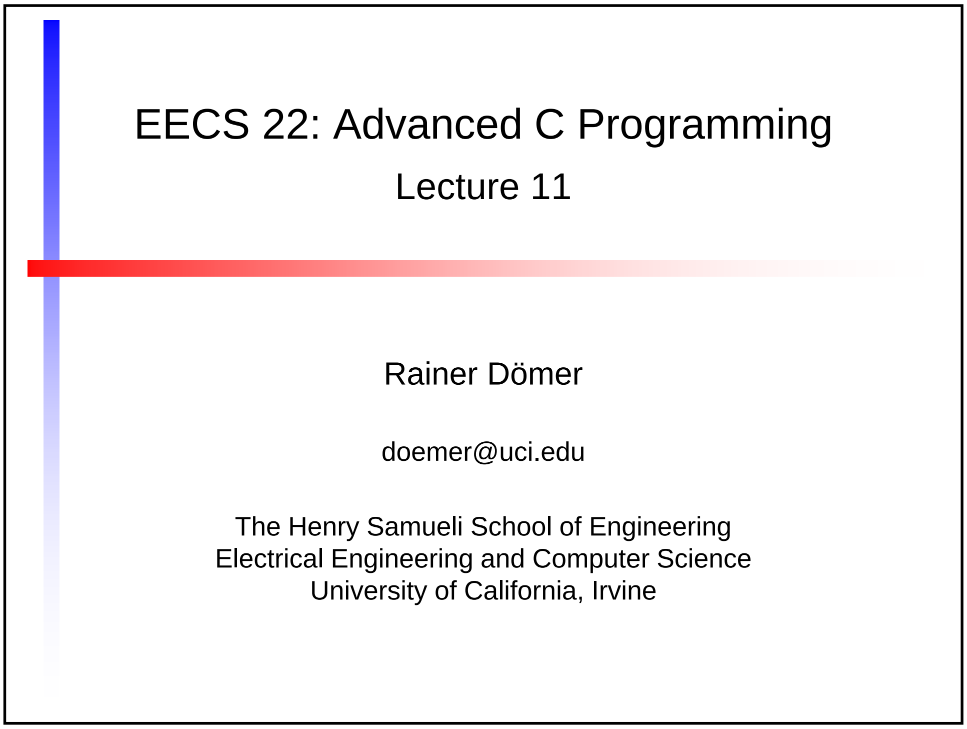

EECS 22: Advanced C Programming

Lecture 11

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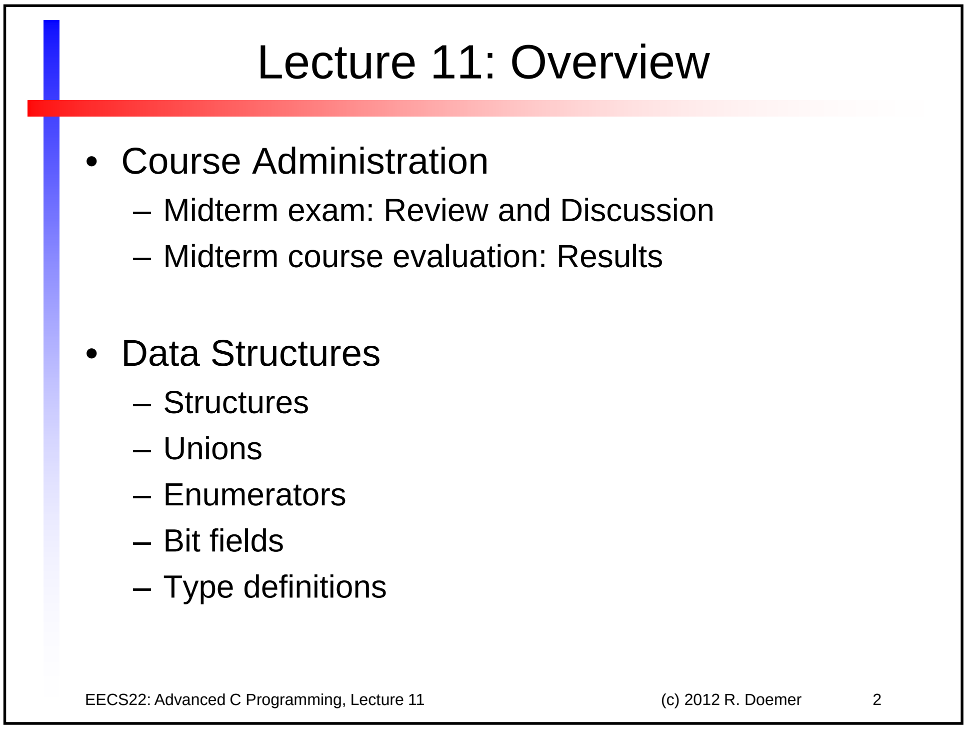
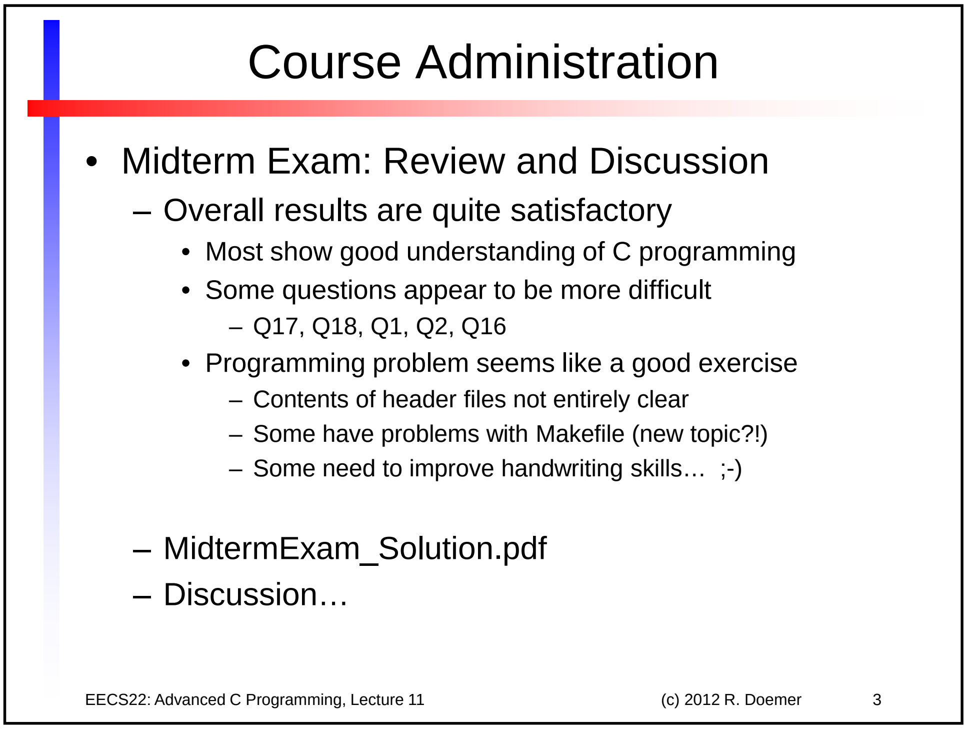


