Control Statements and Functions
Agenda

- Computation
  - What is computable? How best to compute it?
  - Abstractions, algorithms, heuristics, data structures

- Language constructs and ideas
  - Sequential order of execution
  - Expressions and statements
  - Selection
  - Iteration
  - Functional abstraction
  - Vectors
You already know most of this

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  - \( d = a + b \times c \)
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  - “Do 20 reps.”
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So what I’ll be showing you is mainly syntax for things you already know.
Computation: the big picture

- **Input**: from keyboard, files, mouse, other input devices, the network, other programs
- **Code**: consumes the input and does something to produce the output
- **Output**: to the screen, files, printer, other output devices, the network, other other programs
Expressing computation

Our job is to express computations

- simply,
- correctly, and
- efficiently.
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- Data organization (often key to good code)
  - Input/output formats
  - Communication protocols
  - Data structures
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Note the emphasis is on structure and organization
Each language feature exists to express a fundamental idea:

- `+` addition
- `*` multiplication
- `{ stm stm ... }` sequencing
- `if (expr) stm else stm` selection
- `while (expr) stm` iteration
- `f(x);` function call
Programming language features

Each language feature exists to express a fundamental idea:

+ addition
* multiplication
{ stm stm ... } sequencing
if (expr) stm else stm selection
while (expr) stm iteration
f(x); function call

The meaning of each feature is simple, but we combine them into programs of arbitrary complexity.
Expressions

An expression computes a value:

```c
int length = 20;  // simplest expression is a literal
int width = 40;
```
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```c
int length  = 20; // simplest expression is a literal
int width   = 40;

int area    = length * width; // multiplication
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The usual rules of precedence apply:

```
a * b + c / d means (a * b) + (c / d), not ((a * b) + c) / d
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int length = 20;  // simplest expression is a literal
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int average = (length + width) / 2;
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The usual rules of precedence apply:
a \* b + c / d means \((a \* b) + (c / d)\), not \(((a \* b) + c) / d\)

When in doubt, parenthesize (but don’t overdo it)
What expressions are made of

Operators and operands

- operators specify what to do
- operands specify the data to do it to
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Operators and operands

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- operands specify the data to do it to

Some common operators:

<table>
<thead>
<tr>
<th>Operator(s)</th>
<th>Meaning</th>
<th>bool</th>
<th>int</th>
<th>double</th>
</tr>
</thead>
<tbody>
<tr>
<td>+, −, *, /</td>
<td>arithmetic</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>%</td>
<td>remainder</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>==</td>
<td>equal</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>!=</td>
<td>not equal</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>&lt;, &lt;=, &gt;, &gt;=</td>
<td>comparisons</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>&amp;&amp;,</td>
<td></td>
<td></td>
<td>and, or</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Concise operators

For many binary operators, there are (roughly) equivalent more concise versions:

- \( a += c \) means \( a = a + c \)
- \( a *= \) scale means \( a = a * \) scale
- ++a means \( a += 1 \)
  or \( a = a + 1 \)

Use them when they make your code clearer
Statements

A statement is one of:

- an expression followed by a semicolon,
- a declaration, or
- a *control* statement that determines control flow.
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Examples:

- `a = b;`
- `double d2 = 2.5;`
- `if (x == 2) y = 4;`
- `while (cin >> number) numbers.push_back(number);`
- `int average = (length + width) / 2;`
- `return x;`
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- \( \text{if } (x == 2) \ y = 4; \)
- \( \text{while } (\text{cin } >> \text{ number}) \ \text{numbers.push_back(number);} \)
- \( \text{int } \text{average} = (\text{length} + \text{width}) / 2; \)
- \( \text{return } x; \)

I don’t expect you to recognize all of these…yet.
Selection

Sometimes we must choose between alternatives.

For example, suppose we want to identify the larger of two numbers. We can use an `if` statement:

```plaintext
if (a < b)
    max = b;
else
    max = a;
```
Selection

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For example, suppose we want to identify the larger of two numbers. We can use an if statement:

```java
if (a < b)
    max = b;
else
    max = a;
```

The syntax is

```java
if (condition)
    statement-if-true
else
    statement-if-false
```
Sequencing

What if you want to do more than one thing in an if?

Use a compound statement:

```
if (a < b) f = b; min = a;
g
else f = a; min = b;
g
```

The syntax is `first-statement second-statement // etc.`
Sequencing

What if you want to do more than one thing in an if?

Use a compound statement:

```java
if (a < b) {
    max = b;
    min = a;
} else {
    max = a;
    min = b;
}
```
Sequencing

What if you want to do more than one thing in an if?

Use a compound statement:

```cpp
if (a < b) {
    max = b;
    min = a;
} else {
    max = a;
    min = b;
}
```

The syntax is

```cpp
{  
    first-statement
    second-statement
    // etc.
}
```
int i = 0;

while (i < 100) {
    cout << i << 't' << square(i) << '
';
    ++i;
}
Iteration (while)

```cpp
int i = 0;
while (i < 100) {
    cout << i << 't' << square(i) << '\n';
    ++i;
}
```

The syntax is

```cpp
while (condition) statement
```
Iteration (for)

```cpp
int i = 0;       // initialization

while (i < 100) {
    cout << i << ' ' << square(i) << '\n';
    ++i;            // step
}
```

This pattern—a loop with initialization and step—is so common that there’s special syntax for it:

```cpp
for (int i = 0; i < 100; ++i)
    cout << i << ' ' << square(i) << '\n';
```
Iteration (for)

```cpp
int i = 0;   // initialization

while (i < 100) {
    cout << i << ' ' << square(i) << '
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    ++i;   // step
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for (int i = 0; i < 100; ++i)
    cout << i << ' ' << square(i) << '
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```

for loops are the idiomatic way to count in C++
Syntax of for

\[
\text{for } (\text{init-expr}; \text{cond-expr}; \text{step-expr}) \\
\text{body-stm}
\]
Syntax of for

```plaintext
for (init-expr; cond-expr; step-expr) 
body-stm

means

init-expr;

while (cond-expr) {
  body-stm
  step-expr;
}
```
Functions

But what did square(i) mean?
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A call to the function square(int), which might be defined like

```c
int square(int x)
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    return x * x;
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- ...is logically separate.
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Why define a function? We want to separate and name a computation because it…

\begin{itemize}
\item …is logically separate.
\item …make the program clearer.
\item …can be reused.
\item …eases testing, distribution of labor, and maintenance.
\end{itemize}
A function example

```c
int square(int n) {
    return n * n;
}

int main {
    cout << sqrt(square(3) + square(4)) << '\n';
}
```
A function example

```cpp
int square(int n) {
    return n * n;
}

int main {
    double a2 = square(3);
    double b2 = square(4);
    double c2 = a + b;
    double c = sqrt(c2);
    cout << c << '
';
}
```
A function example

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int main {
    double a2 = square(3);
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int main {
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    double c2 = a + b;
    double c   = sqrt(c2);

    cout << c << 'n';
}

int square(int n) {
    return n * n;
}

int square(int n) {
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}

double sqrt(double);
```
Function definition syntax

Our function

```c
int square(int x)
{
    return x * x;
}
```

is an example of

```
return-type function-name(param-type param-name, …)
{
    // code, which can use parameter(s) param-name, etc.
    return some-value;
}
```