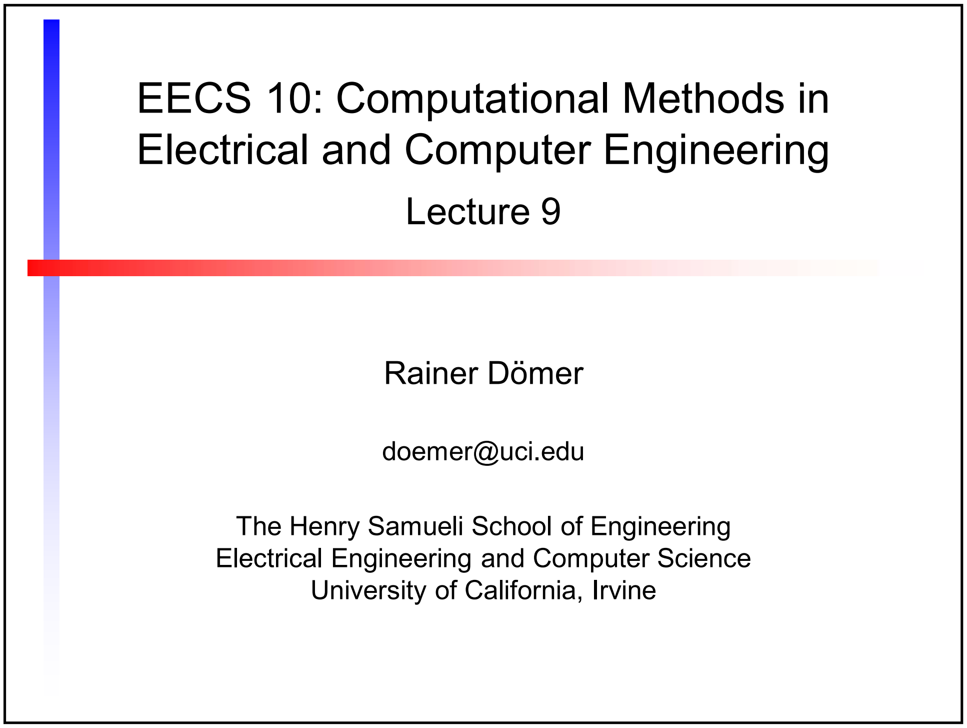

EECS 10: Computational Methods in Electrical and Computer Engineering

Lecture 9

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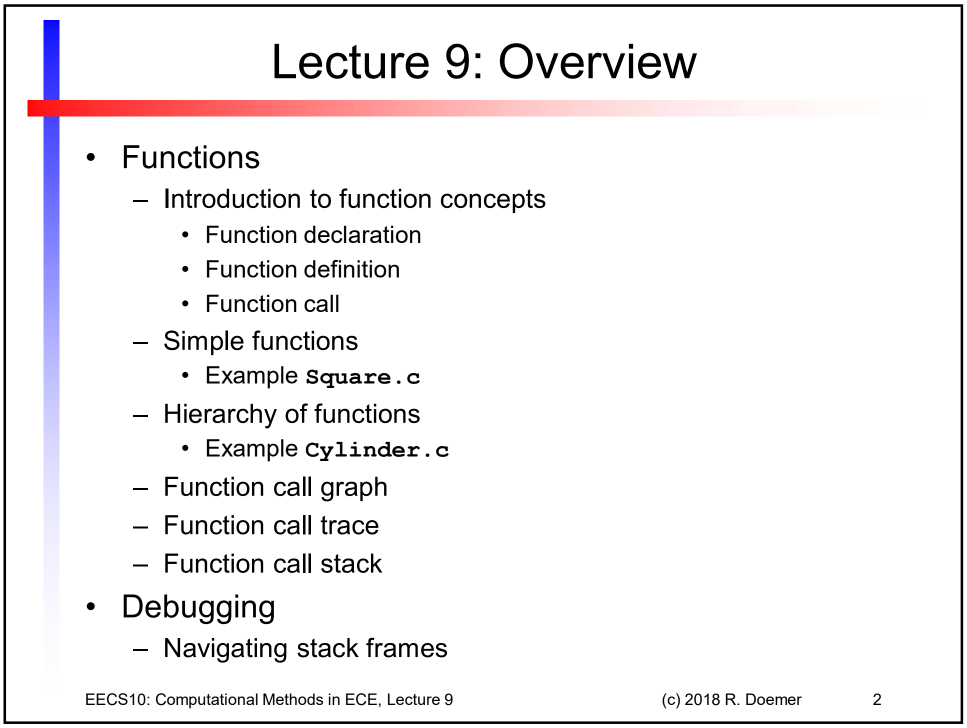
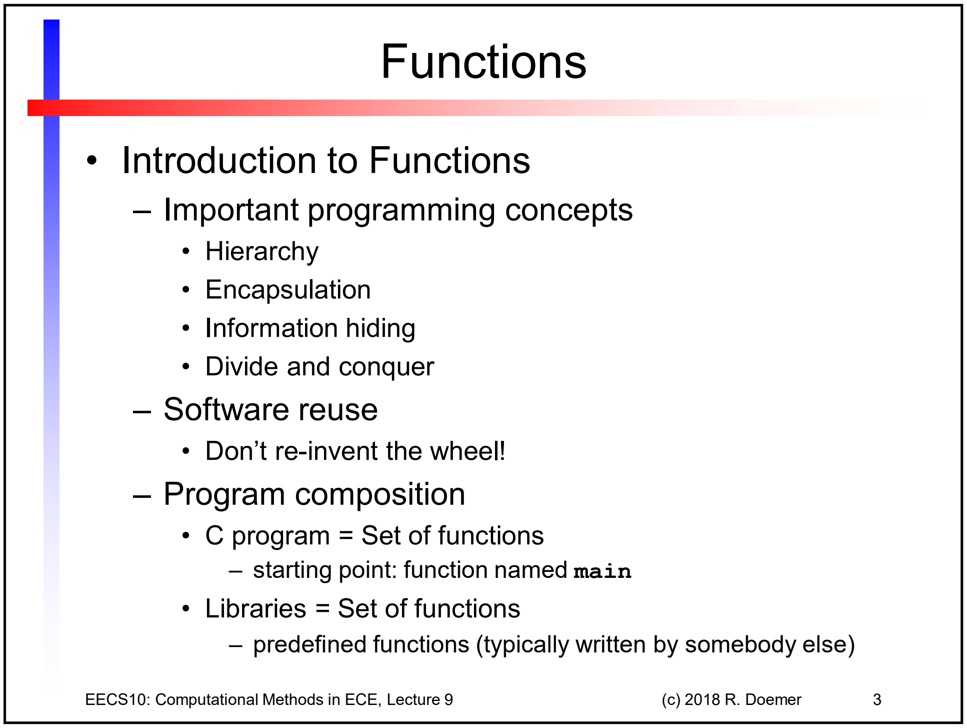


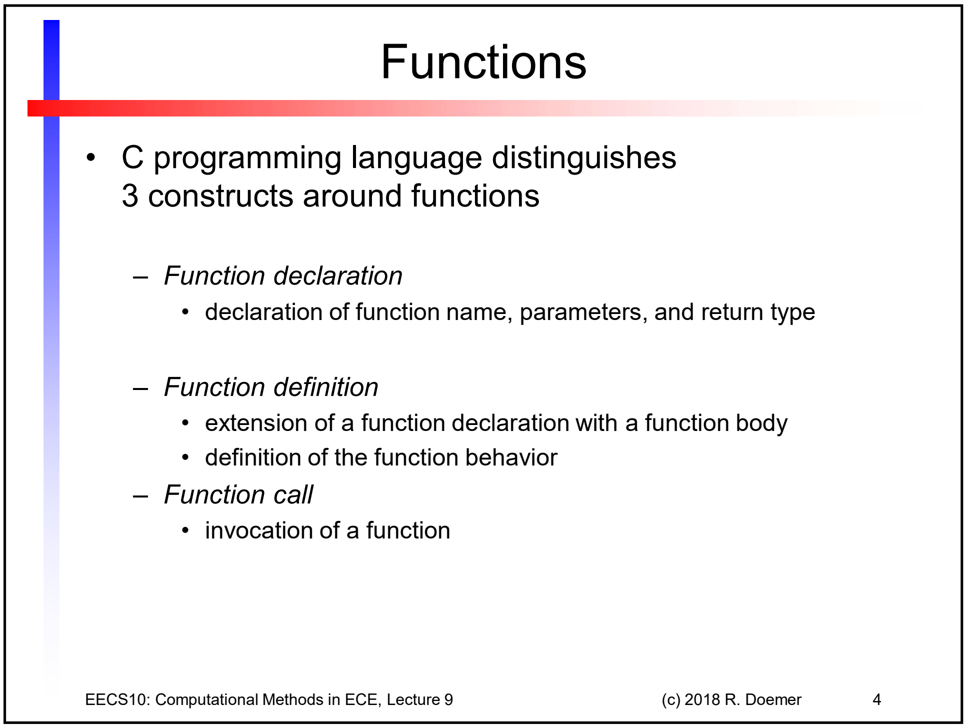
Lecture 9: Overview

- Functions
  - Introduction to function concepts
    - Function declaration
    - Function definition
    - Function call
  - Simple functions
    - Example `Square.c`
  - Hierarchy of functions
    - Example `Cylinder.c`
  - Function call graph
  - Function call trace
  - Function call stack
- Debugging
  - Navigating stack frames



