Principled Programming

Introduction to Coding in Any Imperative Language

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Introduction

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Since I don't want to teach a language, I'll stick to a tiny, universal one.

It's a subset of Java, Python, C/C++, JavaScript, …, (any imperative language).

Can programming be mechanized?

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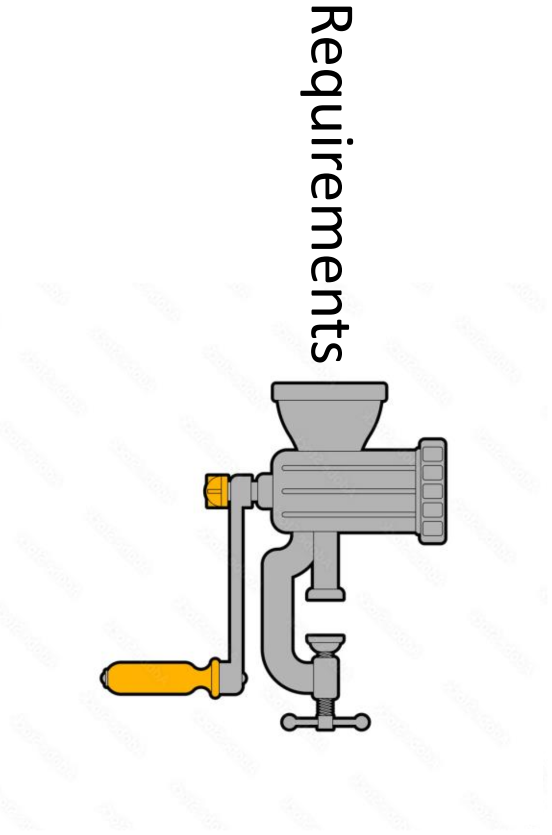

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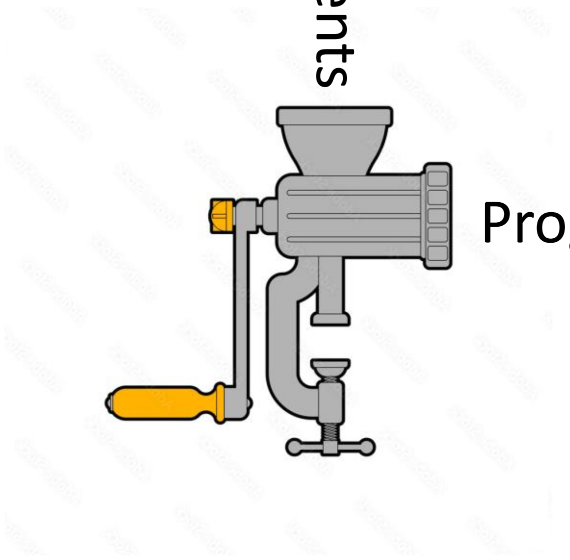

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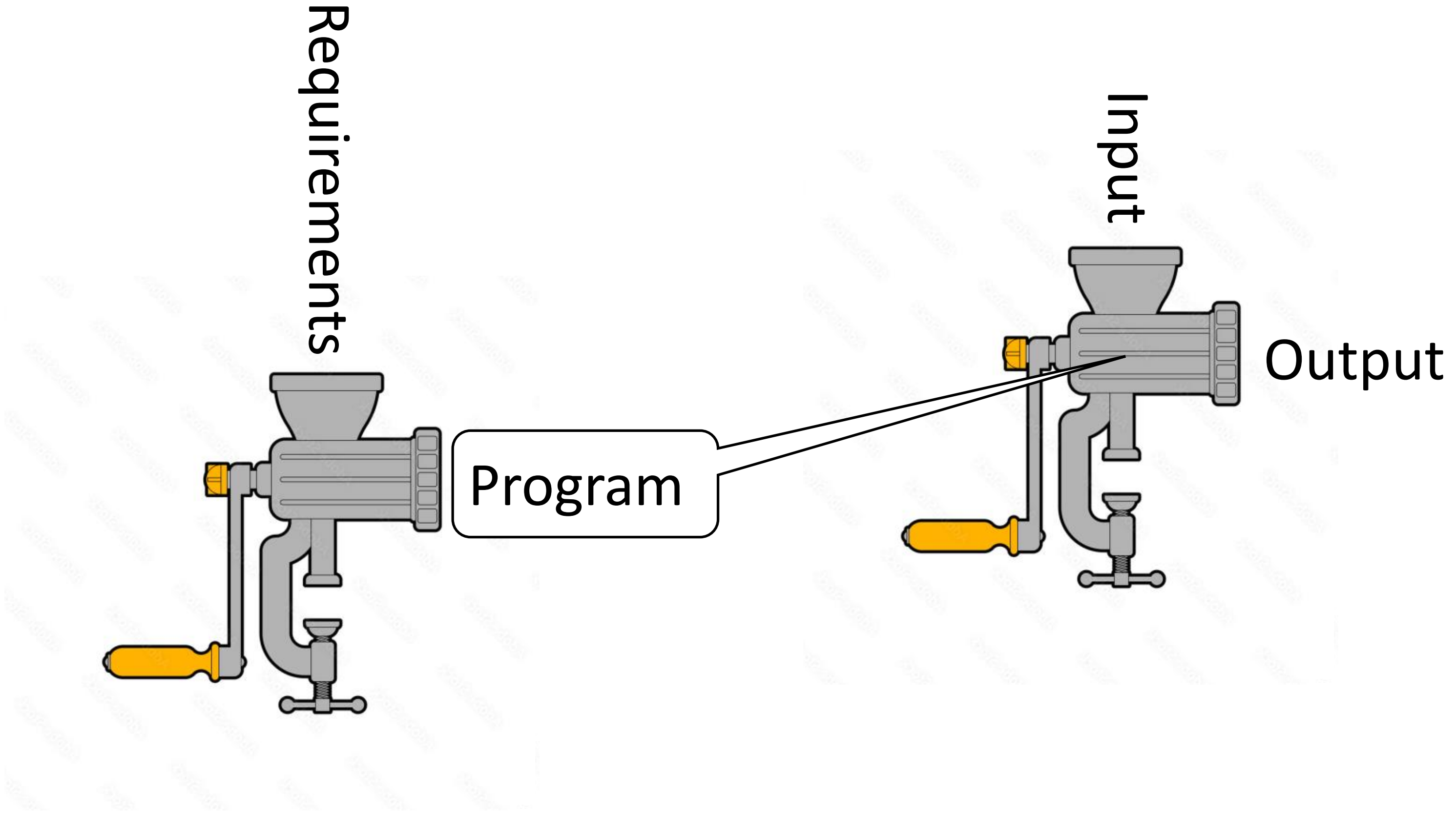