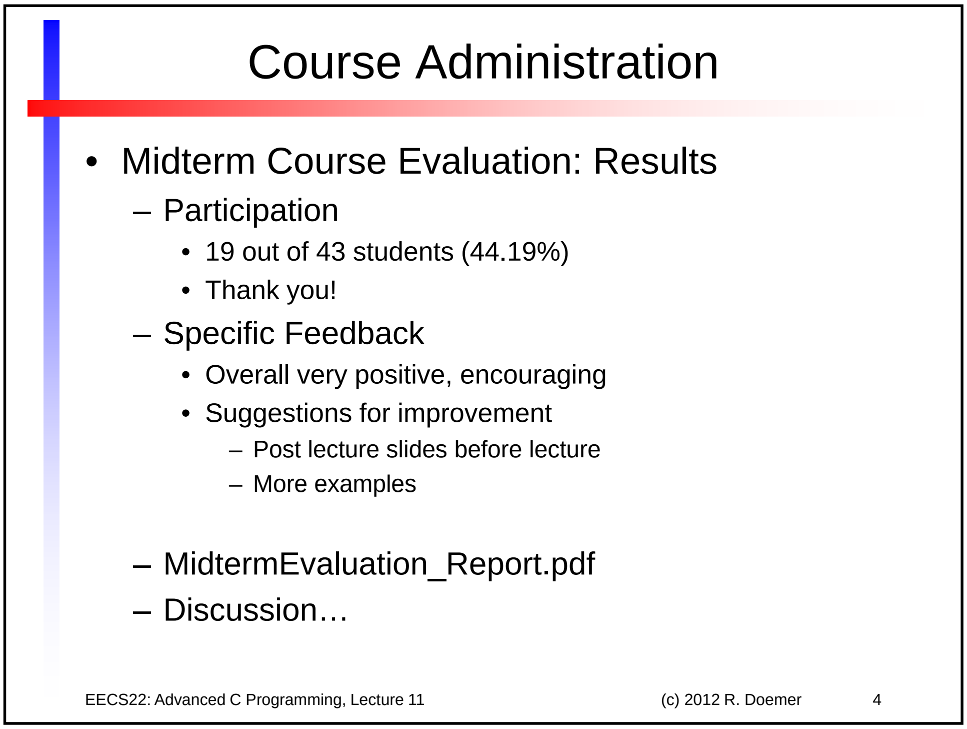
Lecture 11: Overview

- Course Administration
  - Midterm exam: Review and Discussion
  - Midterm course evaluation: Results
- Data Structures
  - Structures
  - Unions
  - Enumerators
  - Bit fields
  - Type definitions



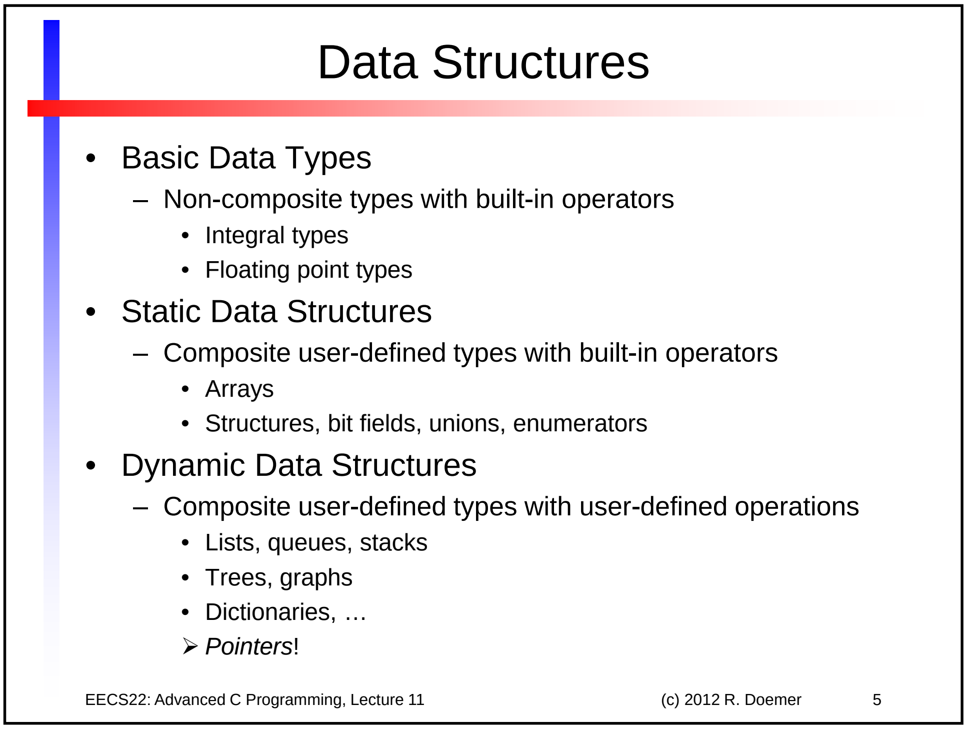
Course Administration

- Midterm Exam: Review and Discussion
  - Overall results are quite satisfactory
    - Most show good understanding of C programming
    - Some questions appear to be more difficult
      - Q17, Q18, Q1, Q2, Q16
    - Programming problem seems like a good exercise
      - Contents of header files not entirely clear
      - Some have problems with Makefile (new topic?!)
      - Some need to improve handwriting skills… ;-)
  - MidtermExam_Solution.pdf
  - Discussion…



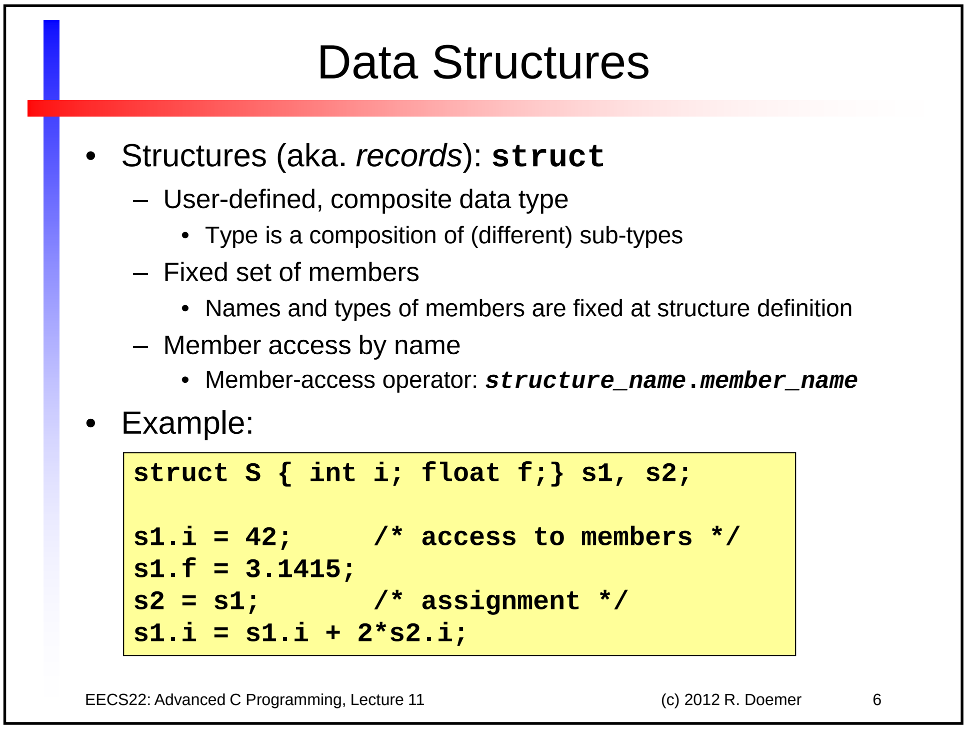
Course Administration

- Midterm Course Evaluation: Results
  - Participation
    - 19 out of 43 students (44.19%)
    - Thank you!
  - Specific Feedback
    - Overall very positive, encouraging
    - Suggestions for improvement
      - Post lecture slides before lecture
      - More examples
  - MidtermEvaluation_Report.pdf
  - Discussion…