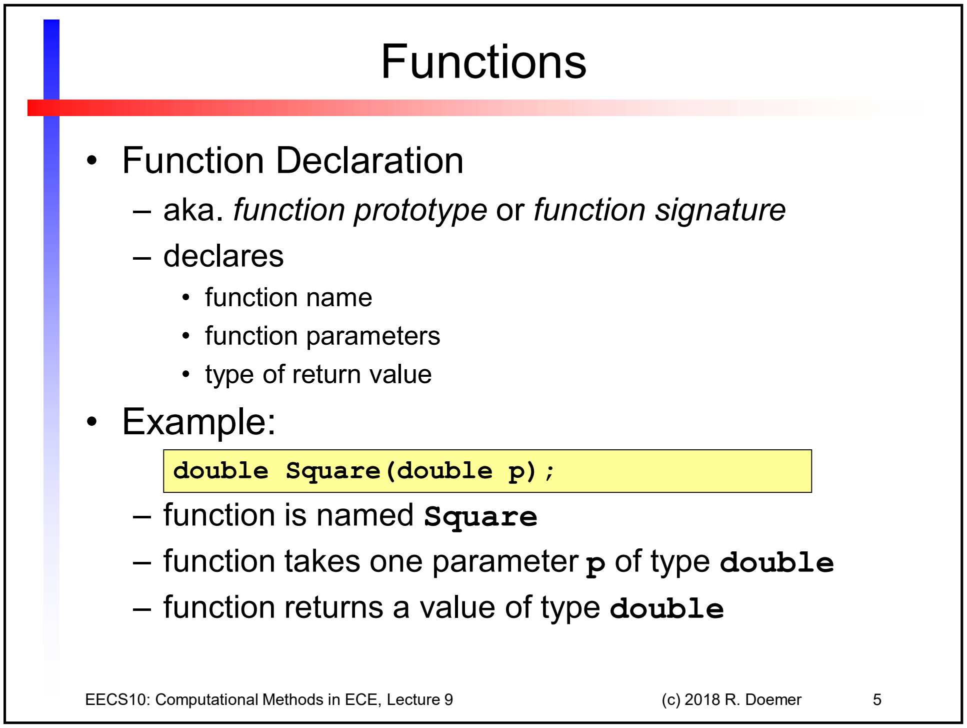
Functions

- Introduction to Functions
  - Important programming concepts
    - Hierarchy
    - Encapsulation
    - Information hiding
    - Divide and conquer
  - Software reuse
    - Don’t re-invent the wheel!
  - Program composition
    - C program = Set of functions
      - starting point: function named **`main`**
    - Libraries = Set of functions
      - predefined functions (typically written by somebody else)



Functions

- C programming language distinguishes
  3 constructs around functions
  - *Function declaration*
    - declaration of function name, parameters, and return type
  - *Function definition*
    - extension of a function declaration with a function body
    - definition of the function behavior
  - *Function call*
    - invocation of a function

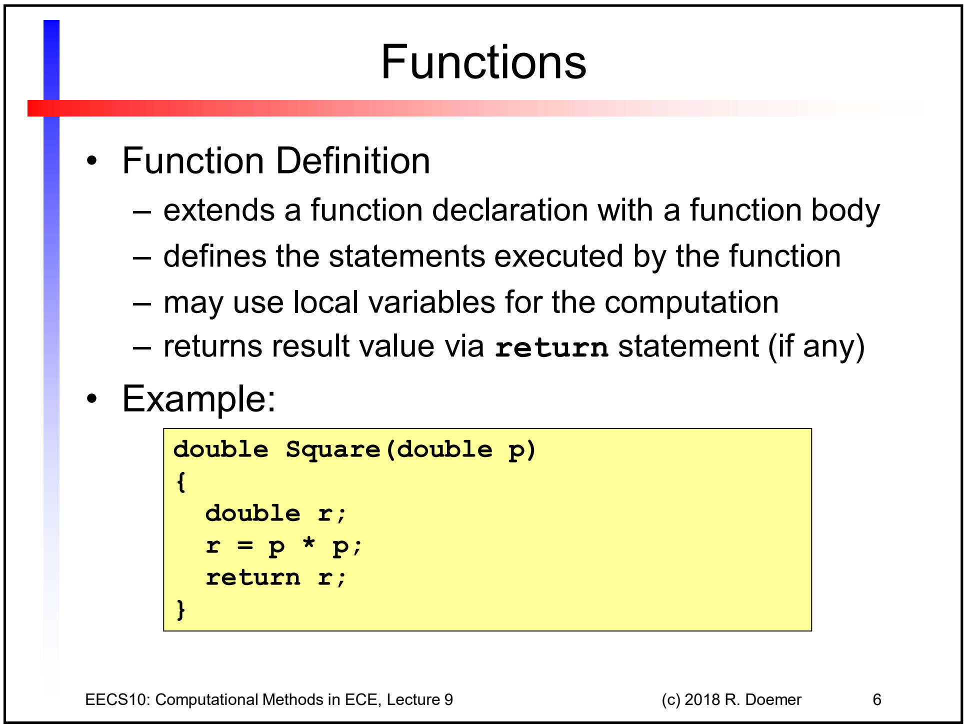


Functions

- Function Declaration
  - aka. *function prototype* or *function signature*
  - declares
    - function name
    - function parameters
    - type of return value
- Example:

```
double Square(double p);
```

  - function is named **`Square`**
  - function takes one parameter **`p`** of type **`double`**
  - function returns a value of type **`double`**



Functions

- Function Definition
  - extends a function declaration with a function body
  - defines the statements executed by the function
  - may use local variables for the computation
  - returns result value via **`return`** statement (if any)
- Example:

```
double Square(double p)
{
  double r;
  r = p * p;
  return r;
}
```

Functions

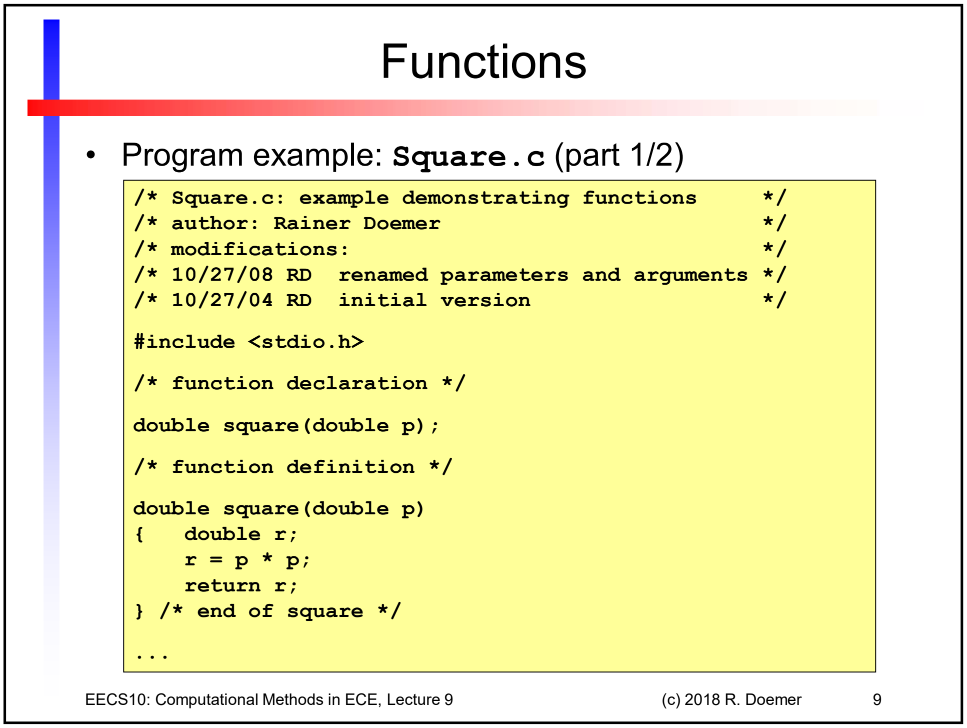
- Function Call
  - expression invoking a function
  - supplies arguments for formal parameters
  - invokes the function
  - result is the value returned by the function
- Example:

```
double a, b;
b = Square(a);
```

  - function **`Square`** is called
  - argument **`a`** is passed for parameter **`p`** (by value)
  - value returned by the function is assigned to **`b`**

Functions

- C programming language distinguishes 3 constructs
  - Function declaration
    - declaration of function name, parameters, and return type
  - Function definition
    - extension of a function declaration with a function body
    - definition of the function behavior
  - Function call
    - invocation of a function
- C program rules
  - A function must be declared before it can be called.
  - Multiple function declarations are allowed (if they match).
  - A function definition is an implicit function declaration.
  - A function must be defined exactly once in a program.
  - A function may be called any number of times.