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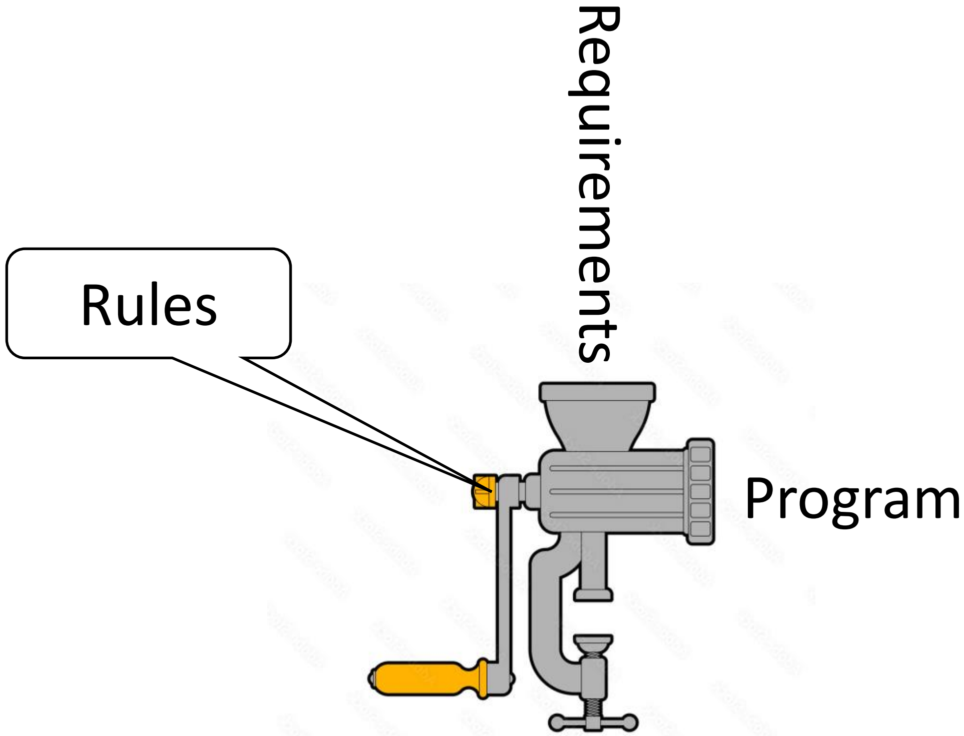
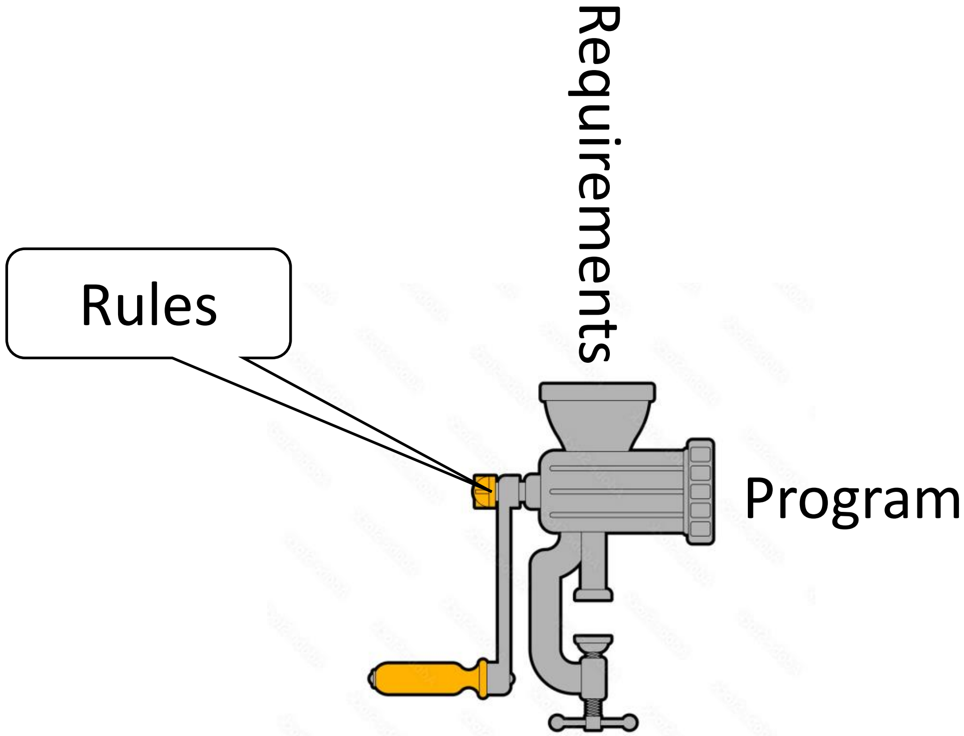


Fully-automatic programming would need rules that are:

- Effective
- Produce good code
- Efficient
- Complete

Can programming be mechanized?

