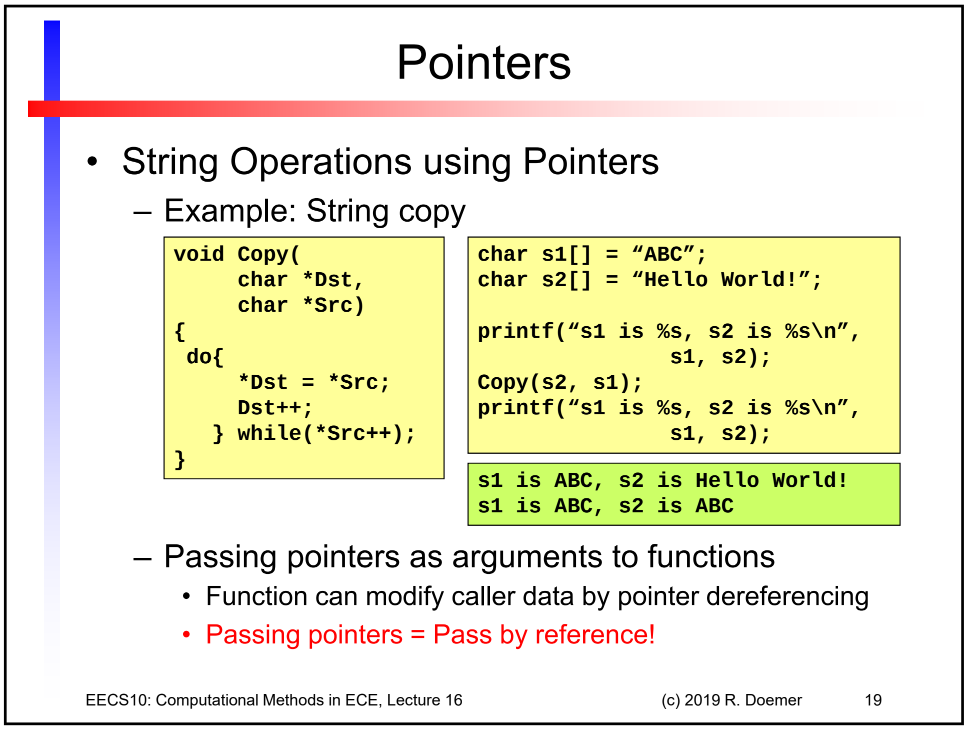

Pointers

- String Operations using Pointers
  - Example: String copy

```
void Copy(
     char *Dst,
     char *Src)
{
 do{
     *Dst = *Src;
     Dst++;
   } while(*Src++);
}
```

```
char s1[] = “ABC”;
char s2[] = “Hello World!”;

printf(“s1 is %s, s2 is %s\n”,
               s1, s2);
Copy(s2, s1);
printf(“s1 is %s, s2 is %s\n”,
               s1, s2);
```

```
s1 is ABC, s2 is Hello World!
s1 is ABC, s2 is ABC
```

  - Passing pointers as arguments to functions
    - Function can modify caller data by pointer dereferencing
    - Passing pointers = Pass by reference!