Functions

- Program example: **Square.c** (part 1/2)

```
/* Square.c: example demonstrating functions      */
/* author: Rainer Doemer                           */
/* modifications:                                  */
/* 10/27/08 RD  renamed parameters and arguments */
/* 10/27/04 RD  initial version                   */

#include <stdio.h>

/* function declaration */

double square(double p);

/* function definition */

double square(double p)
{   double r;
    r = p * p;
    return r;
} /* end of square */

...
```

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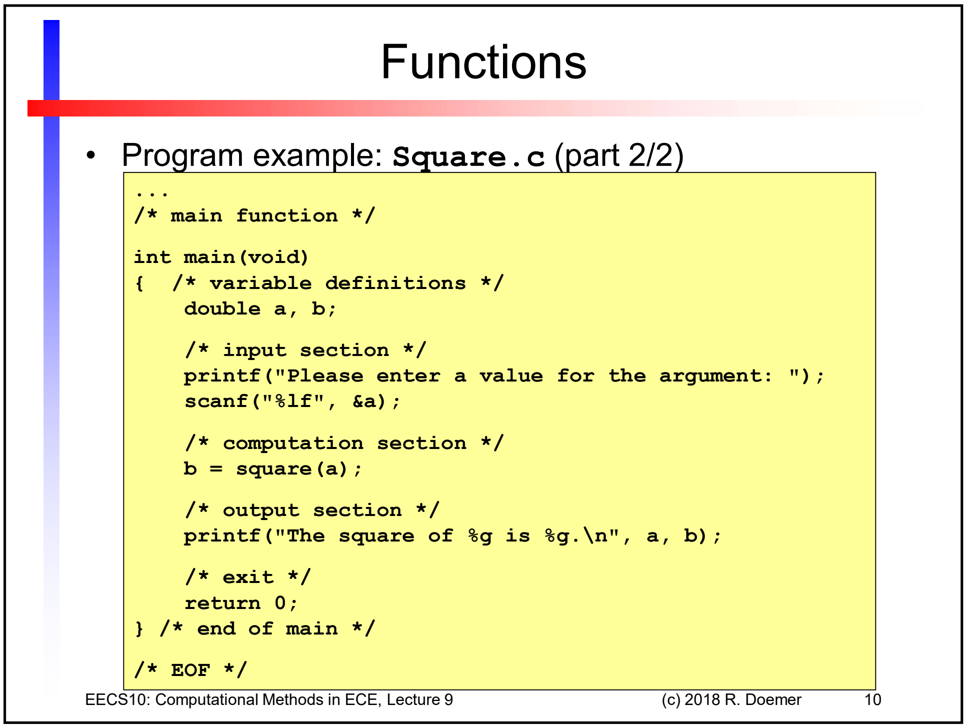

Functions

- Program example: **Square.c** (part 2/2)

```
...
/* main function */

int main(void)
{  /* variable definitions */
    double a, b;

    /* input section */
    printf("Please enter a value for the argument: ");
    scanf("%lf", &a);

    /* computation section */
    b = square(a);

    /* output section */
    printf("The square of %g is %g.\n", a, b);

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

/* EOF */
```

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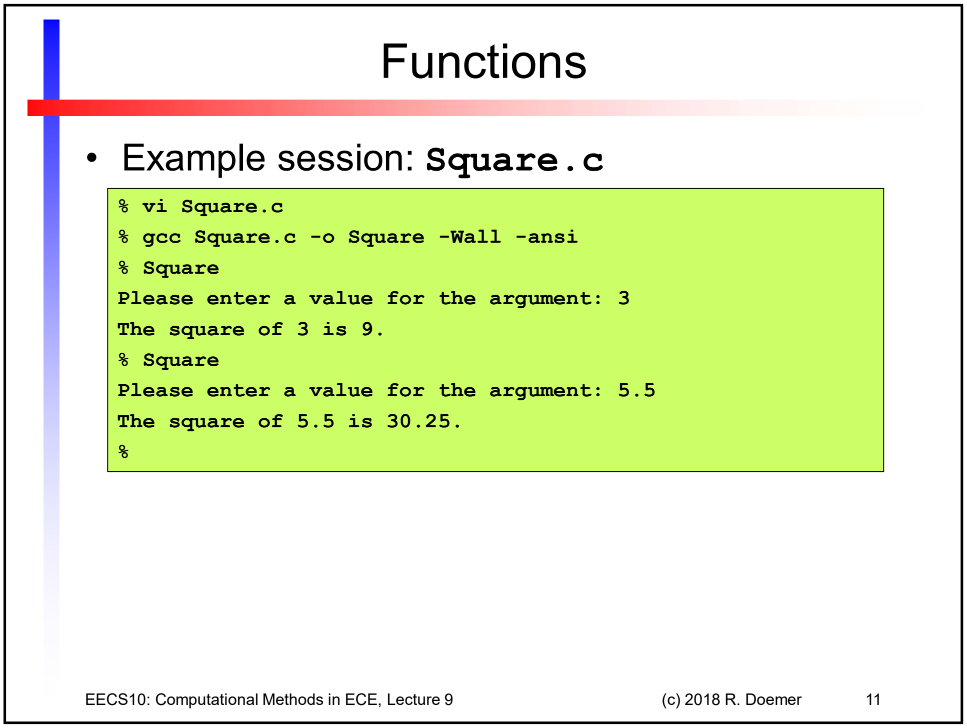
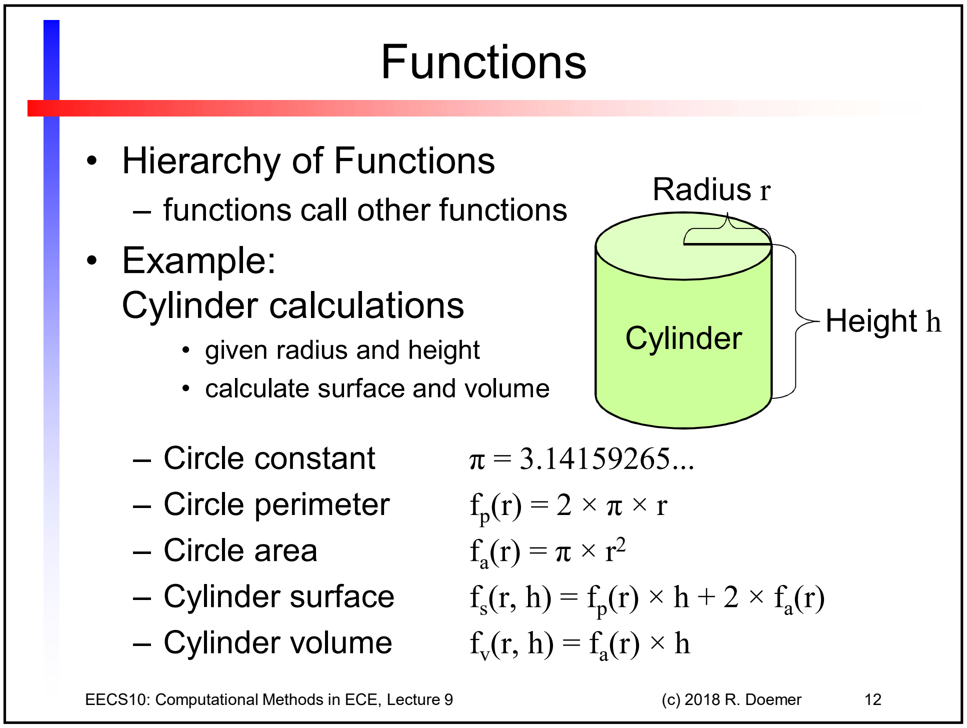


Functions

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

```
% vi Square.c
% gcc Square.c -o Square -Wall -ansi
% Square
Please enter a value for the argument: 3
The square of 3 is 9.
% Square
Please enter a value for the argument: 5.5
The square of 5.5 is 30.25.
%
```