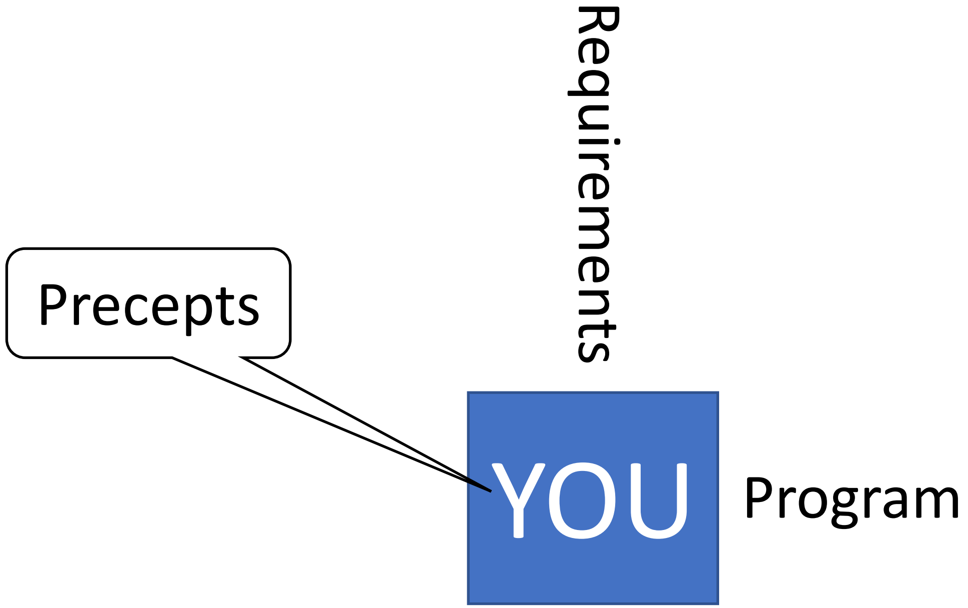


Fall back
- Rules for people
- Make programming
  - Easy
  - Accurate

Precepts

pre·cept

A command or principle intended especially as a general rule of action



Fall back

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pre·cept

A command or principle intended especially as a general rule of action

First Precept

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A command or principle intended especially as a general rule of action

First Precept

☞ **Follow programming precepts.**

pre·cept

A command or principle intended especially as a general rule of action

Second Precept

pre·cept

A command or principle intended especially as a general rule of action

Second Precept

☞ **Ignore precepts, when appropriate.**

pre·cept

A command or principle intended especially as a general rule of action

INCONSISTENCIES

☞ **Code with deliberation. Be mindful.**

Sample precept

Sample precept

☞ **Aspire to making code self-documenting by choosing descriptive names.**

Sample precept, with an application:

```
amount = price * quantity;
```

☞ **Aspire to making code self-documenting by choosing descriptive names.**

Same precept, with a different application:

```
piece = board[row+deltaRow[direction]][column+deltaColumn[direction]];
```

☞ **Aspire to making code self-documenting by choosing descriptive names.**

Same precept, with a different application:

```
piece = board[row+deltaRow[direction]][column+deltaColumn[direction]];

piece = B[r+deltaR[d]][c+deltaC[d]];
```

☞ **Aspire to making code self-documenting by choosing descriptive names.**

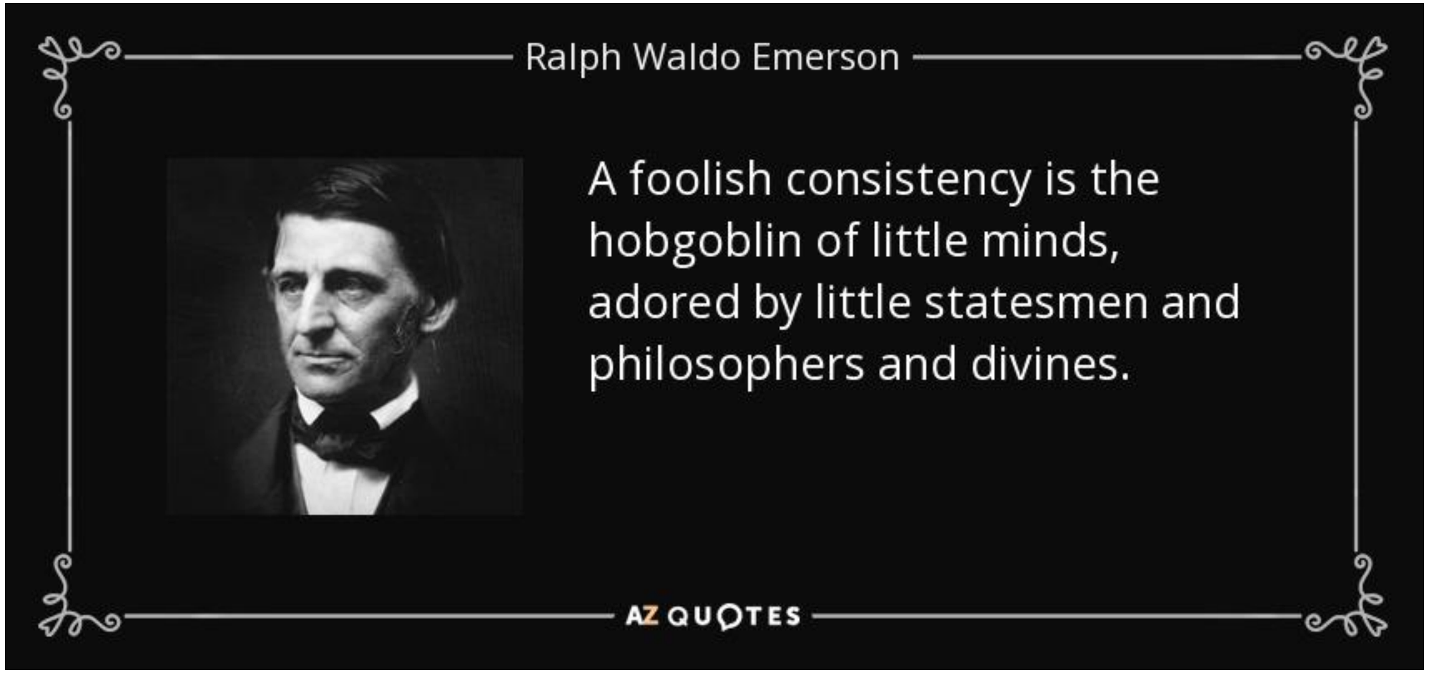
Alternative precept

```
piece = board[row+deltaRow[direction]][column+deltaColumn[direction]];

piece = B[r+deltaR[d]][c+deltaC[d]];
```

