# Structures, Operators

## Basics of Programming 1


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# Content

Chapter 1

# Structures

# User defined types



Built-in types of C language sometimes are not appropriate for storing more complex data.

## Types introduced by the user (programmer)

- Enumeration
- Structures
- Bitfields
- Union

# User defined types



Built-in types of C language sometimes are not appropriate for storing more complex data.

## Types introduced by the user (programmer)

- Enumeration
- Structures ← today's topic
- Bitfields
- Union

# Data elements that are coupled



- Storing date

```
1   int year;
2   int month;
3   int day;
```

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- Storing student data

```
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2  unsigned int smalltests;
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- Data of a chess game (white player, black player, when, where, moves, result)

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- Data of a chess game (white player, black player, when, where, moves, result)
- Data of one move (chess piece, from where, where to)
- Data of one square of the board (column, row)

# Storing data elements that are coupled



- Let's write a function to calculate scalar product (dot product) of 2D vectors!

```
1  double v_scalarproduct(double x1, double y1,
2                         double x2, double y2)
3  {
4     ...
5  }
```

How shall we pass coupled parameters?
The number of parameters may become too large

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```

How shall we pass coupled parameters?
The number of parameters may become too large

- Let's write a function to calculate difference of two vectors!

```
1  ?????? v_difference(double x1, double y1,
2                      double x2, double y2)
3  {
4  ...
5  }
```

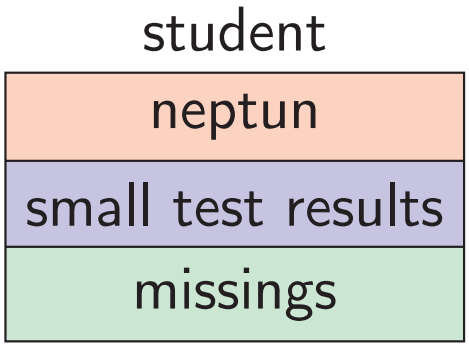
How does the function returns with coupled data?

# Encapsulation



## Structure

compound data type consisting of data elements (maybe of different types) that are coupled (belong together)




- data elements are called fields or members
- can be copied with one assignment
- can be parameter of function
- can be return value of function

- This is the most effective type of C language

# Structures in C

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```c
struct vector { /* definition of structure type  */
  double x; double y;
};

struct vector v_difference(struct vector a,
                           struct vector b) {
  struct vector c;
  c.x = a.x - b.x;
  c.y = a.y - b.y;
  return c;
}

int main(void) {
  struct vector v1, v2, v3;
  v1.x = 1.0;  v1.y = 2.0;
  v2 = v1;
  v3 = v_difference(v1, v2);
  return 0;
}
```

# Syntax of structures



## Declaration of structures

```
struct [<structure label>]opt
{<structure member declarations>}
[<variable identifiers>]opt ;
```

```
1 /* structure type for storing date */
2 struct date {
3   int year;
4   int month;
5   int day;
6 } d1, d2; /* two instances (variables) */
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  can be omitted if we don't refer to it later

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```

- `[<structure label>]opt`
  can be omitted if we don't refer to it later
- `[<variable identifiers>]opt`
  declaration of variables of structure type

# Syntax of structures



Using structure type

- Declaration of variables

  `struct <structure label> <variable identifiers>;`

```
1  struct date d1, d2;
2  d1.year = 2012;
3  d2.year = d1.year;
4  scanf("%d", &d2.month);
```

# Syntax of structures



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# Syntax of structures



Using structure type

- Declaration of variables

  `struct <structure label> <variable identifiers>;`

- Accessing structure members

  `<structure identifier>.<member identifier>`

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1  struct date d1, d2;
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  `struct <structure label> <variable identifiers>;`

- Accessing structure members

  `<structure identifier>.<member identifier>`

  - Structure members can be used in the same way as variables

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Using structure type

- Declaration of variables

  `struct <structure label> <variable identifiers>;`

- Accessing structure members

  `<structure identifier>.<member identifier>`

  - Structure members can be used in the same way as variables

```
1 struct date d1, d2;
2 d1.year = 2012;
3 d2.year = d1.year;
4 scanf("%d", &d2.month);
```

- Initialization of structures is possible in the same way as for arrays:

```
1 struct date d3 = {2011, 5, 2};
```

# Assignment of value to structures



- Value of a structure variable (value of all members) can be updated with one single assignment.