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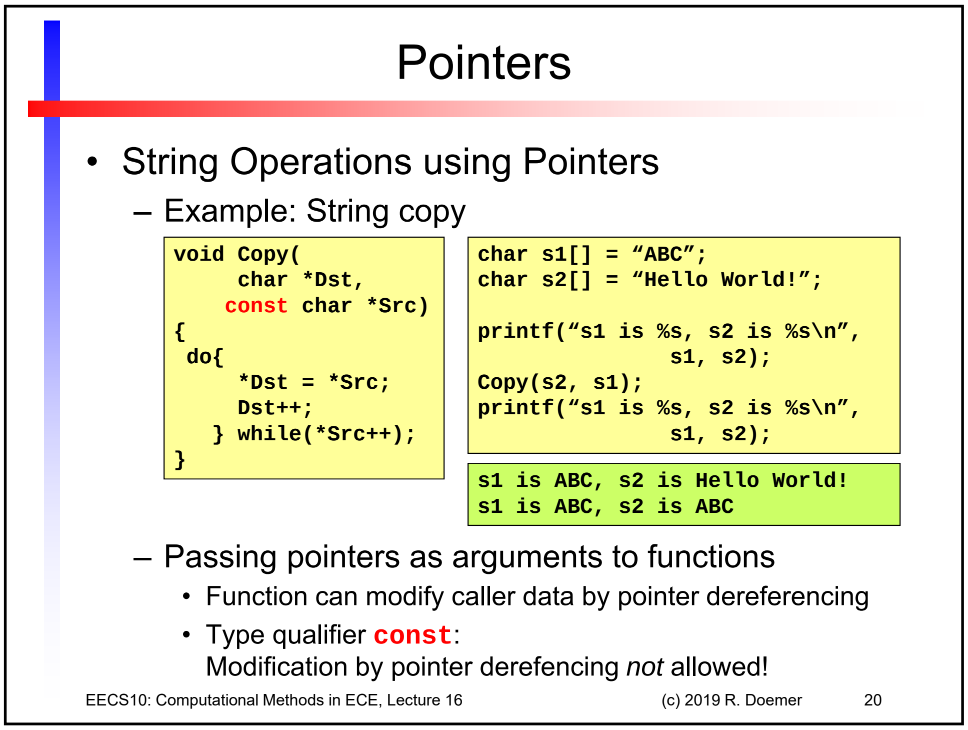

Pointers

- String Operations using Pointers
  - Example: String copy

```
void Copy(
     char *Dst,
    const char *Src)
{
 do{
     *Dst = *Src;
     Dst++;
   } while(*Src++);
}
```

```
char s1[] = “ABC”;
char s2[] = “Hello World!”;

printf(“s1 is %s, s2 is %s\n”,
               s1, s2);
Copy(s2, s1);
printf(“s1 is %s, s2 is %s\n”,
               s1, s2);
```

```
s1 is ABC, s2 is Hello World!
s1 is ABC, s2 is ABC
```

  - Passing pointers as arguments to functions
    - Function can modify caller data by pointer dereferencing
    - Type qualifier `const`:
      Modification by pointer derefencing *not* allowed!

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Pointers

- String Operations using Pointers
  - Example: String copy

```
void Copy(
    const char *Dst,
    const char *Src)
{
 do{
     *Dst = *Src;
     Dst++;
   } while(*Src++);
```

Error!
Write access to **`const`** data!

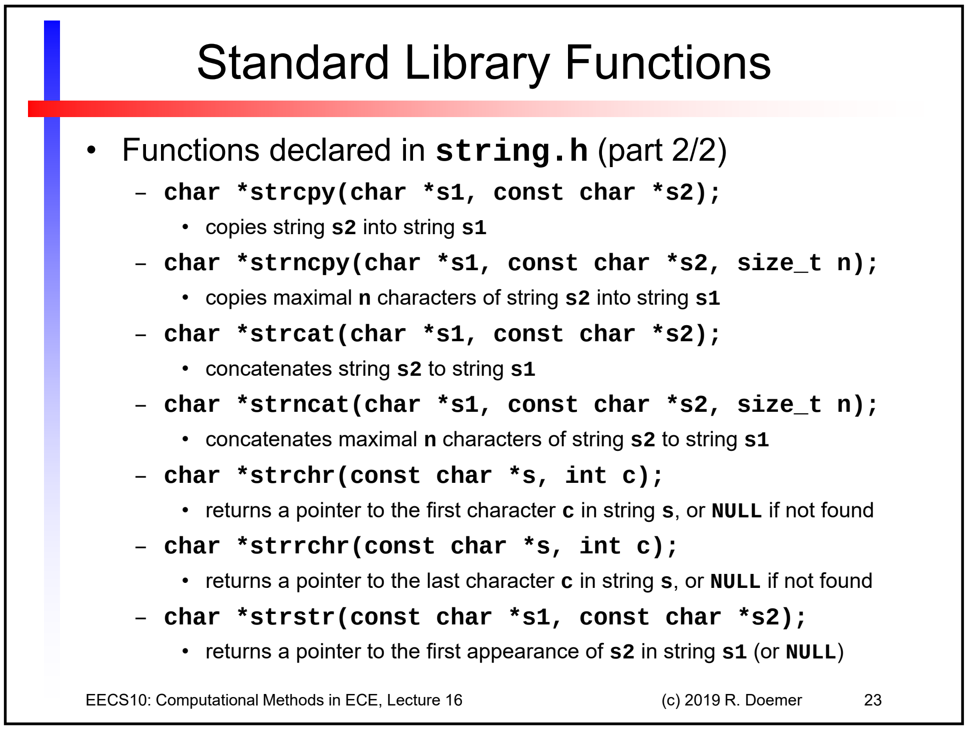
```
char s1[] = "ABC";
char s2[] = "Hello World!";

printf("s1 is %s, s2 is %s\n",
               s1, s2);
Copy(s2, s1);
printf("s1 is %s, s2 is %s\n",
               s1, s2);
```

```
s1 is ABC, s2 is Hello World!
s1 is ABC, s2 is ABC
```