☞ **Use single-letter variable names when it makes code more understandable.**

Precepts



☞ **Resolve contradictory precepts with care.**

Exercise judgement

Make tradeoffs

Don’t make decisions casually

Indulge in personal preference

☞ **Resolve contradictory precepts with care.**

Precepts

☞ **Be humble. Programming is hard and error prone. Respect it.**

Despite your humility, aim for perfection

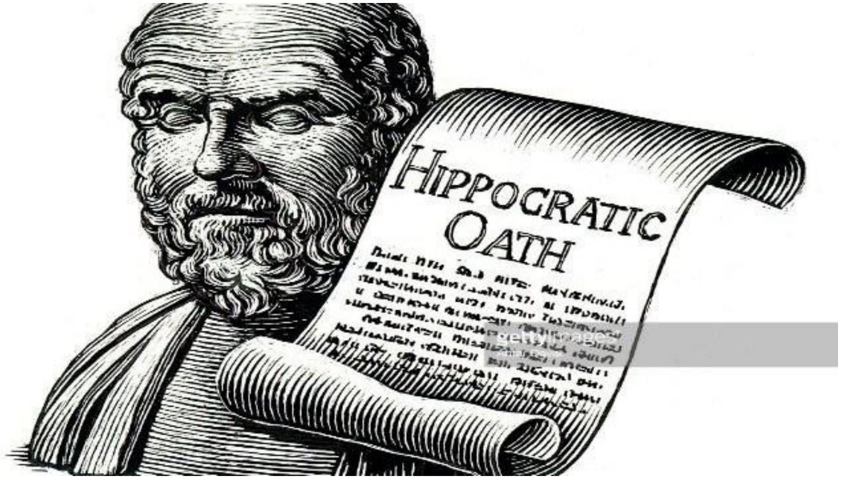
- The quality of the code you write
- The quality of the process you use to write it

☞ **Be humble. Programming is hard and error prone. Respect it.**

Process quality

☞ **Aspire to code it right the first time.**

Process quality: Hippocratic Coding



☞ **Aspire to code it right the first time. Do no harm. Avoid writing code that must be redone.**

An approach to Hippocratic Coding: Patterns

☞ **Master stylized code patterns, and use them.**

An approach to Hippocratic Coding: Patterns

A *pattern* is a *structure* containing *placeholders.*

The *structure* is an arrangement of *computational elements*.

The *placeholders* are named slots to be filled in:

They may be words or phrases in *italics*.

They may be *comments*, which are hash marks (#) followed by text.

Pattern: compute-use

```
/* Compute. */
/* Use. */
```

☞ **Master stylized code patterns, and use them.**

- The *structure* of the *compute-use pattern* is a sequence of two *statements* that command actions to be performed one after the other.
- The *placeholders* describe the actions: compute something, then use it.

Pattern: compute-use

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Pattern: compute-use

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/* Compute. */
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How does this pattern help?

☞ **Master stylized code patterns, and use them.**

Sample programming problem

☞ **Master stylized code patterns, and use them.**

Apply the compute-use pattern

```
/* Compute k. */
/* Use k. */
```

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How does this *pattern* help?

- It divides the problem into two smaller parts.
- It describes those parts, and clarifies that the first step computes something named k, and the second step uses k.

Apply the compute-use pattern

```
/* Compute k. */
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How does this *pattern* help?

- It divides the problem into two smaller parts.
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- It's Hippocratic: A baby step that does no harm.

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- It's Hippocratic: A baby step that does no harm.
- We can then:
  - Replace the first *placeholder* with code.

Apply the compute-use pattern

```
k = thus-and-such;
/* Use k. */
```

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Apply the compute-use pattern

```
k = thus-and-such;
if ( k-has-some-desired-property )
    /* Do-this-and-that. */
```

How does this *pattern* help?

- It divides the problem into two smaller parts.
- It describes those parts, and clarifies that the first step computes something named k, and the second step uses k.
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  and we're making progress.

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- It describes those parts, and clarifies that the first step computes something named k, and the second step uses k.
- It's Hippocratic: A baby step that does no harm.
- We can then:
  - Replace the first *placeholder* with code.
  - Replace the second *placeholder* with code.

  and we're making progress.
- The *Compute* and *Use placeholders* are gone, but the *compute-use pattern* is the skeleton that underlies the code.

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- An alternative to *replacing* a *placeholders* is to …

Apply the compute-use pattern

```
/* Compute k. */
/* Use k. */
```

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- An alternative to *replacing* a *placeholders* is to *amplify* it with specifics that say exactly what a step must do, effectively turning it into a *specification*.

Apply the compute-use pattern

```
/* Compute k, some aspect of the big-hairy-mess. */
/* Use k, the aspect of the big-hairy-mess that has been computed. */
```

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- An alternative to *replacing* a *placeholder* is to *amplify* it with specifics that say exactly what a step must do, effectively turning it into a *specification*.
- The *specification* can then be *implemented*, either by code, or by an instance of another pattern, and remains to show the intent of its *refinement*.

Application of compute-use

```
/* Compute k. */
   k = thus-and-such;
/* Use k. */
   if ( k-has-some-desired-property ) /* Do-this-and-that. */
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- When a *specification* is *implemented*:
  - The *implementation* is indented to show that it is a *refinement*.

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Application of compute-use

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- An alternative to *replacing* a *placeholder* is to *amplify* it with specifics that say exactly what a step must do, effectively turning it into a *specification*.
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- When a *specification* is *implemented*:
  - The *implementation* is indented to show that it is a *refinement*.
  - A blank line may optionally be inserted after it.

☞ **Master stylized code patterns, and use them.**

Another pattern: indeterminate iteration

```
/* Enumerate from start. */
   int k = start;
   while ( condition ) k++;
```

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Another pattern: indeterminate iteration

```
/* Enumerate from start. */
   int k = start;
   while ( condition ) k++;
```

Effect

Initialize k to *start*

Repeatedly add 1 to k
provided *condition* is **true**

☞ **Master stylized code patterns, and use them.**

Yet another pattern: general iterative computation

```
/* Initialize. */
while ( not-finished ) {
   /* Compute. */
   /* Go-on-to-next. */
   }
```

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Yet another pattern: general iterative computation

```
/* Initialize. */
while ( not-finished ) {
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   }
```

Effect

Get ready by initializing

Repeatedly make progress by:

- computing something
- moving on to the next thing

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Indeterminate iteration is a special case of general iterative computation.