```
1 struct date d3 = {2013, 10, 22}, d4;
2 d4 = d3;
```

Chapter 2

# Typename-assignment

# Definition



- We can rename types in C

```
1  typedef int rabbit;
2
3  rabbit main() {
4    rabbit i = 3;
5    return i;
6  }
```

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```

## Typename-assignment

- `typedef` assigns a nickname to the type.
- It does not create a new type, the type of all variables created with the nicname will be the original type.

# What is the use of it?



- More meaningful source code, more easy to read

```
1 typedef double voltage;
2
3 voltage V1 = 1.0;
4 double c = 2.0;
5 voltage V2 = c * V1;
```

# What is the use of it?



- More meaningful source code, more easy to read

```
1 typedef long double voltage; /* we need more accuracy */
2
3 voltage V1 = 1.0;
4 double c = 2.0;
5 voltage V2 = c * V1;
```

- Easy to maintain

# What is the use of it?



- More meaningful source code, more easy to read

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1 typedef float voltage; /* we need a smaller */
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3 voltage V1 = 1.0;
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1 typedef float voltage; /* we need a smaller */
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3 voltage V1 = 1.0;
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```

- Easy to maintain
- We can get rid of typenames of more than one word

```
1 typedef  struct vector  vector;
```

# Vector example with typedef

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```c
struct vector { /* new structure type */
  double x; double y;
};
typedef  struct vector  vector; /* renaming */

vector v_difference(vector a, vector b) {
  vector c;
  c.x = a.x - b.x;
  c.y = a.y - b.y;
  return c;
}

int main(void) {
  vector v1, v2, v3;
  v1.x = 1.0;  v1.y = 2.0;
  v2 = v1;
  v3 = v_difference(v1, v2);
  return 0;
}
```

# Vector example with typedef

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```
1  typedef struct vector { /* done in one step */
2    double x; double y;
3  } vector;
4
5
6  vector v_difference(vector a, vector b) {
7    vector c;
8    c.x = a.x - b.x;
9    c.y = a.y - b.y;
10   return c;
11 }
12
13 int main(void) {
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# Vector example with typedef

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typedef struct { /* we can omit the label */
  double x; double y;
} vector;