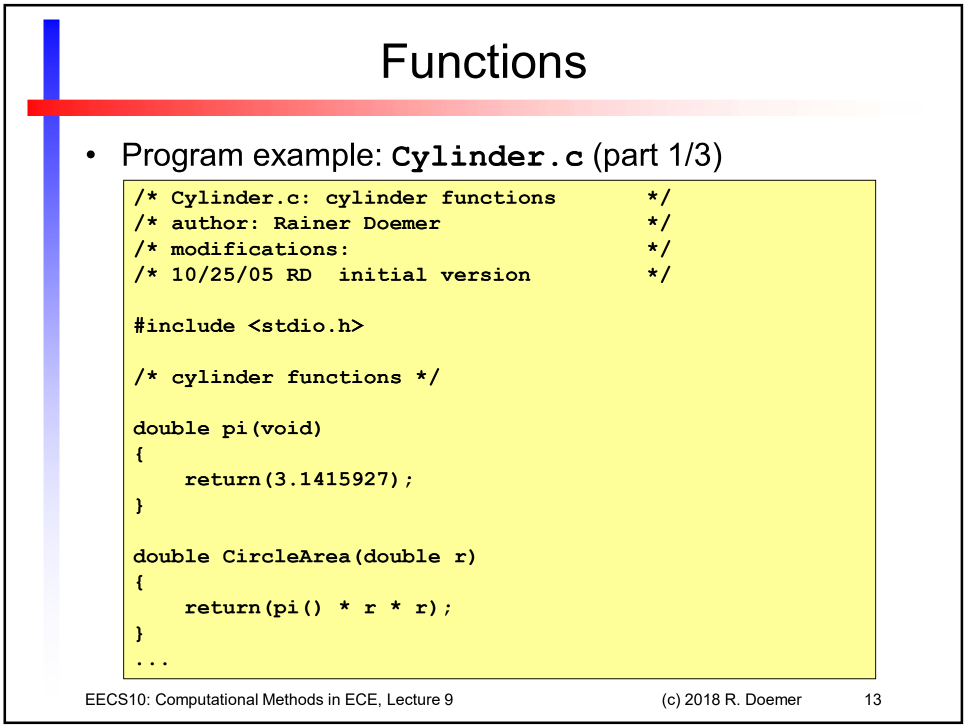


Functions

- Hierarchy of Functions
  - functions call other functions
- Example:
  Cylinder calculations
  - given radius and height
  - calculate surface and volume

Radius r
Cylinder
Height h

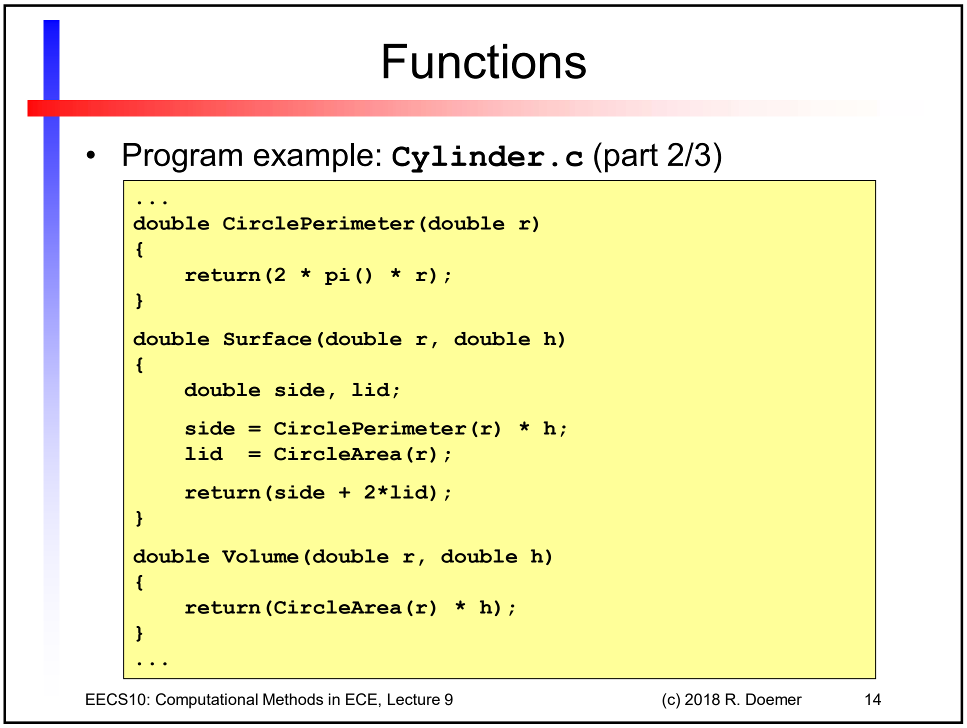
- Circle constant $\pi = 3.14159265...$
- Circle perimeter $f_p(r) = 2 \times \pi \times r$
- Circle area $f_a(r) = \pi \times r^2$
- Cylinder surface $f_s(r, h) = f_p(r) \times h + 2 \times f_a(r)$
- Cylinder volume $f_v(r, h) = f_a(r) \times h$



Functions

- Program example: `Cylinder.c` (part 1/3)

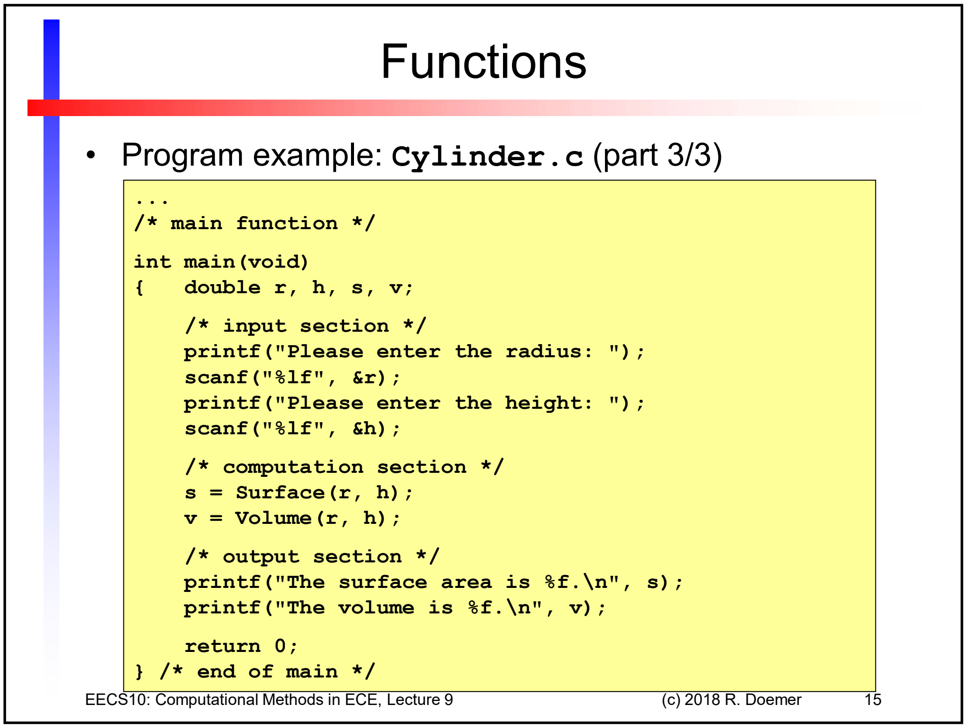
```
/* Cylinder.c: cylinder functions       */
/* author: Rainer Doemer                 */
/* modifications:                        */
/* 10/25/05 RD  initial version          */

#include <stdio.h>

/* cylinder functions */

double pi(void)
{
    return(3.1415927);
}

double CircleArea(double r)
{
    return(pi() * r * r);
}
...
```



Functions

- Program example: `Cylinder.c` (part 2/3)