  - Passing pointers as arguments to functions
    - Function can modify caller data by pointer dereferencing
    - Type qualifier **`const`**:
      Modification by pointer derefencing *not* allowed!

Standard Library Functions

- Functions declared in **`string.h`** (part 1/2)
  - **`typedef unsigned int size_t;`**
    - type definition for length of strings
  - **`size_t strlen(const char *s);`**
    - returns the length of string **`s`**
  - **`int strcmp(const char *s1, const char *s2);`**
    - alphabetically compares string **`s1`** with string **`s2`**
    - returns -1 / 0 / 1 for less-than / equal-to / greater-than
  - **`int strncmp(const char *s1, const char *s2, size_t n);`**
    - same as previous, but compares maximal **`n`** characters
  - **`int strcasecmp(const char *s1, const char *s2);`**
  - **`int strncasecmp(const char *s1, const char *s2, size_t n);`**
    - same as string comparisons above, but case-insensitive



Standard Library Functions

- Functions declared in **`string.h`** (part 2/2)
  - **`char *strcpy(char *s1, const char *s2);`**
    - copies string **`s2`** into string **`s1`**
  - **`char *strncpy(char *s1, const char *s2, size_t n);`**
    - copies maximal **`n`** characters of string **`s2`** into string **`s1`**
  - **`char *strcat(char *s1, const char *s2);`**
    - concatenates string **`s2`** to string **`s1`**
  - **`char *strncat(char *s1, const char *s2, size_t n);`**
    - concatenates maximal **`n`** characters of string **`s2`** to string **`s1`**
  - **`char *strchr(const char *s, int c);`**
    - returns a pointer to the first character **`c`** in string **`s`**, or **`NULL`** if not found
  - **`char *strrchr(const char *s, int c);`**
    - returns a pointer to the last character **`c`** in string **`s`**, or **`NULL`** if not found
  - **`char *strstr(const char *s1, const char *s2);`**
    - returns a pointer to the first appearance of **`s2`** in string **`s1`** (or **`NULL`**)

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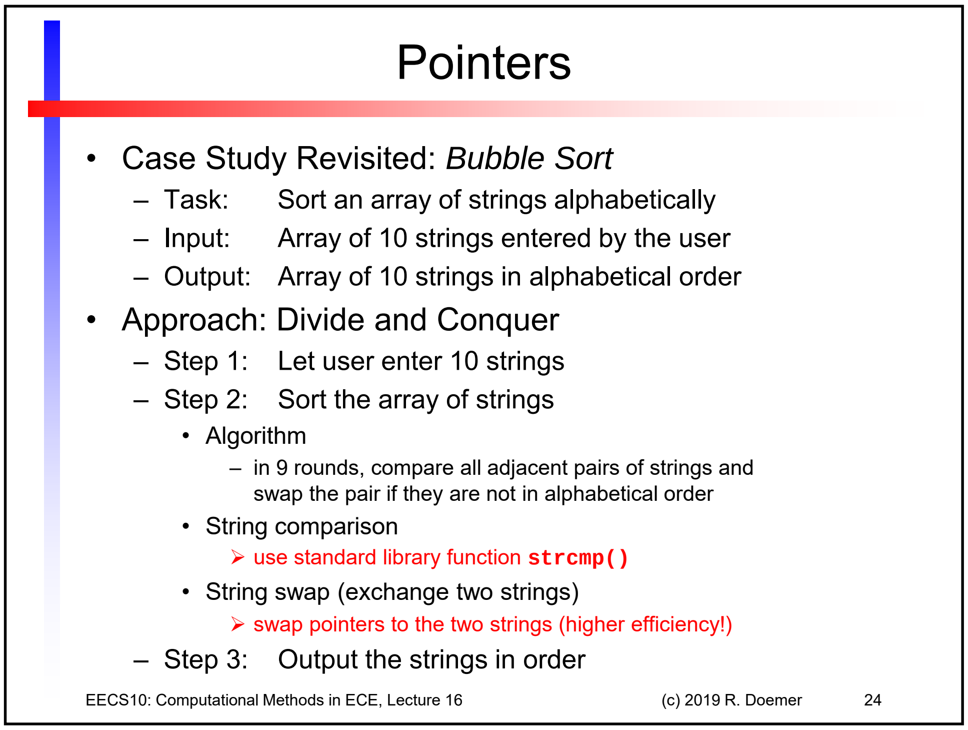