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# A more complex structure

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```
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2    double x;
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6  typedef struct {
7    vector centrepoint;
8    double radius;
9  } circle;
```

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1  circle k = {{3.0, 2.0}, 1.5};
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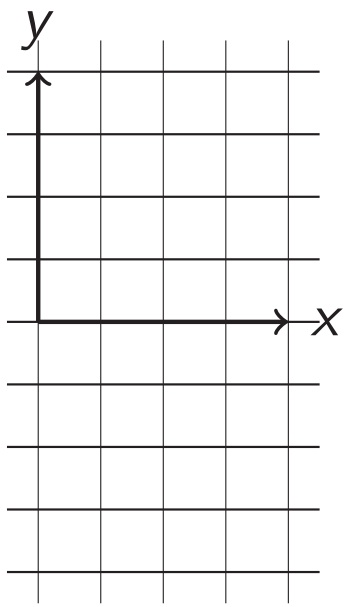

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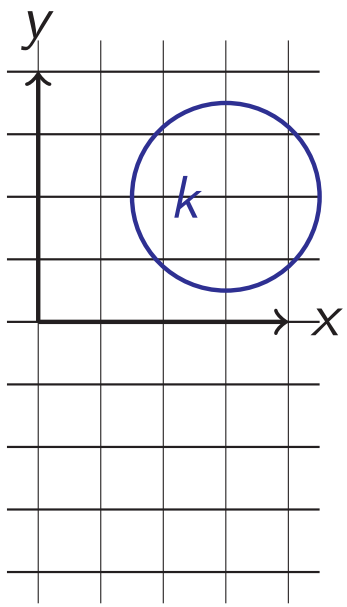

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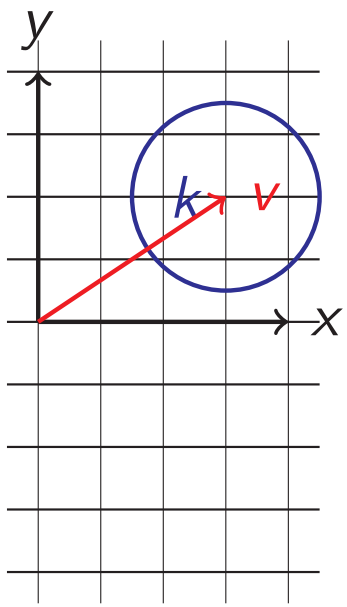

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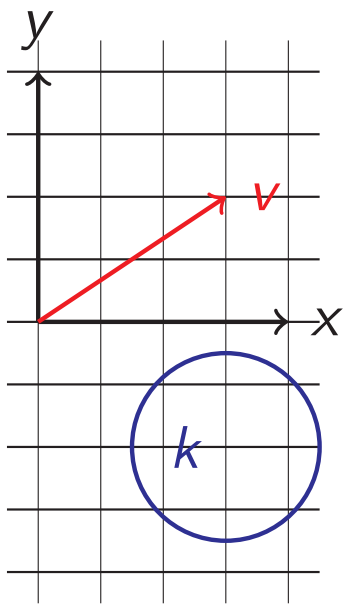


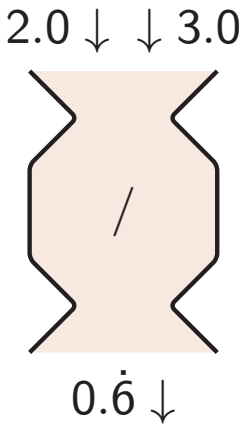
Chapter 3

# Operators

# Operations



- Denoted with operators (special symbols)
- They work with operands
- They result a data with type



# Operations



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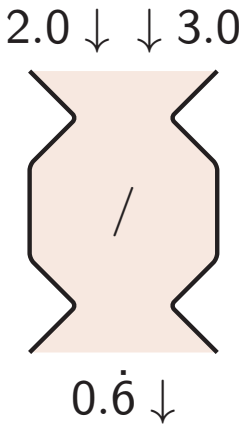
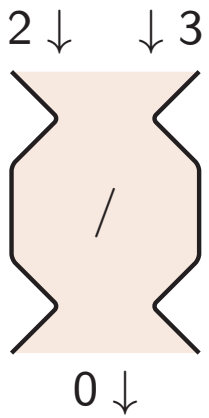
- They work with operands
- They result a data with type
- Polymorphic: have different behaviour on different operand types



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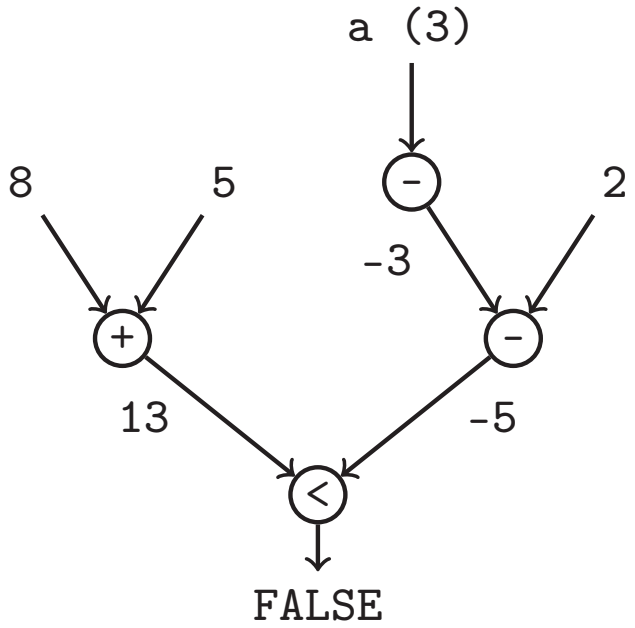

# Expressions and operators



- Expressions
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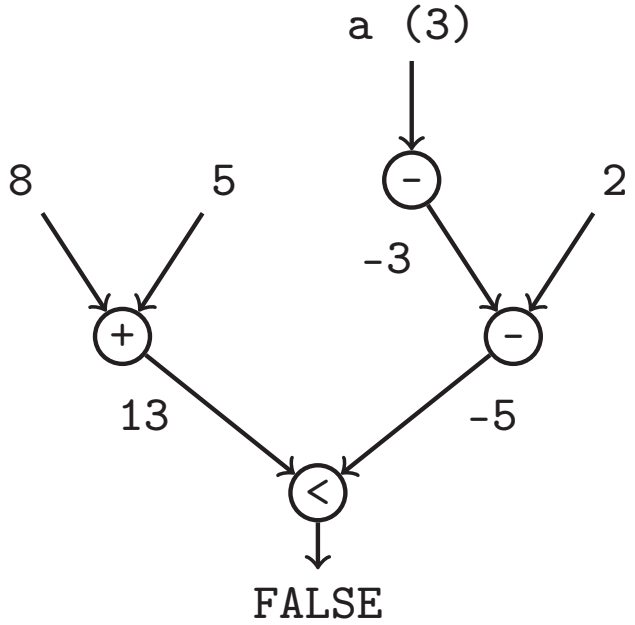


  - by evaluating them the result is one data element with type.

# Types of operators



- Considering the number of operands

# Types of operators



- Considering the number of operands
  - unary – with one operand

    ```
    -a
    ```

# Types of operators



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    `-a`
  - binary – with two operands
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  - logical

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  - relational
  - logical
  - bitwise

# Types of operators



- Considering the number of operands
  - unary – with one operand
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  - binary – with two operands
    `1+2`
- Considering the interpretation of the operand
  - arithmetic
  - relational
  - logical
  - bitwise
  - misc

# Arithmetic operators



| operation | syntax |
|---|---|
| unary plus | `+<expression>` |
| unary minus | `-<expression>` |
| addition | `<expression> + <expression>` |
| subtraction | `<expression> - <expression>` |
| multiplication | `<expression> * <expression>` |
| division | `<expression> / <expression>` |
| type of the result depends on type of the operands, if both are integer, then it is an integer division | |
| modulus | `<expression> % <expression>` |

# True or false – Boolean in C (repeated)



- Every boolean like result is `int` type, and its value is
  - `0`, if false
  - `1`, if true