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while ( not-finished ) {
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int k = start;
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Shorthand: general iterative computation

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for (initialize; condition; go-on-to-next) compute
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Convention: We could use a **for**-statement to express indeterminate iteration

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☞ **Master stylized code patterns, and use them.**

Convention: We could use a **for**-statement to express indeterminate iteration

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for (int k=start; condition; go-on-to-next) compute
```

```
int k = start;
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Convention: We could use a **for**-statement to express indeterminate iteration

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for (int k=start; condition; k++) compute
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Convention: We could use a **for**-statement to express indeterminate iteration

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for (int k=start; condition; k++);
```

```
int k = start;
while ( condition ) k++;
```

☞ **Master stylized code patterns, and use them.**

But, by convention: Never use a **for**-statements for indeterminate iteration

```
for (int k=start; condition; k++);
```

```
int k = start;
while ( condition ) k++;
```

☞ **Master stylized code patterns, and use them.**

Convention: Reserve **for**-statements for determinate iteration

```
for (int k=start; k<limit; k++) compute
for (int k=start; k<=limit; k++) compute
```

k goes up

```
for (int k=start; k>limit; k--) compute
for (int k=start; k>=limit; k--) compute
```

k goes down

☞ **Master stylized code patterns, and use them.**

Key Distinction: determinate iteration vs indeterminate iteration

Determinate: for when the number of iterations is known beforehand

```
for (int k=start; condition; go-on-to-next) compute
```

Indeterminate: for when the number of iterations is not known beforehand

```
k = start;
while ( condition )
    k++;
```

☞ **Master stylized code patterns, and use them.**

- "Known" in the sense that the number of iterations is determined on arrival at the **for**-statement.

Key Distinction: determinate iteration vs indeterminate iteration

Determinate: for when the number of iterations is known beforehand

```
for (int k=start; condition; go-on-to-next) compute
```

Indeterminate: for when the number of iterations is not known beforehand

```
k = start;
while ( condition )
    k++;
```

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Another approach to Hippocratic Coding: Analysis

☞ **Aspire to code it right the first time. Do no harm. Avoid writing code that must be redone.**

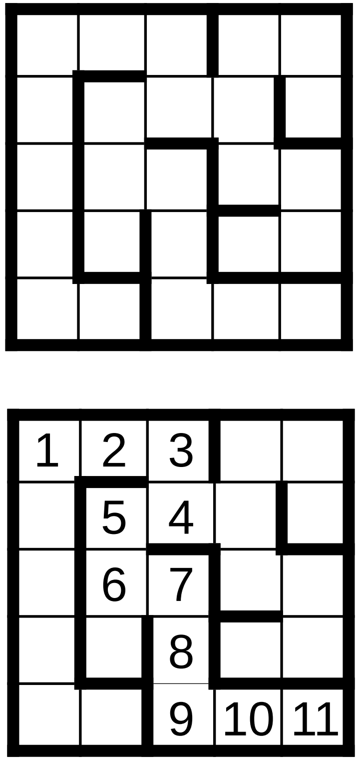
Another approach to Hippocratic Coding: Analysis

☞ Analyze first.

Example: Running a Maze

Background. Define a maze to be a square two-dimensional grid of cells separated (or not) from adjacent cells by walls. One can move between adjacent cells if and only if no wall divides them. A solid wall surrounds the entire grid of cells, so there is no escape from the maze.

Problem Statement. Write a program that inputs a maze, and outputs a direct path from the upper-left cell to the lower-right cell if such a path exists, or outputs "Unreachable" otherwise. A path is direct if it never visits any cell more than once.



Analysis

- Problem
- Architecture
- Data
- Components

☞ **Analyze first.**

Problem

☞ **Make sure you understand the problem.**

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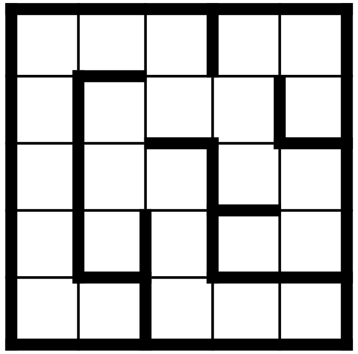
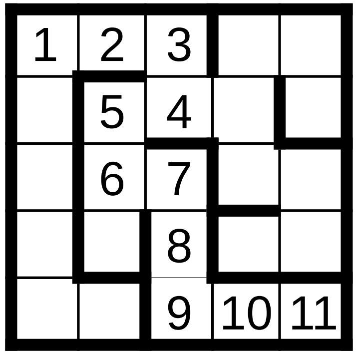
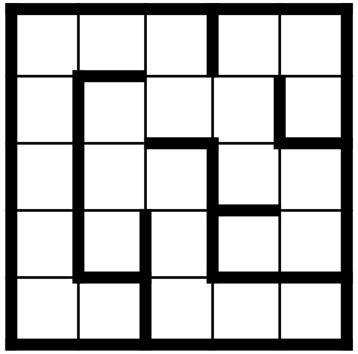


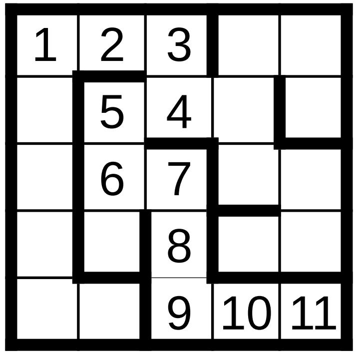


☞ **Make sure you understand the problem.**

Example: Running a Maze

- Do I understand each noun: *maze*, *grid*, *cell*, *wall*, *path*, and *direct path*?
- Do I understand the verbs: Specifically, how does one *move* between cells?
- How is a maze represented in the input?
- Is there any upper limit on the size of a maze? Is there a lower limit?
- What is the expected program behavior if the input is not well-formed?
- Is a direct path the same as a shortest path?
- What if there is more than one direct path?
- How is a path to be displayed in the output?





☞ **Make sure you understand the problem.**

Architecture: What sort of computation will it be?

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- **Online**. Read a sequence of inputs, and process them on the fly.
- **Offline**. Read all inputs, perform a computation, output result.
- **Other**.

Architecture: Offline computation pattern