Data Structures

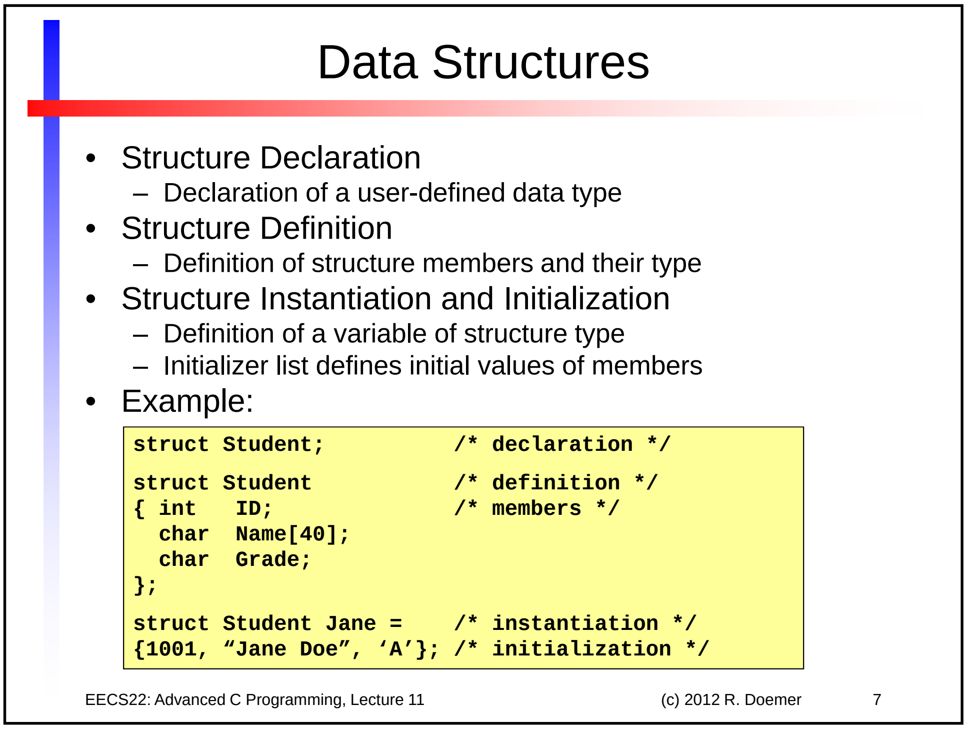
- Basic Data Types
  - Non-composite types with built-in operators
    - Integral types
    - Floating point types
- Static Data Structures
  - Composite user-defined types with built-in operators
    - Arrays
    - Structures, bit fields, unions, enumerators
- Dynamic Data Structures
  - Composite user-defined types with user-defined operations
    - Lists, queues, stacks
    - Trees, graphs
    - Dictionaries, …
    - ➢ *Pointers*!



Data Structures

- Structures (aka. *records*): **`struct`**
  - User-defined, composite data type
    - Type is a composition of (different) sub-types
  - Fixed set of members
    - Names and types of members are fixed at structure definition
  - Member access by name
    - Member-access operator: ***structure_name.member_name***
- Example:

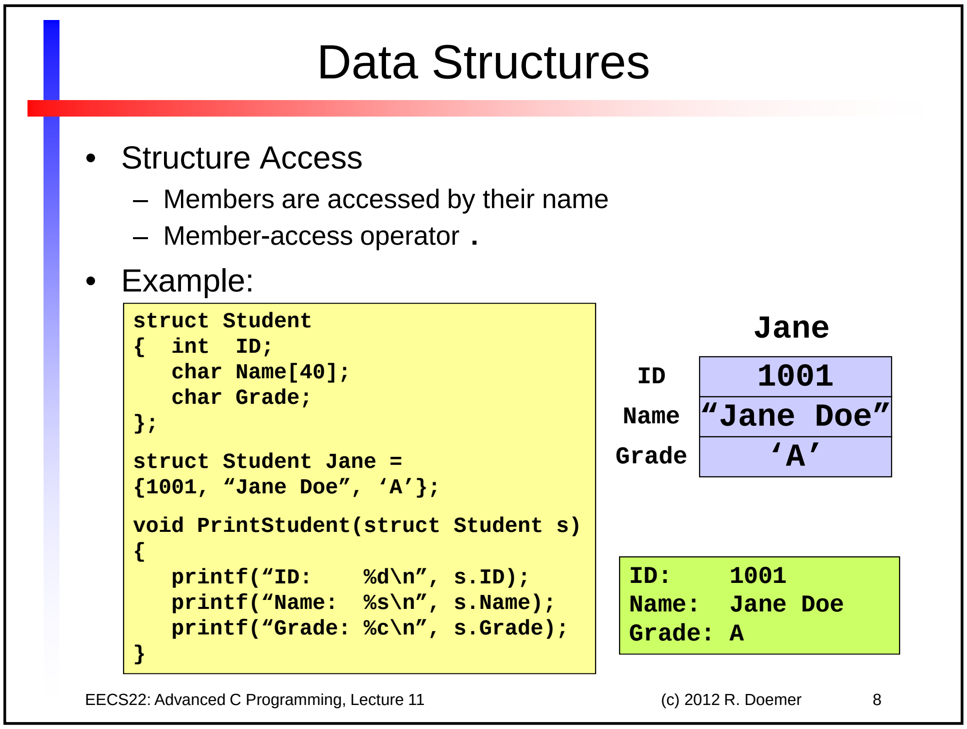
```
struct S { int i; float f;} s1, s2;

s1.i = 42;      /* access to members */
s1.f = 3.1415;
s2 = s1;        /* assignment */
s1.i = s1.i + 2*s2.i;
```



Data Structures

- Structure Declaration
  - Declaration of a user-defined data type
- Structure Definition
  - Definition of structure members and their type
- Structure Instantiation and Initialization
  - Definition of a variable of structure type
  - Initializer list defines initial values of members
- Example:

```
struct Student;          /* declaration */

struct Student           /* definition */
{ int   ID;              /* members */
  char  Name[40];
  char  Grade;
};

struct Student Jane =    /* instantiation */
{1001, “Jane Doe”, ‘A’}; /* initialization */
```



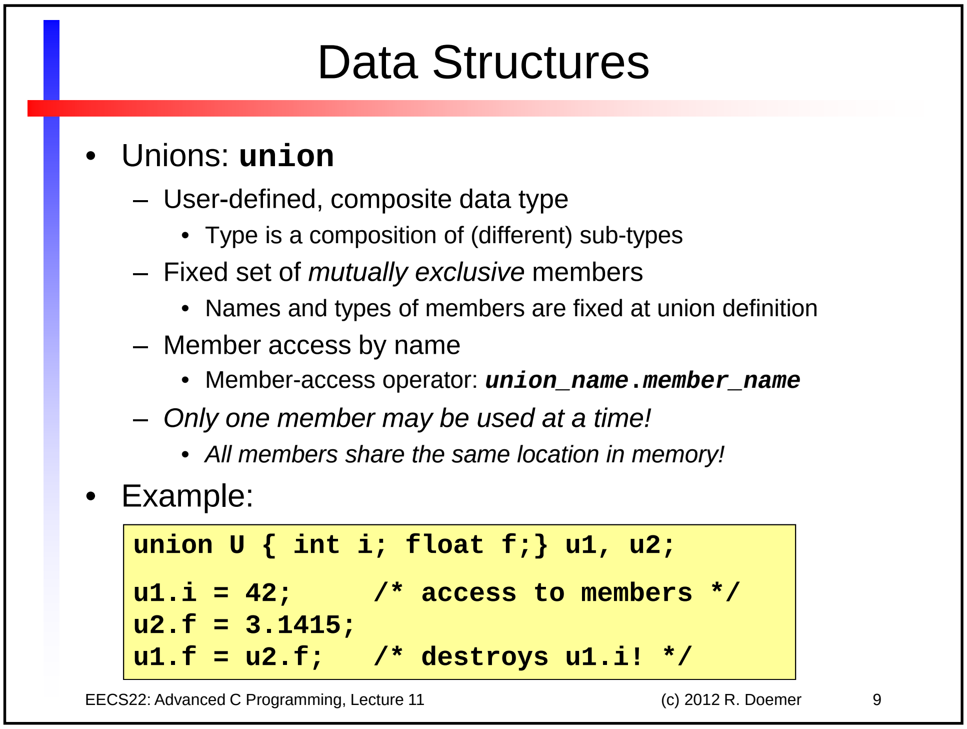
Data Structures

- Structure Access
  - Members are accessed by their name
  - Member-access operator **.**
- Example:

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

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

void PrintStudent(struct Student s)
{
   printf(“ID:    %d\n”, s.ID);
   printf(“Name:  %s\n”, s.Name);
   printf(“Grade: %c\n”, s.Grade);
}
```

	Jane
ID	1001
Name	“Jane Doe”
Grade	‘A’

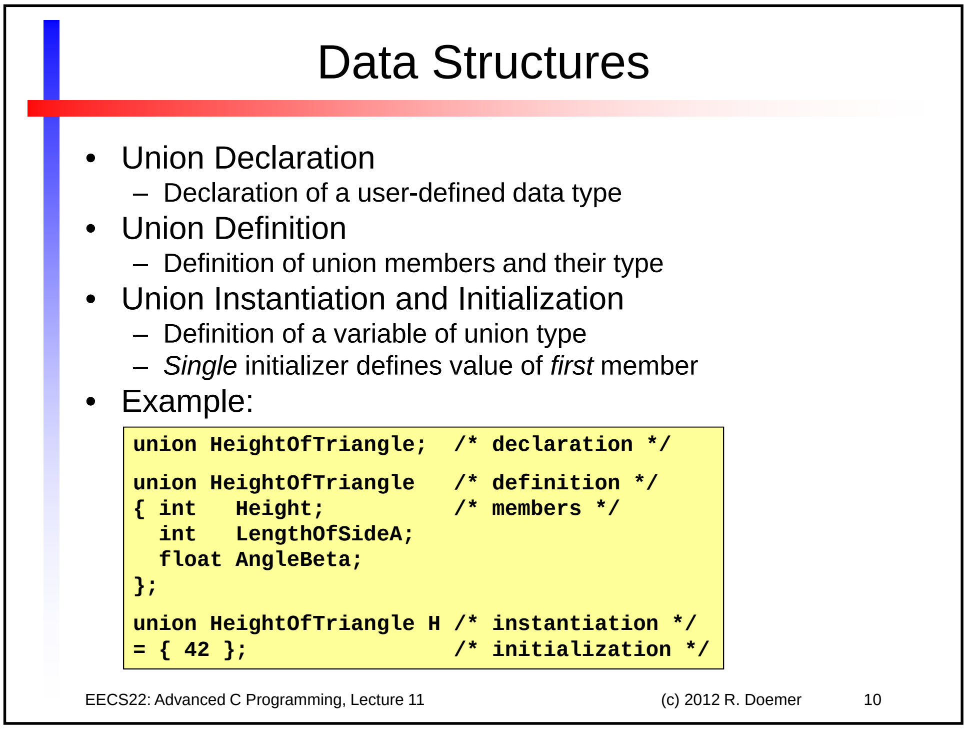
```
ID:    1001
Name:  Jane Doe
Grade: A
```



Data Structures

- Unions: **`union`**
  - User-defined, composite data type
    - Type is a composition of (different) sub-types
  - Fixed set of *mutually exclusive* members
    - Names and types of members are fixed at union definition
  - Member access by name
    - Member-access operator: ***`union_name.member_name`***
  - *Only one member may be used at a time!*
    - *All members share the same location in memory!*
- Example:

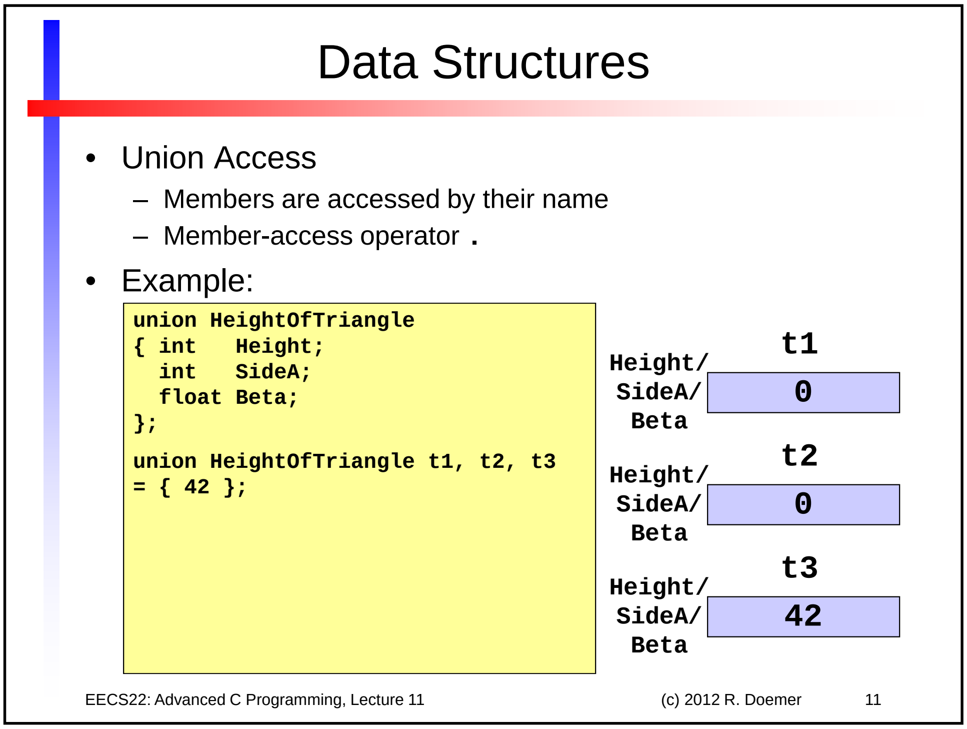
```
union U { int i; float f;} u1, u2;

u1.i = 42;     /* access to members */
u2.f = 3.1415;
u1.f = u2.f;   /* destroys u1.i! */
```



Data Structures

- Union Declaration
  - Declaration of a user-defined data type
- Union Definition
  - Definition of union members and their type
- Union Instantiation and Initialization
  - Definition of a variable of union type
  - *Single* initializer defines value of *first* member
- Example:

```
union HeightOfTriangle;  /* declaration */

union HeightOfTriangle   /* definition */
{ int   Height;          /* members */
  int   LengthOfSideA;
  float AngleBeta;
};

union HeightOfTriangle H /* instantiation */
= { 42 };                /* initialization */
```



Data Structures

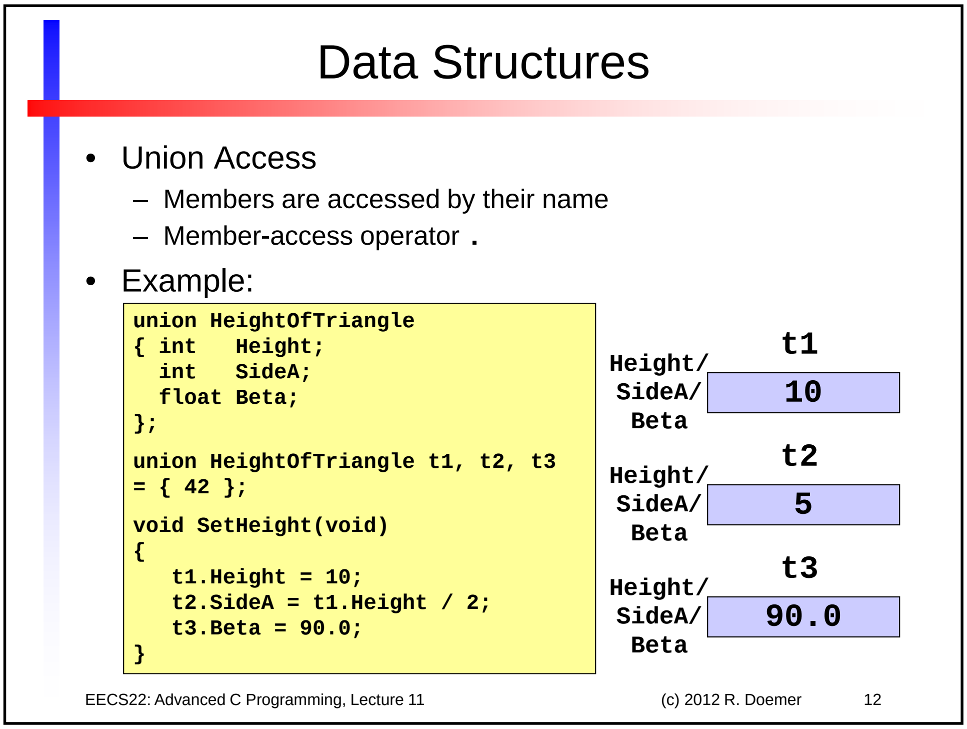
- Union Access
  - Members are accessed by their name
  - Member-access operator .
- Example:

```
union HeightOfTriangle
{ int   Height;
  int   SideA;
  float Beta;
};

union HeightOfTriangle t1, t2, t3
= { 42 };
```

t1
Height/
SideA/
Beta
0

t2
Height/
SideA/
Beta
0

t3
Height/
SideA/
Beta
42



Data Structures

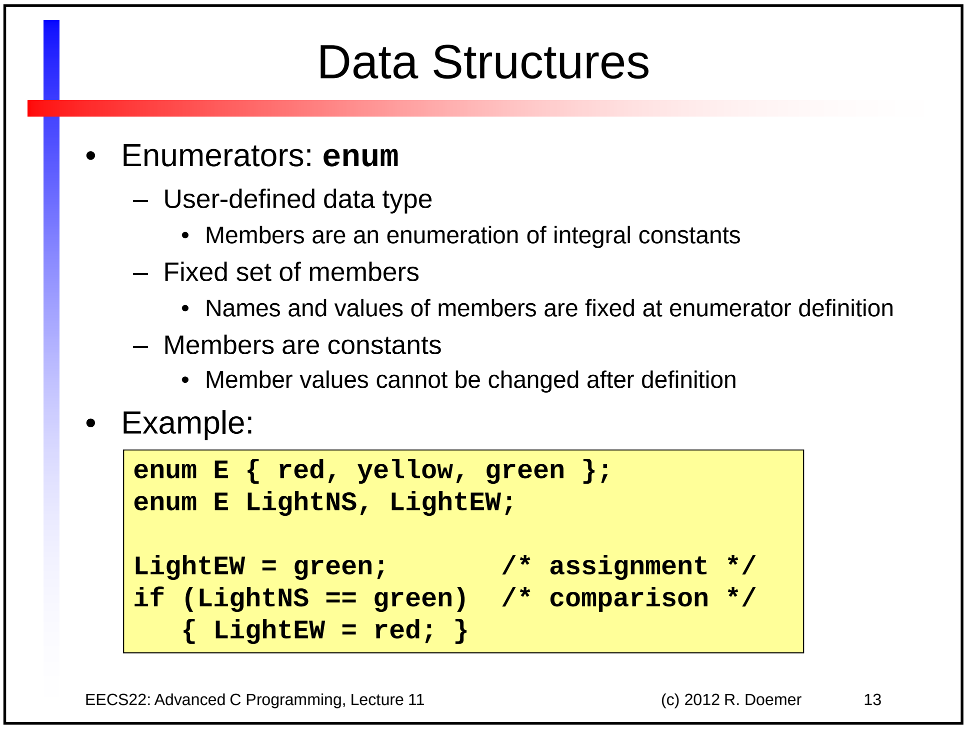
- Union Access
  - Members are accessed by their name
  - Member-access operator .
- Example:

```
union HeightOfTriangle
{ int   Height;
  int   SideA;
  float Beta;
};

union HeightOfTriangle t1, t2, t3
= { 42 };

void SetHeight(void)
{
   t1.Height = 10;
   t2.SideA = t1.Height / 2;
   t3.Beta = 90.0;
}
```

t1
Height/
SideA/
Beta
10

t2
Height/
SideA/
Beta
5

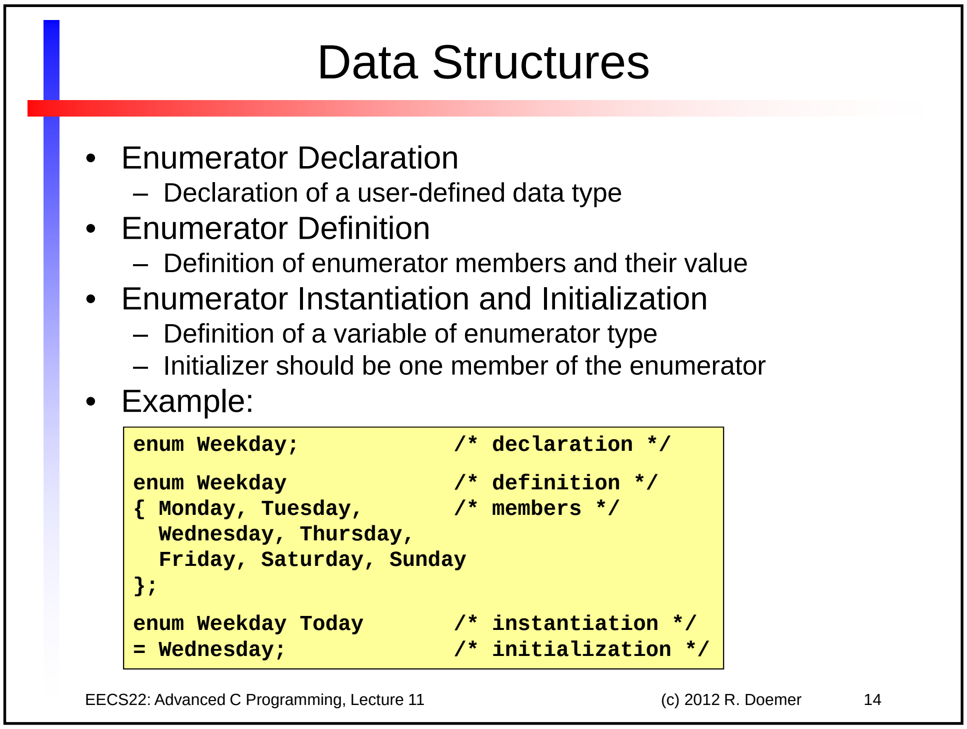
t3
Height/
SideA/
Beta
90.0



Data Structures

- Enumerators: **`enum`**
  - User-defined data type
    - Members are an enumeration of integral constants
  - Fixed set of members
    - Names and values of members are fixed at enumerator definition
  - Members are constants
    - Member values cannot be changed after definition
- Example:

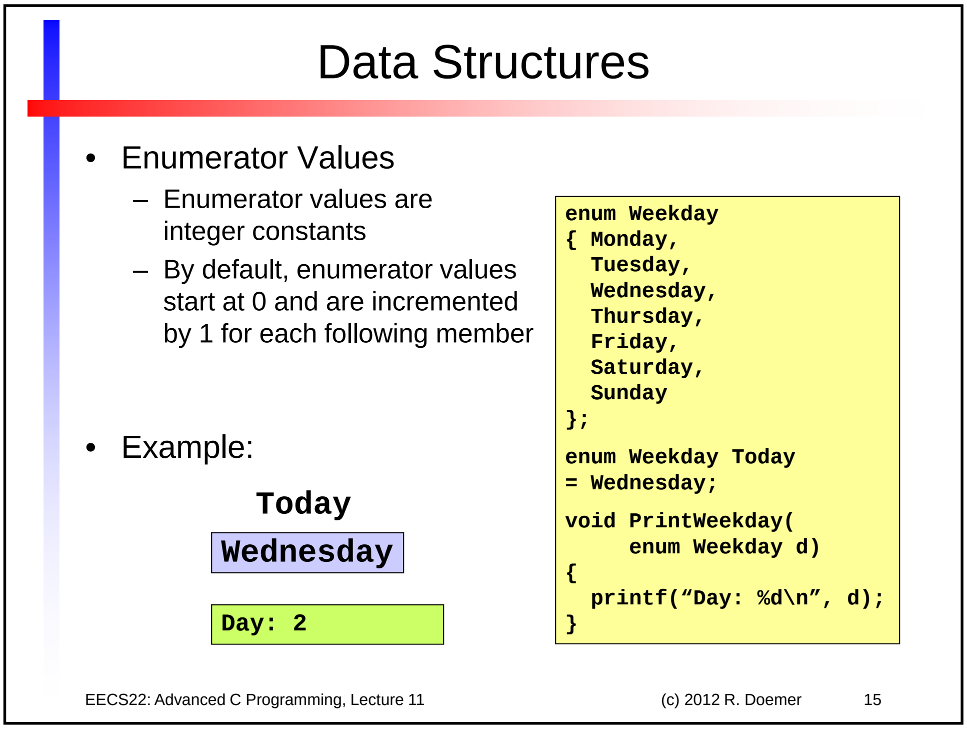
```
enum E { red, yellow, green };
enum E LightNS, LightEW;