```
1  printf("%d\t%d", 2<3, 2==3);
```

```
1    0
```

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1  printf("%d\t%d", 2<3, 2==3);
```

```
1    0
```

- A value interpreted as boolean is
  - false, if its value is represented with 0 bits only
  - true, if its value is represented with **not** only 0 bits

```
1  while (1)     { /* infinite loop */ }
2  while (-3.0)  { /* infinite loop */ }
3  while (0)     { /* this here is never executed */ }
```

# Relational operators



| operation | syntax |
|---|---|
| relational operators | `<left value> < <expression>` |
| | `<left value> <= <expression>` |
| | `<left value> > <expression>` |
| | `<left value> >= <expression>` |
| checking equality | `<left value> == <expression>` |
| checking non-equality | `<left value> != <expression>` |

They give logical value (`int`, 0 or 1) as result.

# Logical operators



| operation | syntax |
|---|---|
| logical NOT (complement) | `!<expression>` |

```
1  int a = 0x5c; /* 0101 1100, true */
2  int b = !a;   /* 0000 0000, false */
3  int c = !b;   /* 0000 0001, true */
```

- Conlusion: `!!a` $\neq$ `a`, only if we look at their boolean value.

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- Conlusion: `!!a` $\neq$ a, only if we look at their boolean value.

```
1  int finish = 0;
2  while (!finish) {
3    int b;
4    scanf("%d", &b);
5    if (b == 0)
6      finish = 1;
7  }
```

# Logical operators



| operation | syntax |
|---|---|
| logical AND | `<expression> && <expression>` |
| logical OR | `<expression> \|\| <expression>` |

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Logical short-cut: Operands are evaluated from left to right. But only until the result is not obvious.

# Logical operators



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|---|---|
| logical AND | <expression> && <expression> |
| logical OR | <expression> \|\| <expression> |

Logical short-cut: Operands are evaluated from left to right. But only until the result is not obvious.
We make use of this feature very often.

```
1  int a[5] = {1, 2, 3, 4, 5};
2  int i = 0;
3  while (i < 5 && a[i] < 20)
4    i = i+1; /* no over-indexing */
```

# Some more operators



We have used them so far, but never have called them operators before.

| operation | syntax |
|---|---|
| function call | `<function>(<actual arguments>)` |
| array reference | `<array>[<index>]` |
| structure-reference | `<structure>.<member>` |

```
1  c = sin(3.2); /* () */
2  a[28] = 3;    /* [] */
3  v.x = 2.0;    /* . */
```

# Operators with side effects



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  - In C language, assignment is an expression!
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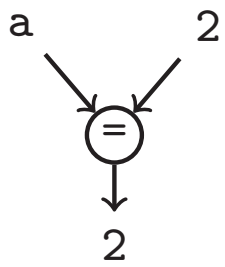

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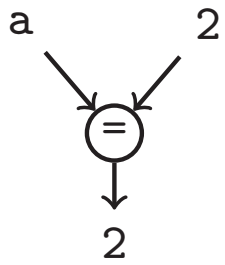


- Because of its main effect, this is also meaningful:

```
1 int a;
2 int b = a = 2;
```

- b is initialised with the value of expression a=2 (this also has a side effect), and the side effect of it is that a is also modified.

# Left-value



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  - a variable reference `a = 2`
  - element of an array `array[3] = 2`
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  - ...
- Examples for non-left-value expressions
  - constant `3 = 2` error
  - arithmetic expression `a+4 = 2` error
  - logical expression `a>3 = 2` error
  - function value `sin(2.0) = 2` error

# Expression or statement?



An operation that has side effect can be a statement in a program.

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## Expression statement

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<Expression>;
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- Expression is evaluated, but the result is thrown away (but all side effects are completed).

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```
1 a = 2; /* statement, it has no value  */
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```

- As the main effect is surpressed, there is no sense of making expression statements if the expression has no side effect.

```
1 2 + 3; /* valid statement, it generates nothing */
```

# Assignement operators



| expression | syntax |
|---|---|
| compound assignment | `<left-value> += <expression>` |
| | `<left-value> -= <expression>` |
| | `<left-value> *= <expression>` |
| | `<left-value> /= <expression>` |
| | `<left-value> %= <expression>` |

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- Almost: `<left-value>=<left-value><op><expression>`

```
1 a += 2;           /* a = a + 2; */
2 t[rand()] += 2; /* NOT t[rand()] = t[rand()] + 2; */
```

Left-value is evaluated only once.