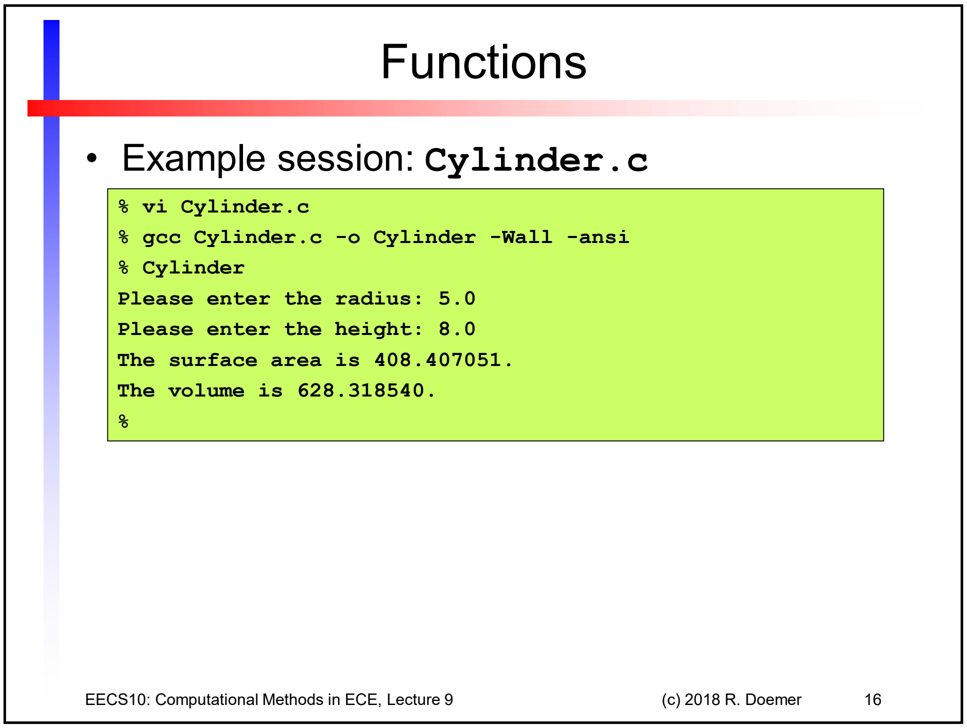
```
...
double CirclePerimeter(double r)
{
    return(2 * pi() * r);
}
double Surface(double r, double h)
{
    double side, lid;
    side = CirclePerimeter(r) * h;
    lid  = CircleArea(r);
    return(side + 2*lid);
}
double Volume(double r, double h)
{
    return(CircleArea(r) * h);
}
...
```



Functions

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

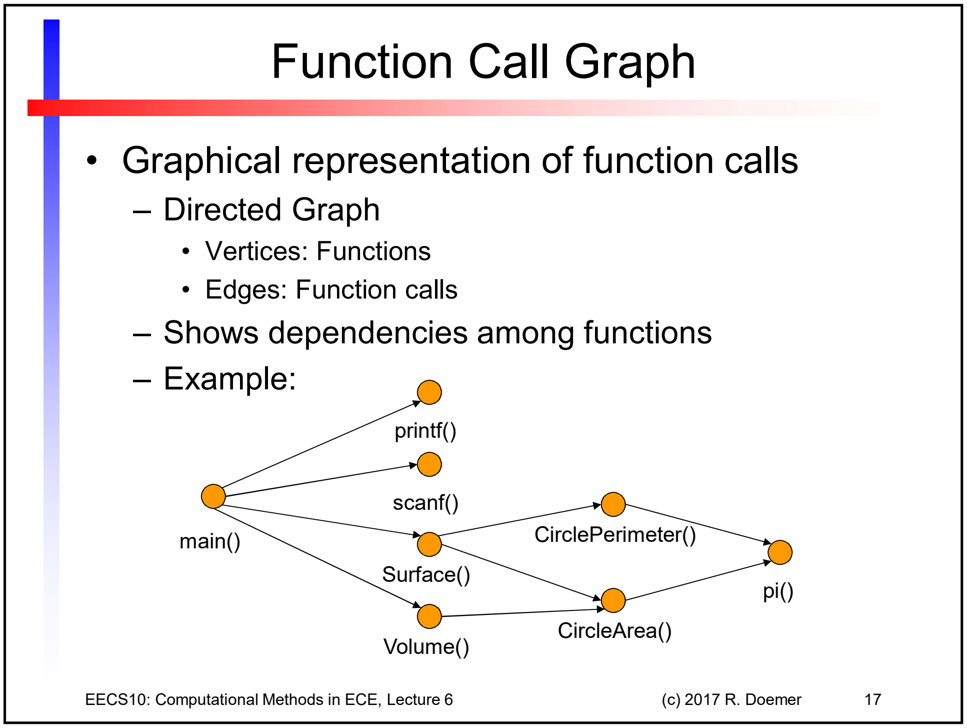
```
...
/* main function */

int main(void)
{   double r, h, s, v;

    /* input section */
    printf("Please enter the radius: ");
    scanf("%lf", &r);
    printf("Please enter the height: ");
    scanf("%lf", &h);

    /* computation section */
    s = Surface(r, h);
    v = Volume(r, h);

    /* output section */
    printf("The surface area is %f.\n", s);
    printf("The volume is %f.\n", v);

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



Functions

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

```
% vi Cylinder.c
% gcc Cylinder.c -o Cylinder -Wall -ansi
% Cylinder
Please enter the radius: 5.0
Please enter the height: 8.0
The surface area is 408.407051.
The volume is 628.318540.
%
```



Function Call Graph

- Graphical representation of function calls
  - Directed Graph
    - Vertices: Functions
    - Edges: Function calls
  - Shows dependencies among functions
  - Example:

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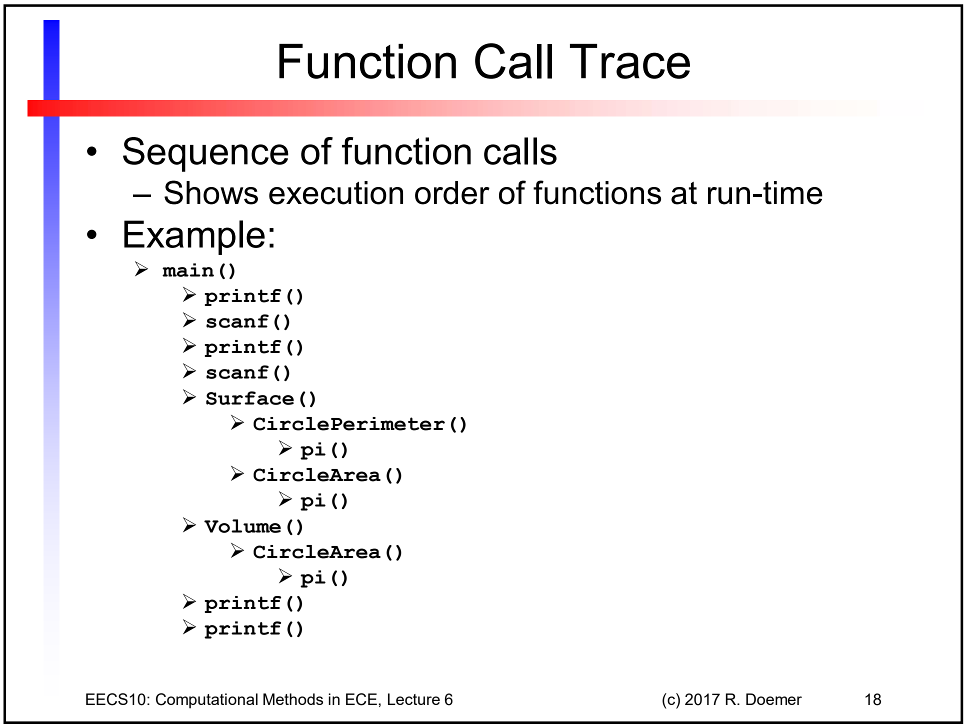

Function Call Trace

- Sequence of function calls
  - Shows execution order of functions at run-time
- Example:

```
➢ main()
  ➢ printf()
  ➢ scanf()
  ➢ printf()
  ➢ scanf()
  ➢ Surface()
    ➢ CirclePerimeter()
      ➢ pi()
    ➢ CircleArea()
      ➢ pi()
  ➢ Volume()
    ➢ CircleArea()
      ➢ pi()
  ➢ printf()
  ➢ printf()
```

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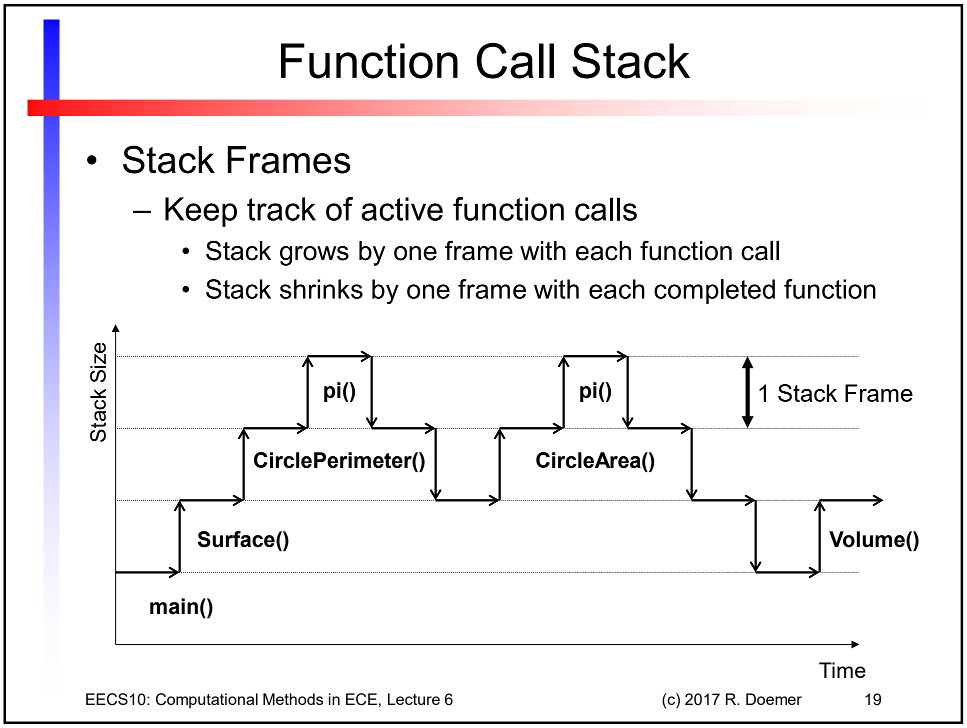
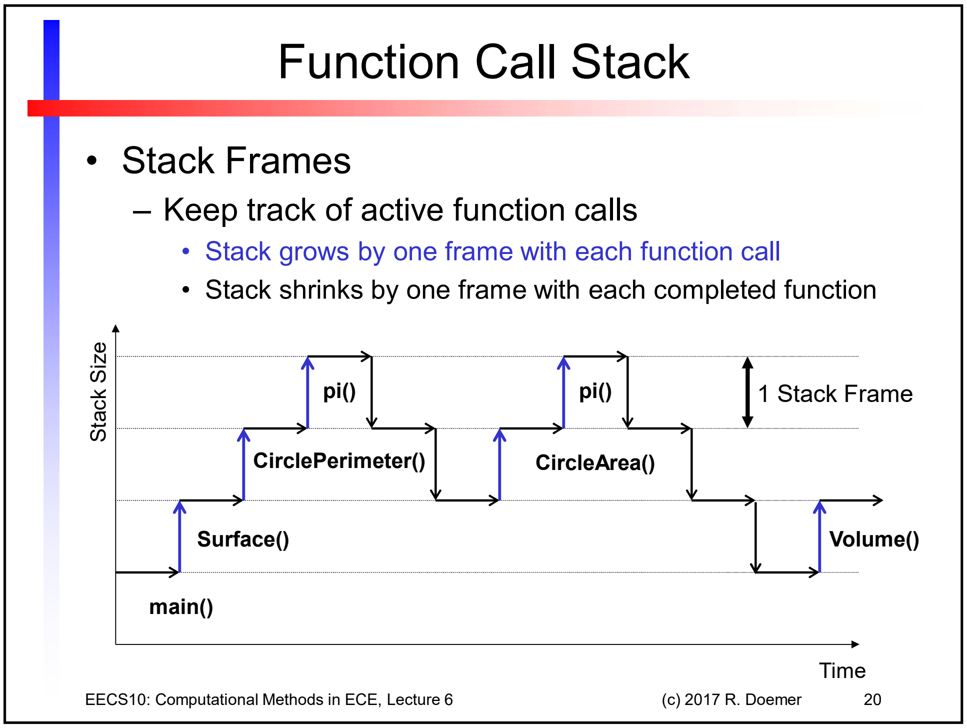


Function Call Stack

- Stack Frames
  - Keep track of active function calls
    - Stack grows by one frame with each function call
    - Stack shrinks by one frame with each completed function



Function Call Stack

- Stack Frames
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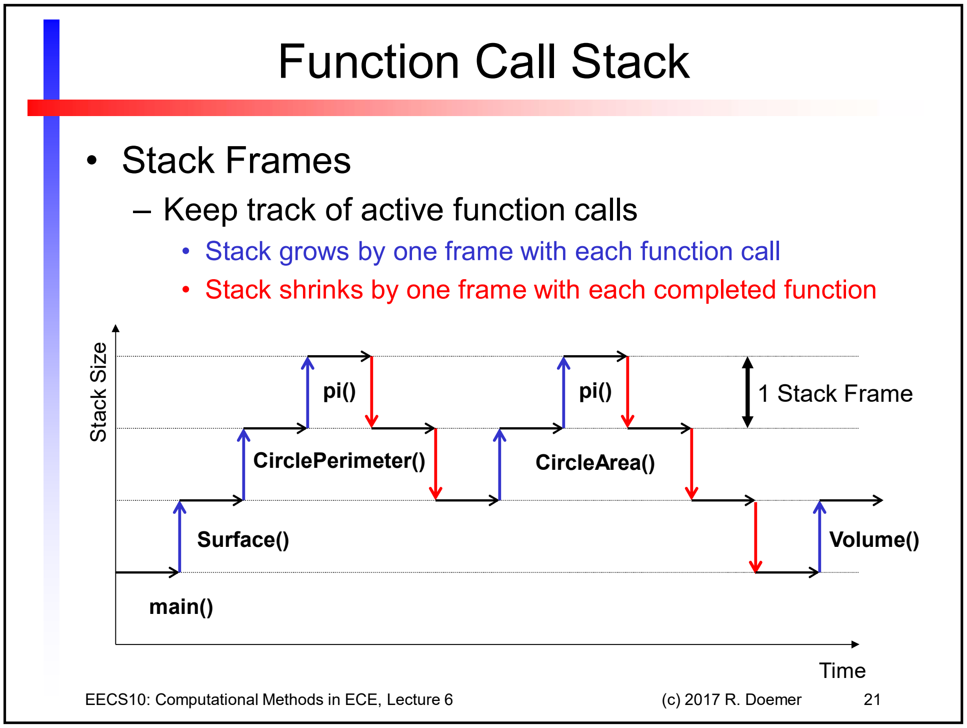

Function Call Stack

- Stack Frames
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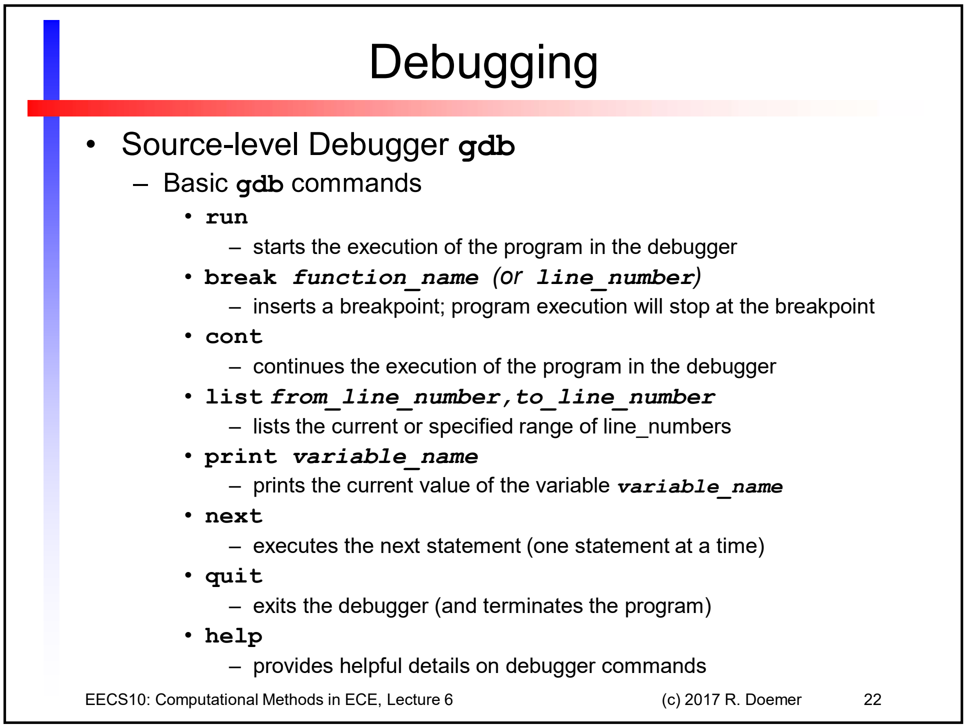

Debugging

- Source-level Debugger **`gdb`**
  - Basic **`gdb`** commands
    - **`run`**
      - starts the execution of the program in the debugger
    - **`break`** ***`function_name`*** (or ***`line_number`***)
      - inserts a breakpoint; program execution will stop at the breakpoint
    - **`cont`**
      - continues the execution of the program in the debugger
    - **`list`** ***`from_line_number,to_line_number`***
      - lists the current or specified range of line_numbers
    - **`print`** ***`variable_name`***
      - prints the current value of the variable ***`variable_name`***
    - **`next`**
      - executes the next statement (one statement at a time)
    - **`quit`**
      - exits the debugger (and terminates the program)
    - **`help`**
      - provides helpful details on debugger commands

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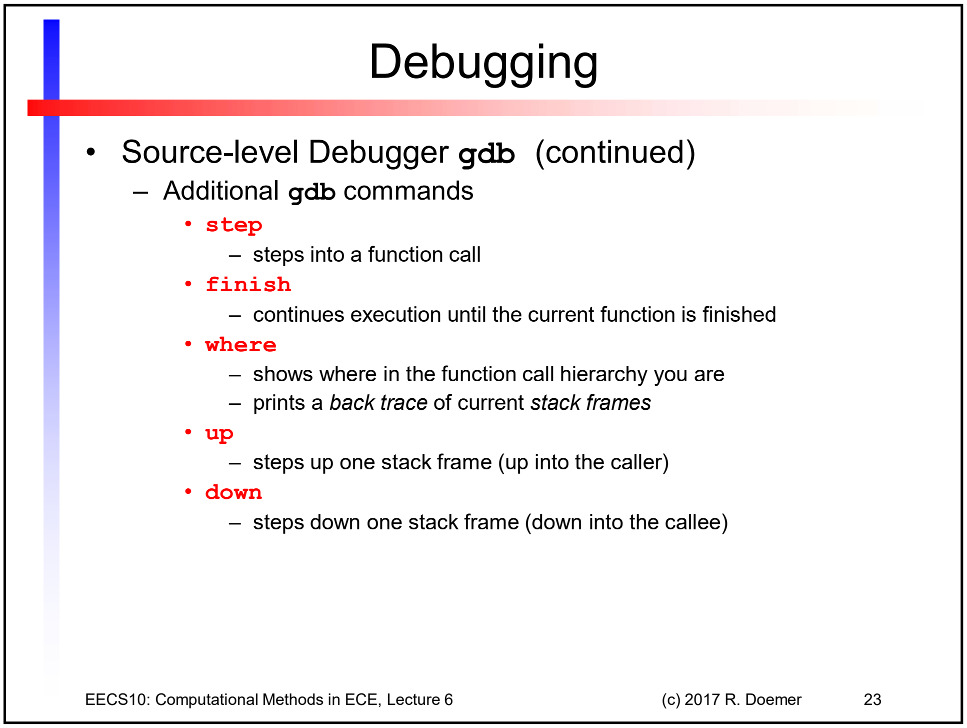
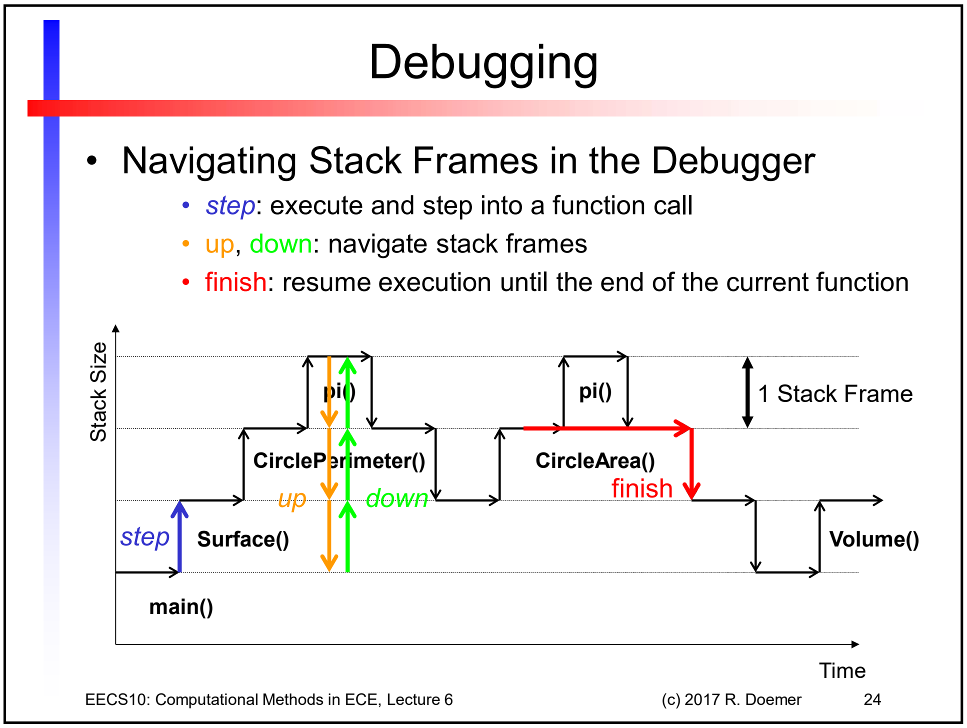


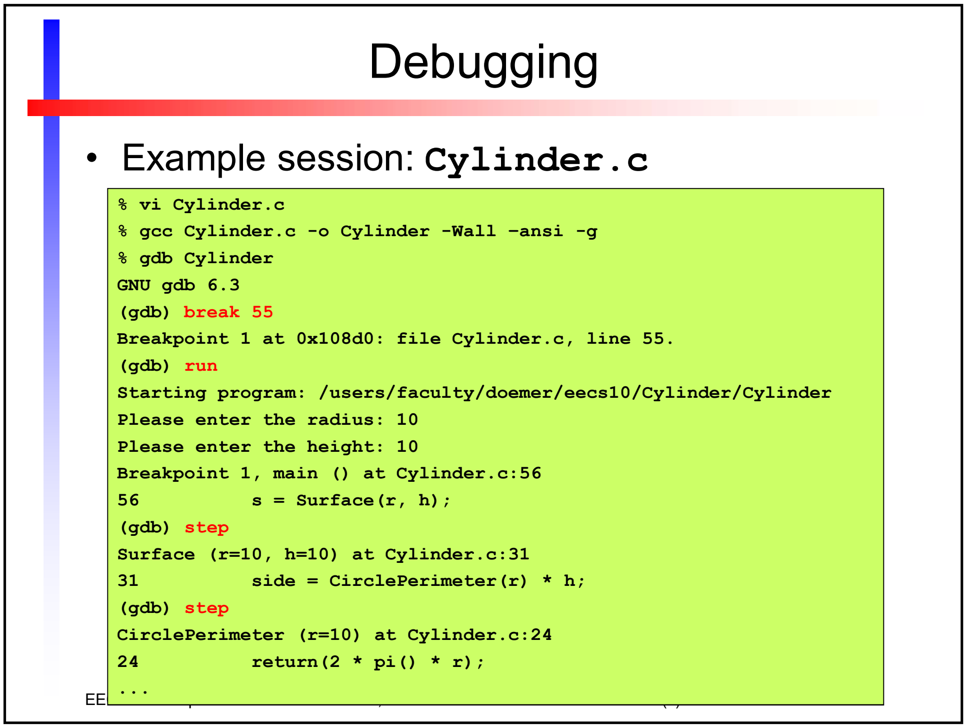
Debugging

- Source-level Debugger **gdb** (continued)
  - Additional **gdb** commands
    - **step**
      - steps into a function call
    - **finish**