LightEW = green;        /* assignment */
if (LightNS == green)   /* comparison */
   { LightEW = red; }
```



Data Structures

- Enumerator Declaration
  - Declaration of a user-defined data type
- Enumerator Definition
  - Definition of enumerator members and their value
- Enumerator Instantiation and Initialization
  - Definition of a variable of enumerator type
  - Initializer should be one member of the enumerator
- Example:

```
enum Weekday;               /* declaration */

enum Weekday                /* definition */
{ Monday, Tuesday,          /* members */
  Wednesday, Thursday,
  Friday, Saturday, Sunday
};

enum Weekday Today          /* instantiation */
= Wednesday;                /* initialization */
```



Data Structures

- Enumerator Values
  - Enumerator values are integer constants
  - By default, enumerator values start at 0 and are incremented by 1 for each following member
- Example:

Today

Wednesday

```
Day: 2
```

```
enum Weekday
{ Monday,
  Tuesday,
  Wednesday,
  Thursday,
  Friday,
  Saturday,
  Sunday
};
enum Weekday Today
= Wednesday;
void PrintWeekday(
     enum Weekday d)
{
  printf(“Day: %d\n”, d);
}
```

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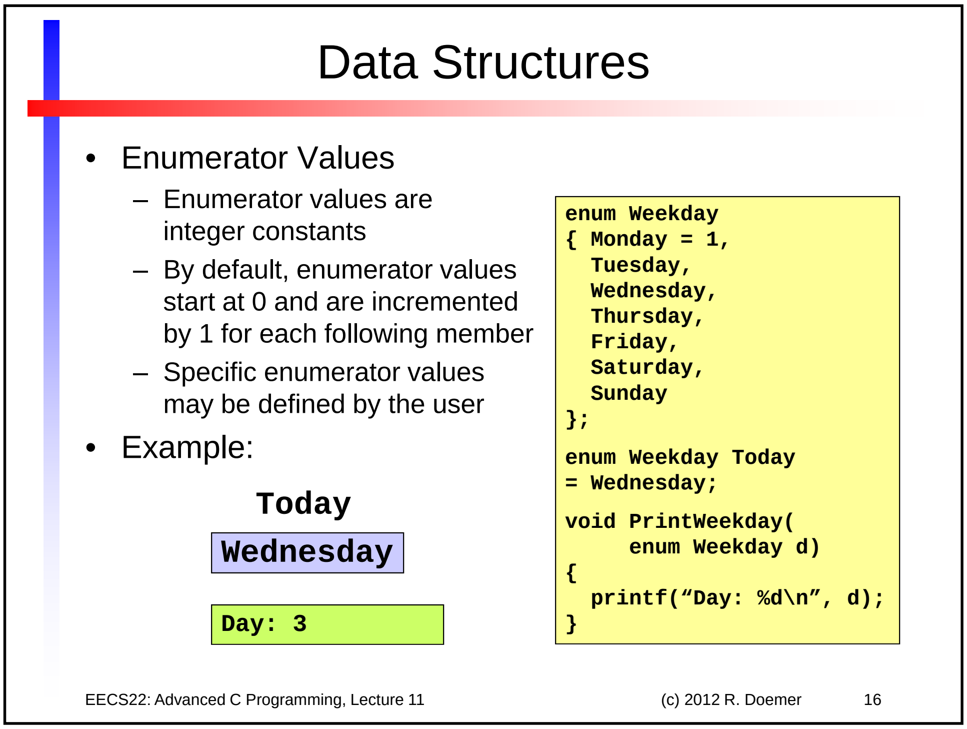

Data Structures

- Enumerator Values
  - Enumerator values are integer constants
  - By default, enumerator values start at 0 and are incremented by 1 for each following member
  - Specific enumerator values may be defined by the user
- Example:

Today

Wednesday