Pointers

- Case Study Revisited: *Bubble Sort*
  - Task: Sort an array of strings alphabetically
  - Input: Array of 10 strings entered by the user
  - Output: Array of 10 strings in alphabetical order
- Approach: Divide and Conquer
  - Step 1: Let user enter 10 strings
  - Step 2: Sort the array of strings
    - Algorithm
      - in 9 rounds, compare all adjacent pairs of strings and swap the pair if they are not in alphabetical order
    - String comparison
      - ➢ use standard library function **`strcmp()`**
    - String swap (exchange two strings)
      - ➢ swap pointers to the two strings (higher efficiency!)
  - Step 3: Output the strings in order

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Pointers

- Program example: **`BubbleSort2.c`** (part 1/6)

```
/* BubbleSort.c: sort strings alphabetically    */
/* author: Rainer Doemer                        */
/* modifications:                               */
/* 09/02/13 RD  pointer table for efficiency    */
/* 11/01/06 RD  swap only adjacent elements     */
/* 11/06/04 RD  initial version                 */

#include <stdio.h>
#include <string.h>

/* constant definitions */
#define NUM 10  /* ten strings  */
#define LEN 20  /* of length 20 */

/* function declarations */
void EnterText(char Text[NUM][LEN], char *P[NUM]);
void PrintText(char *P[NUM]);
void SwapStrings(char *P[NUM], int i, int j);
void BubbleSort(char *P[NUM]);
...
```

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Pointers

- Program example: **`BubbleSort2.c`** (part 2/6)

```
...

/* function definitions */

/* let the user enter the text array            */

void EnterText(char Text[NUM][LEN], char *P[NUM])
{
   int i;

   for(i = 0; i < NUM; i++)
      { printf("Enter text string %2d: ", i+1);
        scanf("%19s", Text[i]);
        P[i] = Text[i];
       } /* rof */
} /* end of EnterText */

...
```