      - continues execution until the current function is finished
    - **where**
      - shows where in the function call hierarchy you are
      - prints a *back trace* of current *stack frames*
    - **up**
      - steps up one stack frame (up into the caller)
    - **down**
      - steps down one stack frame (down into the callee)



Debugging

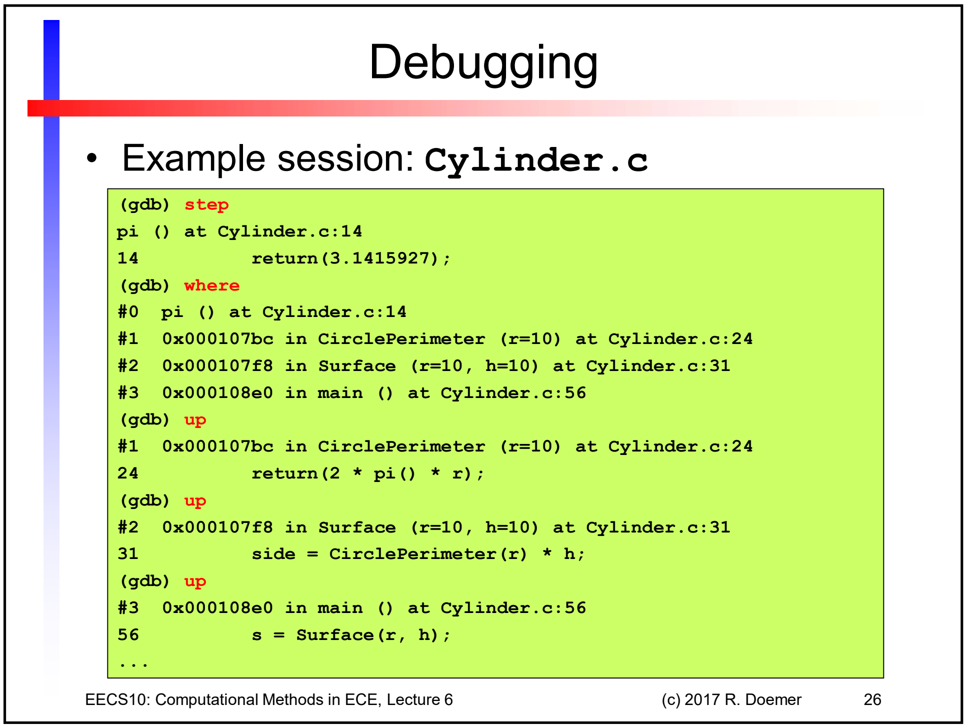
- Navigating Stack Frames in the Debugger
  - *step*: execute and step into a function call
  - up, down: navigate stack frames
  - finish: resume execution until the end of the current function



Debugging

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

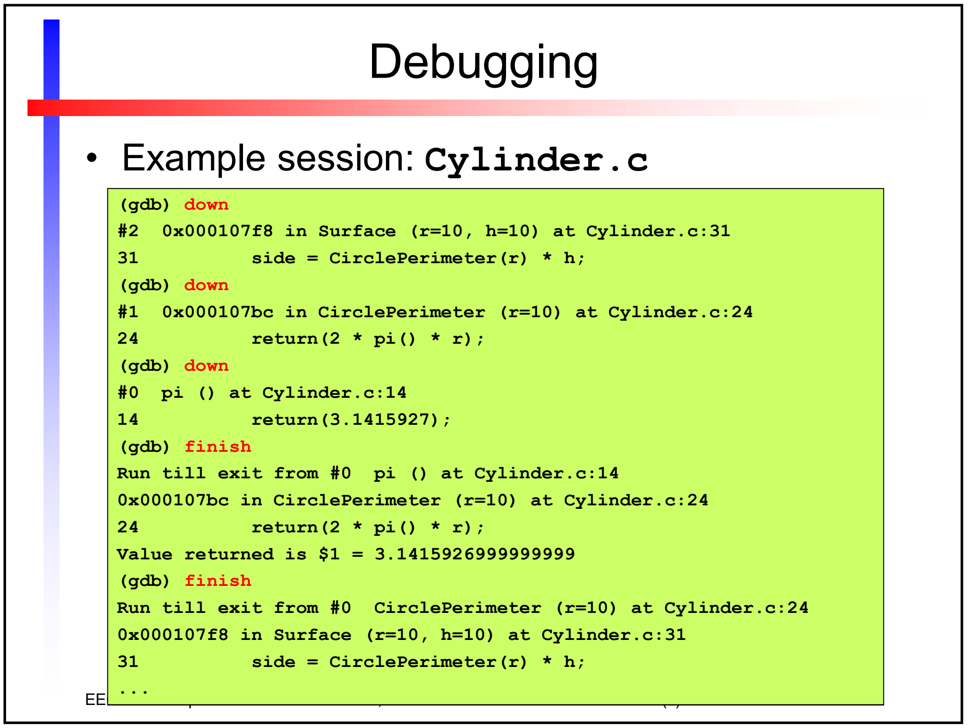
```
% vi Cylinder.c
% gcc Cylinder.c -o Cylinder -Wall -ansi -g
% gdb Cylinder
GNU gdb 6.3
(gdb) break 55
Breakpoint 1 at 0x108d0: file Cylinder.c, line 55.
(gdb) run
Starting program: /users/faculty/doemer/eecs10/Cylinder/Cylinder
Please enter the radius: 10
Please enter the height: 10
Breakpoint 1, main () at Cylinder.c:56
56          s = Surface(r, h);
(gdb) step
Surface (r=10, h=10) at Cylinder.c:31
31          side = CirclePerimeter(r) * h;
(gdb) step
CirclePerimeter (r=10) at Cylinder.c:24
24          return(2 * pi() * r);
...
```



Debugging

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

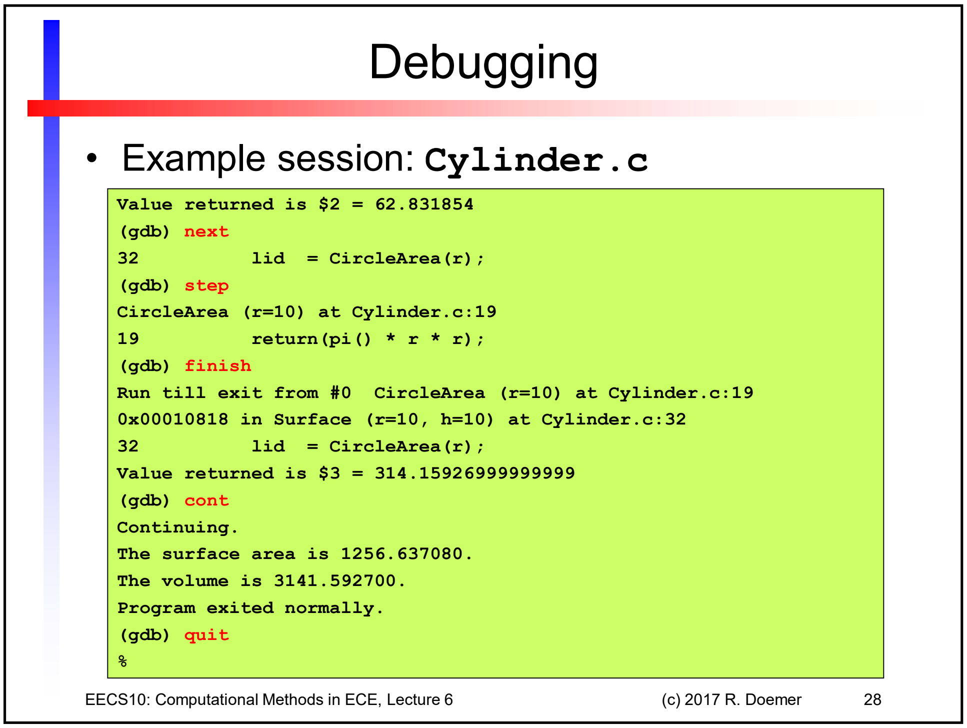
```
(gdb) step
pi () at Cylinder.c:14
14          return(3.1415927);
(gdb) where
#0  pi () at Cylinder.c:14
#1  0x000107bc in CirclePerimeter (r=10) at Cylinder.c:24
#2  0x000107f8 in Surface (r=10, h=10) at Cylinder.c:31
#3  0x000108e0 in main () at Cylinder.c:56
(gdb) up
#1  0x000107bc in CirclePerimeter (r=10) at Cylinder.c:24
24          return(2 * pi() * r);
(gdb) up
#2  0x000107f8 in Surface (r=10, h=10) at Cylinder.c:31
31          side = CirclePerimeter(r) * h;
(gdb) up
#3  0x000108e0 in main () at Cylinder.c:56
56          s = Surface(r, h);
...
```



Debugging

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