```
Day: 3
```

```
enum Weekday
{ Monday = 1,
  Tuesday,
  Wednesday,
  Thursday,
  Friday,
  Saturday,
  Sunday
};
enum Weekday Today
= Wednesday;
void PrintWeekday(
     enum Weekday d)
{
  printf(“Day: %d\n”, d);
}
```

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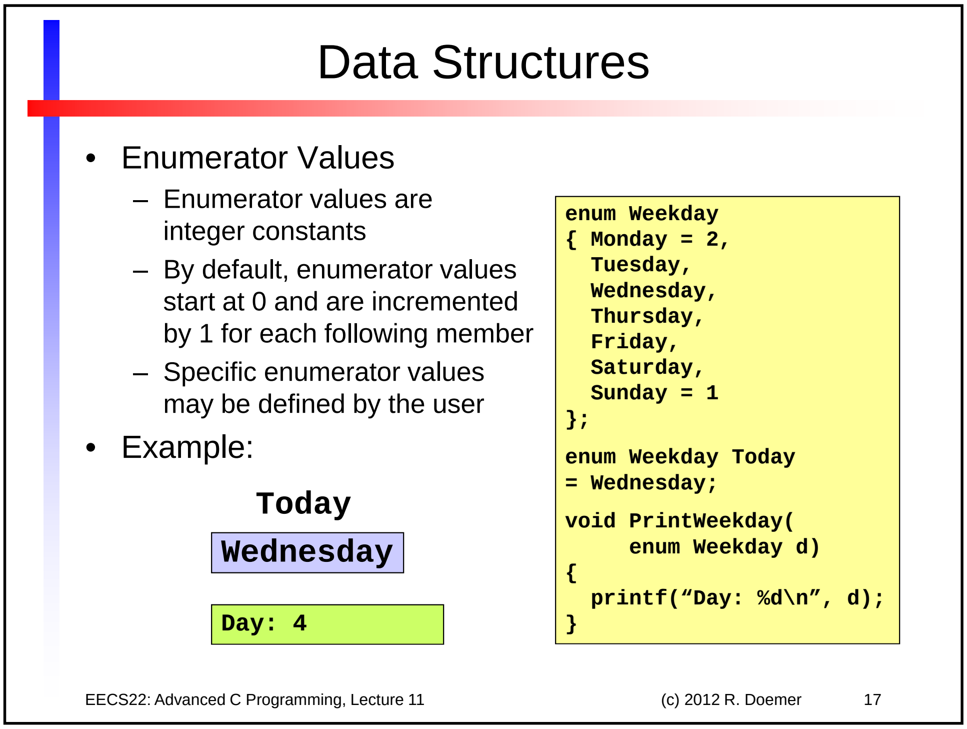


Data Structures

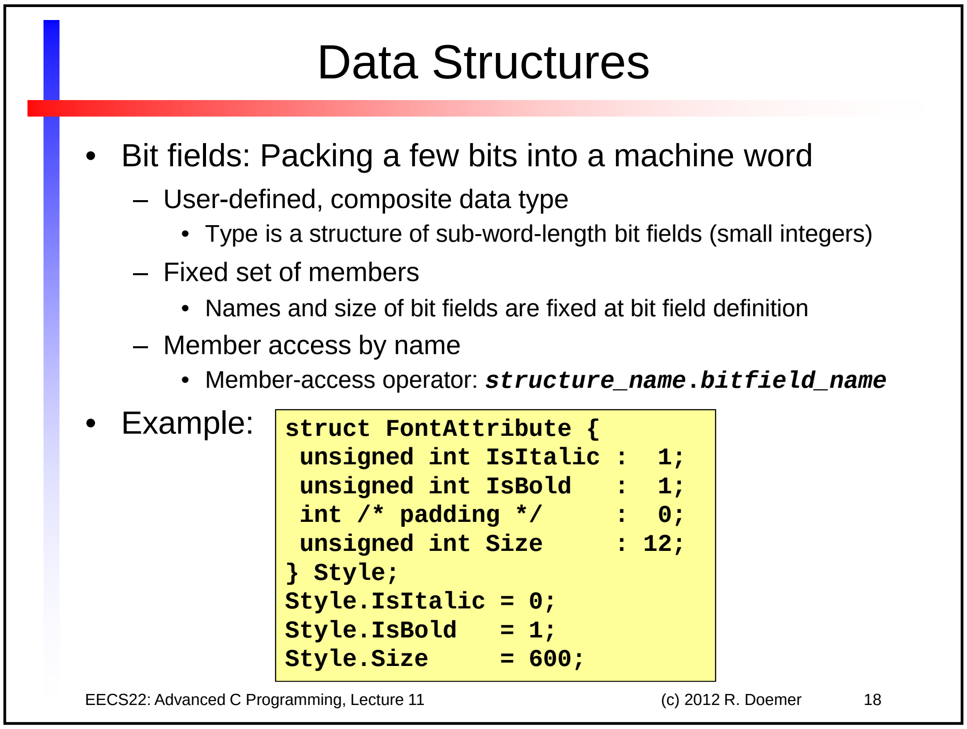
- Enumerator Values
  - Enumerator values are integer constants
  - By default, enumerator values start at 0 and are incremented by 1 for each following member
  - Specific enumerator values may be defined by the user
- Example:

Today

Wednesday

Day: 4

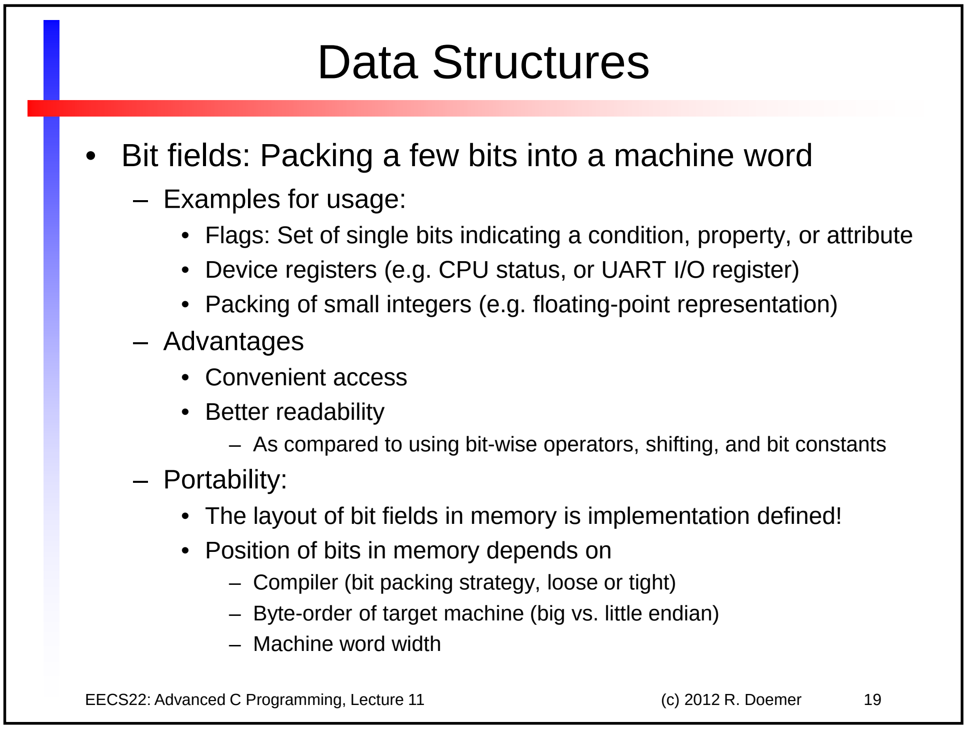
```
enum Weekday
{ Monday = 2,
  Tuesday,
  Wednesday,
  Thursday,
  Friday,
  Saturday,
  Sunday = 1
};
enum Weekday Today
= Wednesday;
void PrintWeekday(
     enum Weekday d)
{
  printf("Day: %d\n", d);
}
```



Data Structures

- Bit fields: Packing a few bits into a machine word
  - User-defined, composite data type
    - Type is a structure of sub-word-length bit fields (small integers)
  - Fixed set of members
    - Names and size of bit fields are fixed at bit field definition
  - Member access by name
    - Member-access operator: ***structure_name.bitfield_name***
- Example:

```
struct FontAttribute {
 unsigned int IsItalic :  1;
 unsigned int IsBold   :  1;
 int /* padding */     :  0;
 unsigned int Size     : 12;
} Style;
Style.IsItalic = 0;
Style.IsBold   = 1;
Style.Size     = 600;
```



Data Structures

- Bit fields: Packing a few bits into a machine word
  - Examples for usage:
    - Flags: Set of single bits indicating a condition, property, or attribute
    - Device registers (e.g. CPU status, or UART I/O register)
    - Packing of small integers (e.g. floating-point representation)
  - Advantages
    - Convenient access
    - Better readability
      - As compared to using bit-wise operators, shifting, and bit constants
  - Portability:
    - The layout of bit fields in memory is implementation defined!
    - Position of bits in memory depends on
      - Compiler (bit packing strategy, loose or tight)
      - Byte-order of target machine (big vs. little endian)
      - Machine word width

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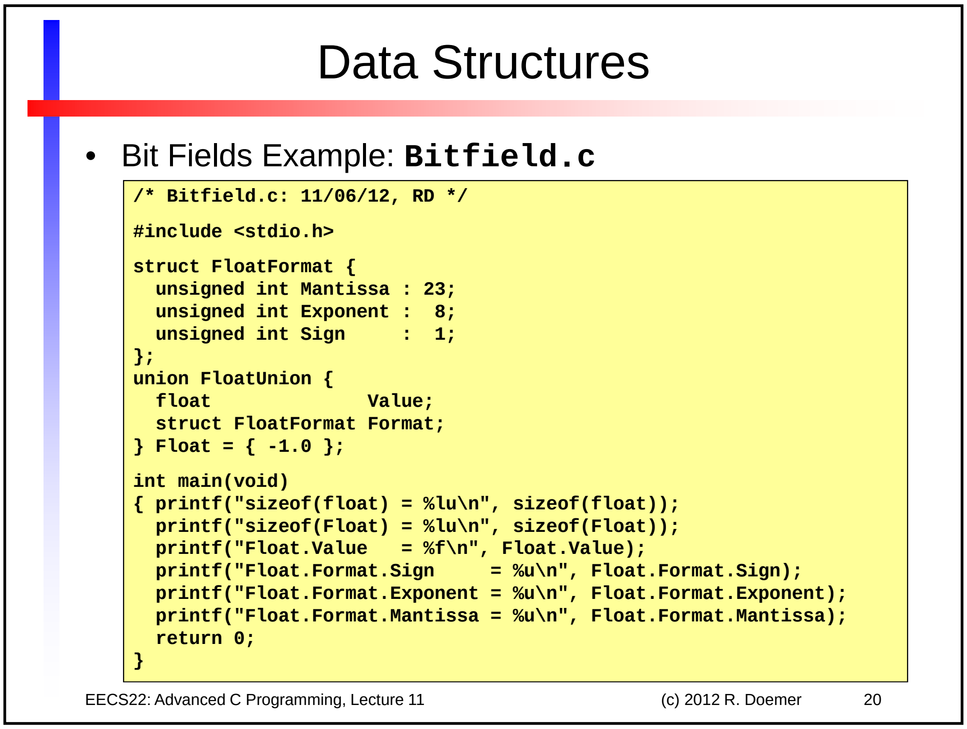

Data Structures

- Bit Fields Example: **`Bitfield.c`**