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Pointers

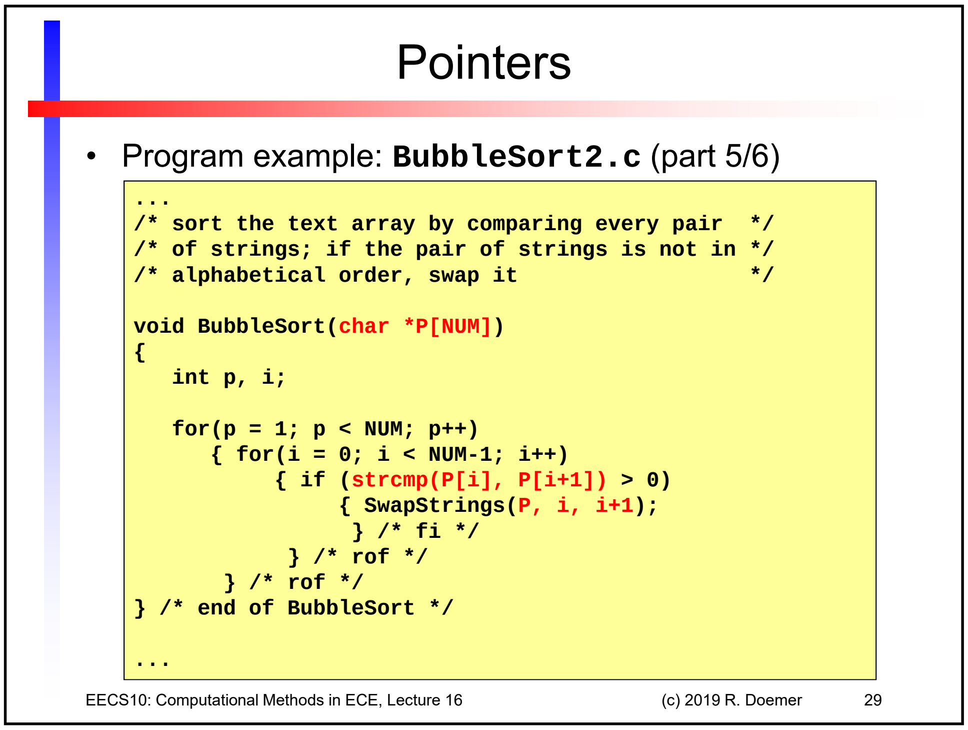
- Program example: **`BubbleSort2.c`** (part 3/6)

```
...

/* print the text array on the screen           */

void PrintText(char *P[NUM])
{
   int i;

   for(i = 0; i < NUM; i++)
      { printf("String %2d: %s\n", i+1, P[i]);
       } /* rof */
} /* end of PrintText */

...
```

Pointers

- Program example: **`BubbleSort2.c`** (part 4/6)

```
...

/* swap/exchange the pointers to two strings */

void SwapStrings(char *P[NUM], int i, int j)
{
    char *tmp;

    tmp = P[i];
    P[i] = P[j];
    P[j] = tmp;

} /* end of SwapStrings */

...
```



Pointers

- Program example: **`BubbleSort2.c`** (part 5/6)

```
...
/* sort the text array by comparing every pair  */
/* of strings; if the pair of strings is not in */
/* alphabetical order, swap it                  */

void BubbleSort(char *P[NUM])
{
   int p, i;

   for(p = 1; p < NUM; p++)
      { for(i = 0; i < NUM-1; i++)
           { if (strcmp(P[i], P[i+1]) > 0)
                { SwapStrings(P, i, i+1);
                 } /* fi */
            } /* rof */
       } /* rof */
} /* end of BubbleSort */

...
```

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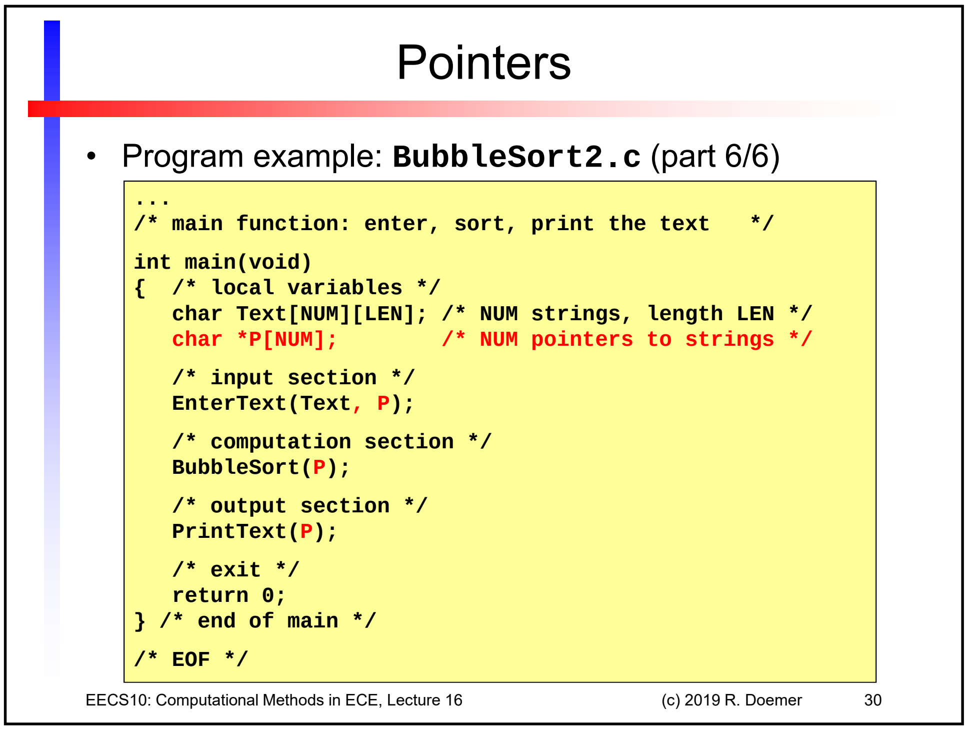