```
/* Input. */
/* Compute. */
/* Output. */
```

Architecture: Restate the problem on the architecture

```
/* Input a maze of arbitrary size, or output “malformed input” and stop if the
   input is improper. Input format: TBD. */
/* Compute a direct path through the maze, if one exists. */
/* Output the direct path found, or “unreachable” if there is none. Output
   format: TBD. */
```

Programs: Instructions for manipulating values

Instructions: code

Values: data

Patterns and Architecture: Code-centered perspective

☞ **Dovetail thinking about code and data.**

Code

```
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Data

maze

```
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```

path

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External Data

external data (maze)

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   format: TBD. */
```

external data (path)

☞ **Dovetail thinking about code and data.**

Variables

```
/* Input a maze of arbitrary size, or output “malformed input” and stop if the
   input is improper. Input format: TBD. */
```

maze

```
/* Compute a direct path through the maze, if one exists. */
```

path

```
/* Output the direct path found, or “unreachable” if there is none. Output
   format: TBD. */
```

☞ **Specify how individual program steps will cooperate with one another.**

Internal Data

```
/* Input a maze of arbitrary size, or output “malformed input” and stop if the
   input is improper. Input format: TBD. */
```

internal data (maze)

```
/* Compute a direct path through the maze, if one exists. */
```

internal data (path)

```
/* Output the direct path found, or “unreachable” if there is none. Output
   format: TBD. */
```

☞ **A program’s internal data representation is central to the code; consider it early.**

External Data

external data (maze)

```
/* Input a maze of arbitrary size, or output “malformed input” and stop if the
   input is improper. Input format: TBD. */
/* Compute a direct path through the maze, if one exists. */
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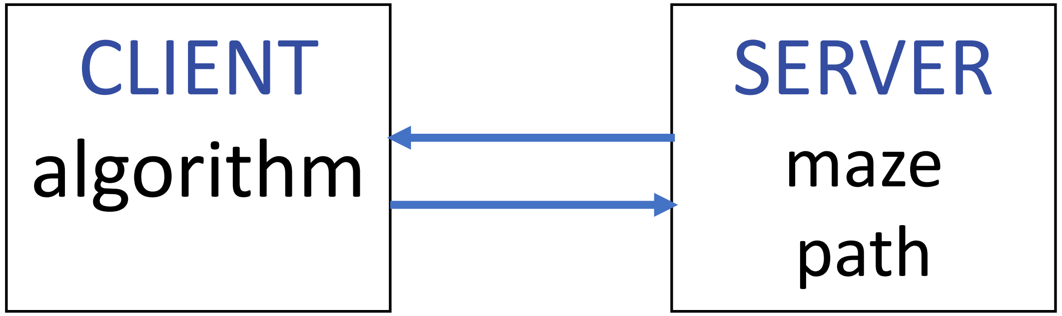
   format: TBD. */
```

external data (path)

☞ **Consider a program’s external data representation late.**

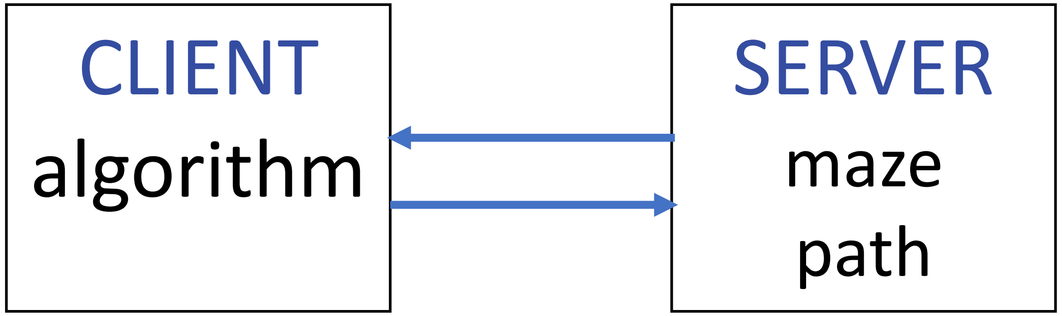
Components

- A program can be organized into components.
- Distinguish between the maze-running algorithm (a client of data) and the data itself (housed in a server).
- What operations are needed by the client?
- What operations can be provided by the server?
- Resolve differences by negotiation.



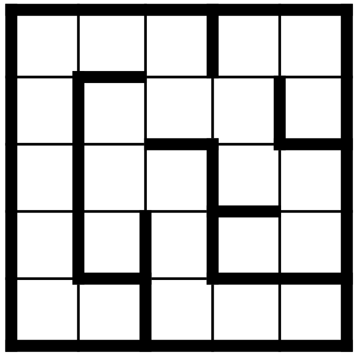
Components

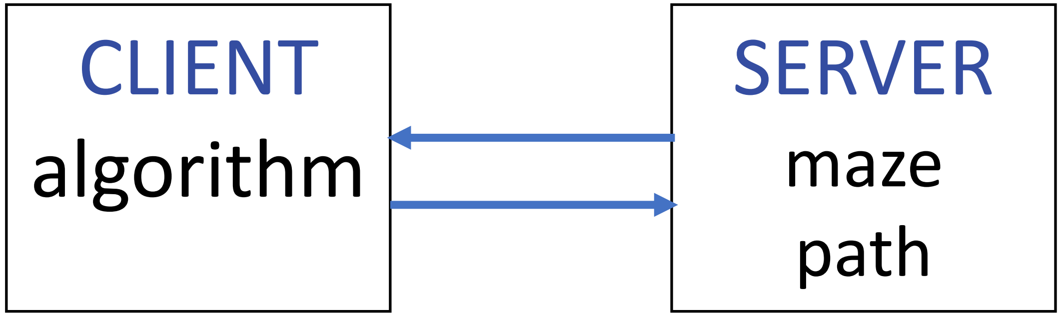
- Some aspects of data are static, i.e., don't change (maze)
- The client learns of static data by queries.
- Other aspects of data are dynamic, i.e., change (path)
- The client is an actor that effects changes by actions:
  - extend path (if possible); retract path (if necessary)
  - The cumulative effect of actions is recorded in state.