```
/* Bitfield.c: 11/06/12, RD */

#include <stdio.h>

struct FloatFormat {
  unsigned int Mantissa : 23;
  unsigned int Exponent :  8;
  unsigned int Sign     :  1;
};
union FloatUnion {
  float             Value;
  struct FloatFormat Format;
} Float = { -1.0 };

int main(void)
{ printf("sizeof(float) = %lu\n", sizeof(float));
  printf("sizeof(Float) = %lu\n", sizeof(Float));
  printf("Float.Value   = %f\n", Float.Value);
  printf("Float.Format.Sign     = %u\n", Float.Format.Sign);
  printf("Float.Format.Exponent = %u\n", Float.Format.Exponent);
  printf("Float.Format.Mantissa = %u\n", Float.Format.Mantissa);
  return 0;
}
```

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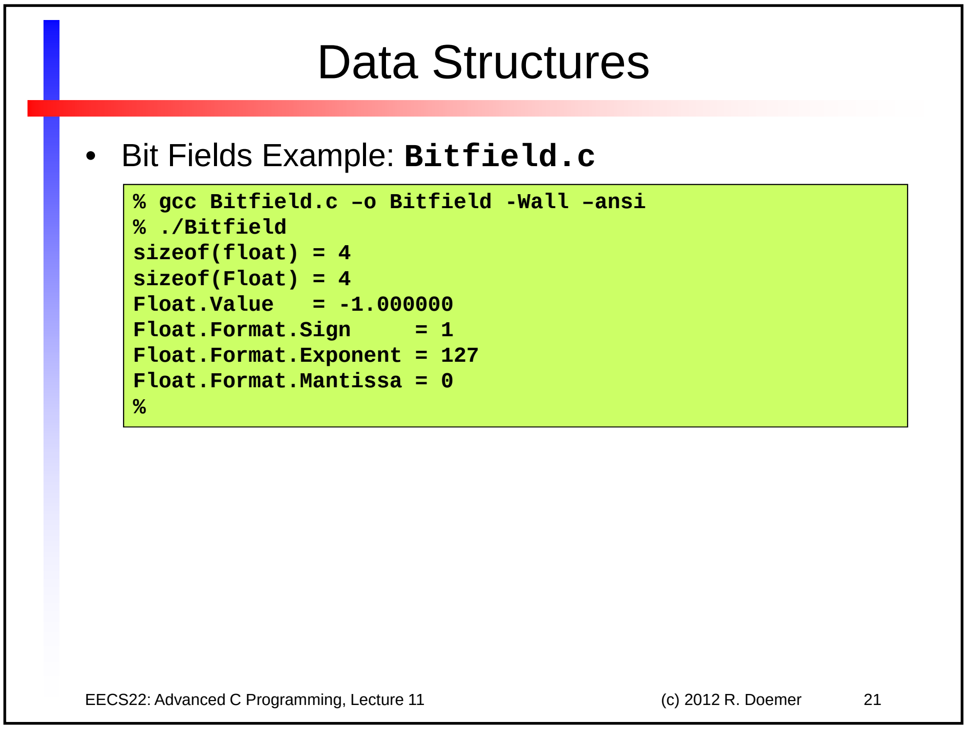
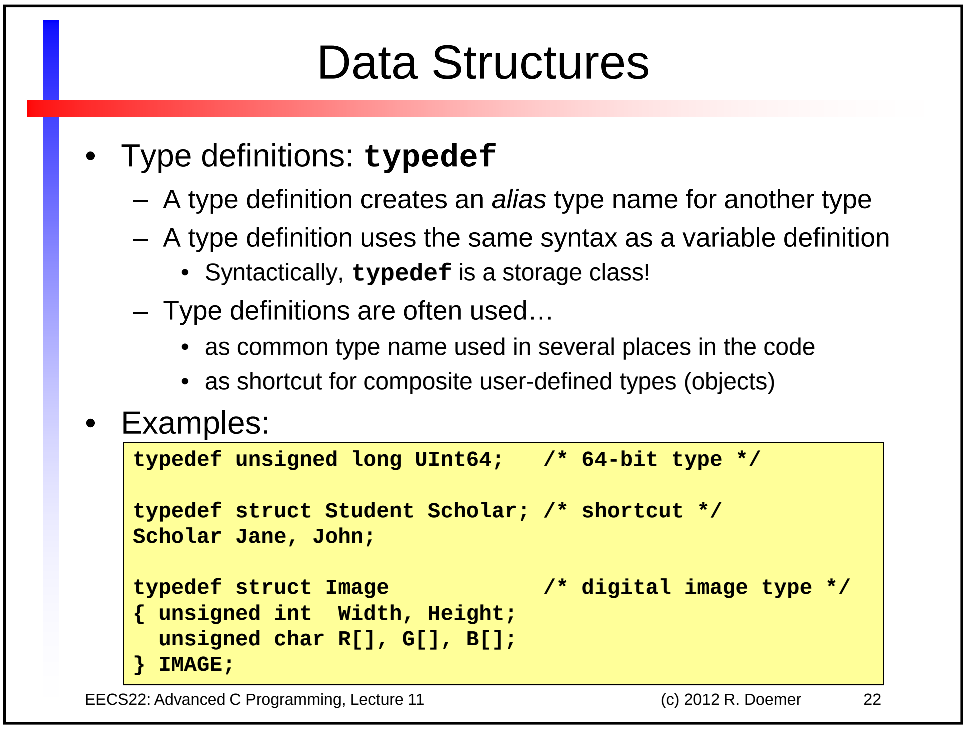


Data Structures

- Bit Fields Example: **`Bitfield.c`**

```
% gcc Bitfield.c –o Bitfield -Wall –ansi
% ./Bitfield
sizeof(float) = 4
sizeof(Float) = 4
Float.Value   = -1.000000
Float.Format.Sign     = 1
Float.Format.Exponent = 127
Float.Format.Mantissa = 0
%
```



Data Structures

- Type definitions: **`typedef`**
  - A type definition creates an *alias* type name for another type
  - A type definition uses the same syntax as a variable definition
    - Syntactically, **`typedef`** is a storage class!
  - Type definitions are often used…
    - as common type name used in several places in the code
    - as shortcut for composite user-defined types (objects)
- Examples:

```
typedef unsigned long UInt64;   /* 64-bit type */

typedef struct Student Scholar; /* shortcut */
Scholar Jane, John;

typedef struct Image            /* digital image type */
{ unsigned int  Width, Height;
  unsigned char R[], G[], B[];
} IMAGE;
```