Pointers

- Program example: **`BubbleSort2.c`** (part 6/6)

```
...
/* main function: enter, sort, print the text   */

int main(void)
{  /* local variables */
   char Text[NUM][LEN]; /* NUM strings, length LEN */
   char *P[NUM];        /* NUM pointers to strings */

   /* input section */
   EnterText(Text, P);

   /* computation section */
   BubbleSort(P);

   /* output section */
   PrintText(P);

   /* exit */
   return 0;
} /* end of main */

/* EOF */
```

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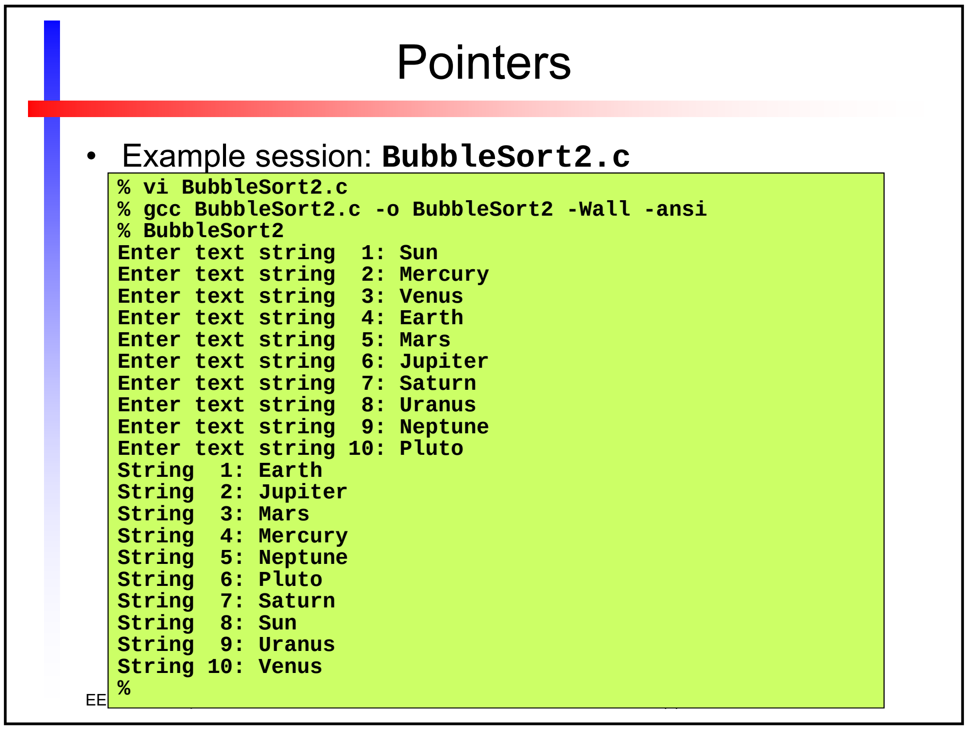

Pointers

- Example session: **`BubbleSort2.c`**

```
% vi BubbleSort2.c
% gcc BubbleSort2.c -o BubbleSort2 -Wall -ansi
% BubbleSort2
Enter text string  1: Sun
Enter text string  2: Mercury
Enter text string  3: Venus
Enter text string  4: Earth
Enter text string  5: Mars
Enter text string  6: Jupiter
Enter text string  7: Saturn
Enter text string  8: Uranus
Enter text string  9: Neptune
Enter text string 10: Pluto
String  1: Earth
String  2: Jupiter
String  3: Mars
String  4: Mercury
String  5: Neptune
String  6: Pluto
String  7: Saturn
String  8: Sun
String  9: Uranus
String 10: Venus
%
```

EE