Components

- A client may have/want global perspective
  - algorithm is aware of the full maze





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- A client may have/want global perspective
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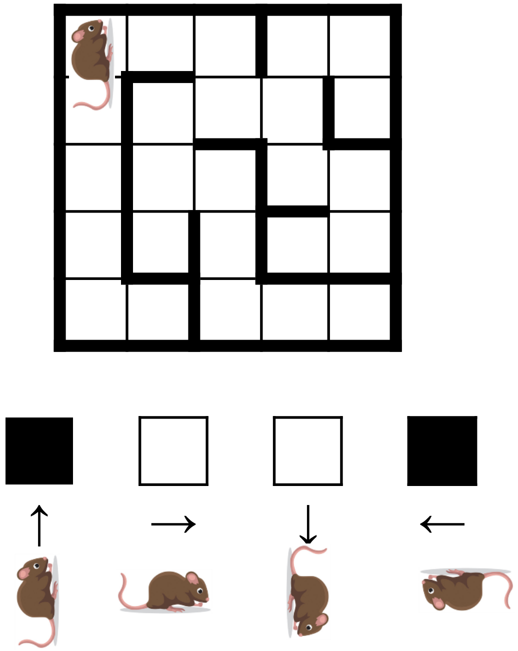

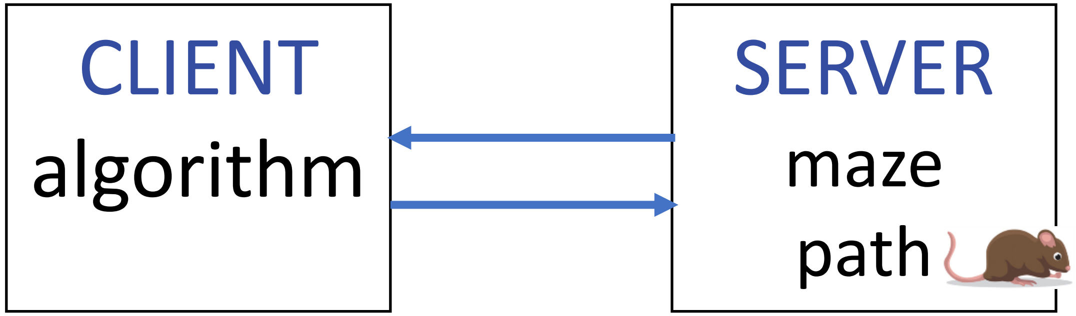

Analysis

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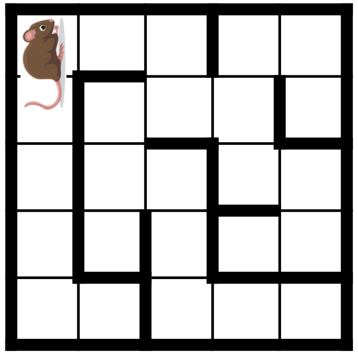

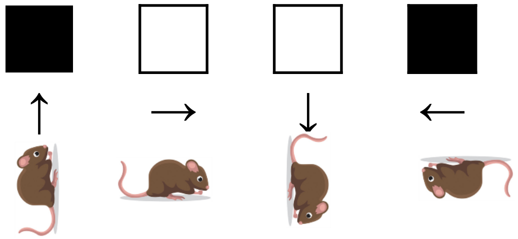

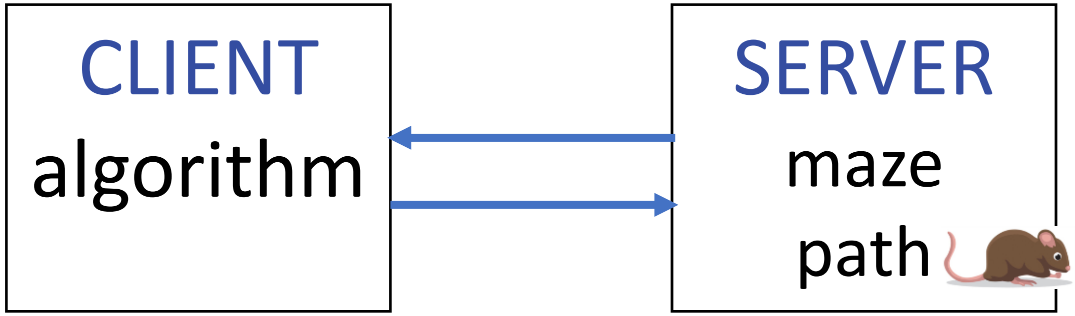

Another programming problem

☞ **Analyze first.**

Example: Ricocheting Bee-Bee

Background. A square tin box measuring one foot on each side has a slit of size d centered on one side. Insert a bee-bee gun at the center of the slit at angle Θ, and shoot. The bee-bee ricochets off sides, one after another. On each ricochet, the angle of reflection is equal to the angle of incidence.

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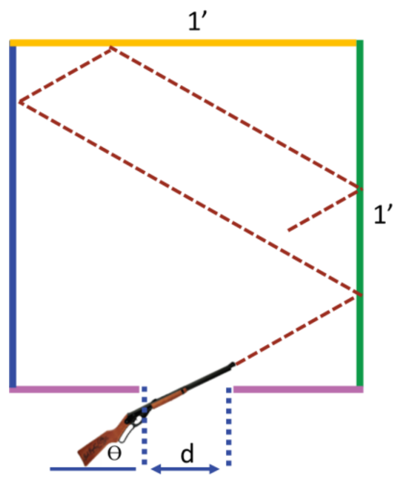

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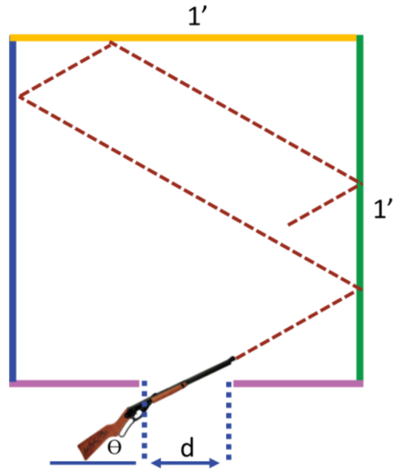

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An analogous example: Output the sum of the integers between 1 and n.