```
(gdb) down
#2  0x000107f8 in Surface (r=10, h=10) at Cylinder.c:31
31          side = CirclePerimeter(r) * h;
(gdb) down
#1  0x000107bc in CirclePerimeter (r=10) at Cylinder.c:24
24          return(2 * pi() * r);
(gdb) down
#0  pi () at Cylinder.c:14
14          return(3.1415927);
(gdb) finish
Run till exit from #0  pi () at Cylinder.c:14
0x000107bc in CirclePerimeter (r=10) at Cylinder.c:24
24          return(2 * pi() * r);
Value returned is $1 = 3.1415926999999999
(gdb) finish
Run till exit from #0  CirclePerimeter (r=10) at Cylinder.c:24
0x000107f8 in Surface (r=10, h=10) at Cylinder.c:31
31          side = CirclePerimeter(r) * h;
...
```



Debugging

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

```
Value returned is $2 = 62.831854
(gdb) next
32          lid  = CircleArea(r);
(gdb) step
CircleArea (r=10) at Cylinder.c:19
19          return(pi() * r * r);
(gdb) finish
Run till exit from #0  CircleArea (r=10) at Cylinder.c:19
0x00010818 in Surface (r=10, h=10) at Cylinder.c:32
32          lid  = CircleArea(r);
Value returned is $3 = 314.15926999999999
(gdb) cont
Continuing.
The surface area is 1256.637080.
The volume is 3141.592700.
Program exited normally.
(gdb) quit
%
```