# Other operators with side effects



| expression | syntax |
|---|---|
| post increment | `<left-value> ++` |
| post decrement | `<left-value> --` |
| it is increased/decreased by one after evaluation | |
| pre increment | `++<left-value>` |
| pre decrement | `--<left-value>` |
| it is increased/decreased by one before evaluation | |

```
1  b = a++; /* b = a; a += 1; */
2  b = ++a; /* a += 1; b = a; */
```

```
1  for (i = 0; i < 5; ++i) { /* five times */ }
```

# Other operators



| operation | syntax |
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| modifying type<br>(casting) | `(<type>)<expression>` |
| size for storage (in bytes)<br>the expression is not evaluated | `sizeof <expression>` |

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2  double b;
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DEPARTMENT OF NETWORKED SYSTEMS AND SERVICES

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```
1  int step, j;
2  /* two-digit numbers with increasing step size */
3  for(step=1,j=10; j<100; j+=step, step++)
4    printf("%d\n", j);
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| operation | syntax |
|---|---|
| (ternary) conditional expr. | <cond.> ? <expr.1> : <expr.2> |

- if <cond.> is true, then <expr.1>, otherwise <expr.2>.
- only one of <expr.1> and <expr.2> is evaluated.
- It does not subtitute the `if` statement.

```
1  a = a < 0 ? -a : a; /* determining absolute value */
```

# Features of operations performed on data

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## Precedence

If there are **different** operations, which is evaluated first?

```
1  int a = 2 + 3 * 4; /* 2 + (3 * 4) */
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# Features of operations performed on data



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If there are **equivalent** operations, which is evaluated first?
(Does it bind from left to right or from right to left?)

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1  int b = 11 - 8 - 2;  /* (11 - 8) - 2 */
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1  int b = 11 - 8 - 2;  /* (11 - 8) - 2 */
```

Instead of memorizing the rules, use parentheses!

# List of operators in C



Operateors are listed top to bottom, in descending precedence (operators in the same row have the same precedence)

```
1  ()   []   .   -> /* highest */
2  !   ~   ++   --   +   -   *   &   (<type>)   sizeof
3  *   /   %
4  +   -
5  <<   >>
6  <   <=   >   >=
7  ==   !=              /* forbidden to learn! */
8  &                    /* use parentheses! */
9  ^
10 |
11 &&
12 ||
13 ?:
14 =   +=   -=   *=   /=   %=   &=   ^=   |=   <<=   >>=
15 , /* lowest */
```

# Operators of C language



## Summarized

- A lot of effective operators

# Operators of C language



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# Operators of C language



Summarized

- A lot of effective operators
- Some operators have side effects that will occur during evaluation
- We always try to separate main and side effects
  Instead of this:

```
1  t[++i] = func(c-=2);
```

we rather write this:

```
1  c -= 2;              /* means the same */
2  ++i;                 /* not less effective */
3  t[i] = func(c);      /* and I will understand it tomorrow too */
```

Chapter 4

# Type conversion

# What is that?



In some cases the C-program needs to convert the type of our expressions.

```
1  long func(float f) {
2    return f;
3  }
4
5  int main(void) {
6    int i = 2;
7    short s = func(i);
8    return 0;
9  }
```

In this example: `int` → `float` → `long` → `short`

- `int` → `float` rounding, if the number is large
- `float` → `long` may cause overflow, rounding to integer
- `long` → `short` may cause overflow

# Converting types



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- Conversion with two operands (eg. `2/3.4` )

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  - preserve the value, if possible
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  - at assignment of value
  - at calling a function (when actualising the formal parameters)
- Conversion with two operands (eg. `2/3.4` )
  - evaluating an operation

# Conversion with two operands



The conversion of the two operands to the same, common type happens according to these rules

| operand one | the other operand | common, new type |
|---|---|---|
| `long double` | anything | `long double` |
| `double` | anything | `double` |
| `float` | anything | `float` |
| `unsigned long` | anything | `unsigned long` |
| `long` | anything (`int`, `unsigned`) | `long` |
| `unsigned` | anything (`int`) | `unsigned` |
| `int` | anything (`int`) | `int` |

# Type conversions



## Example for conversion

```
1  int a = 3;
2  double b = 2.4;
3  a = a*b;
```

# Type conversions



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```

1. $3 \rightarrow 3.0$
2. $3.0 * 2.4 \rightarrow 7.2$
3. $7.2 \rightarrow 7$

Thank you for your attention.