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```
/* Output the sum of 1 through n. */
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```
/* Output the sum of 1 through n. */
   int sum = 0;
   for (int k=1; k<=n; k++) sum = sum + k;
   System.out.println( sum );
```

} knee-jerk, brute force

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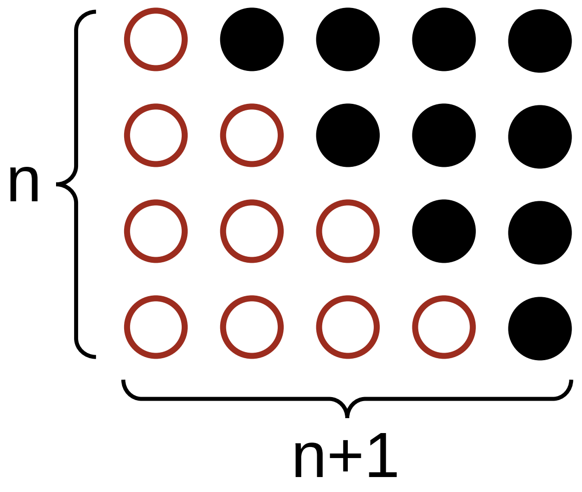

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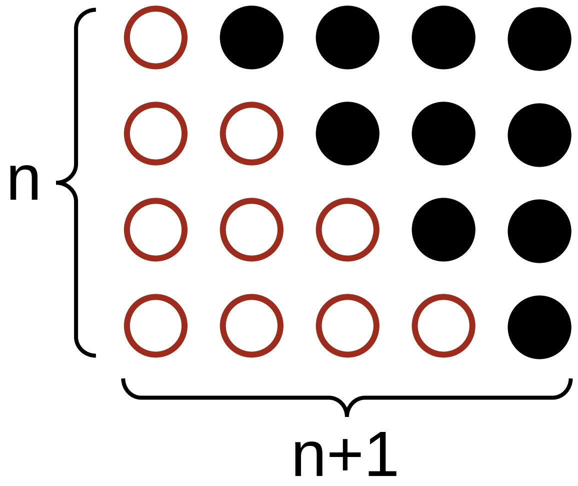
An analogous example: Output the sum of the integers between 1 and n.

```
/* Output the sum of 1 through n. */
   System.out.println( n*(n+1)/2 );
```

Integer division, with fractional part truncated.



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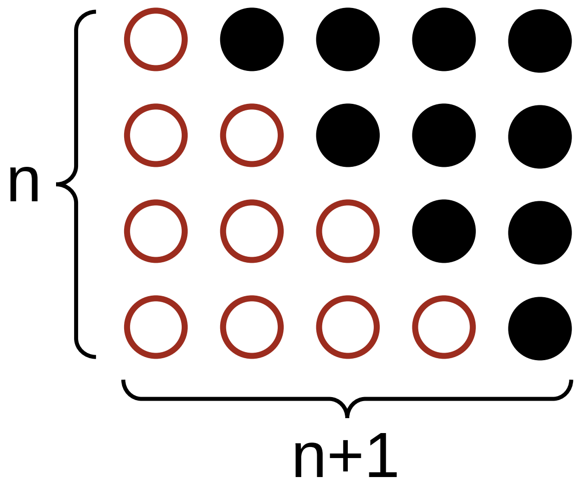

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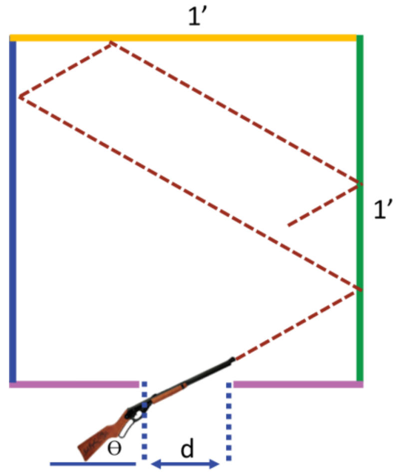

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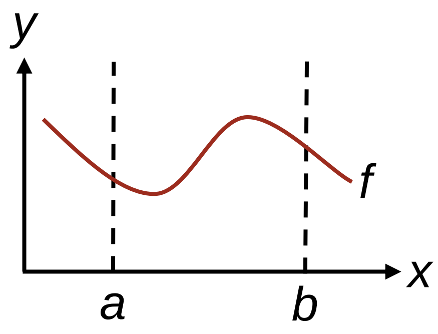
Another analogy: A possible source of inspiration.

Another analogy: Computing the arc length *s* of a curve y=*f(x),* between a and b.



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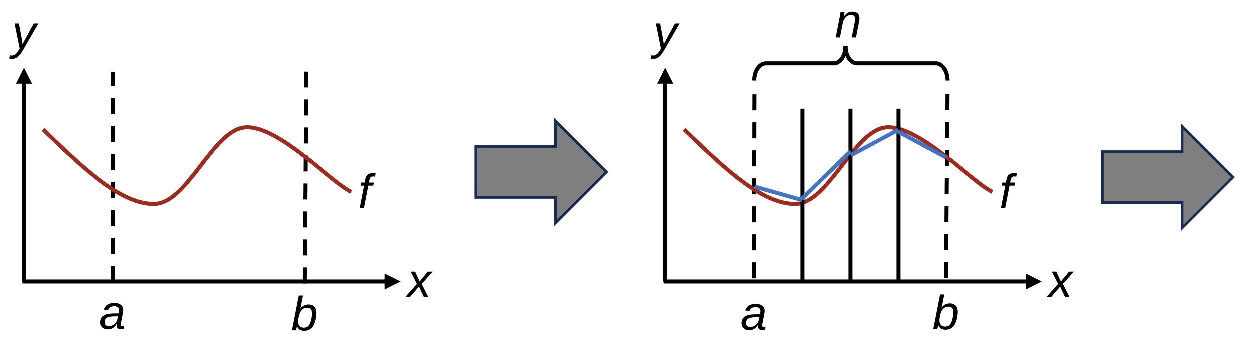
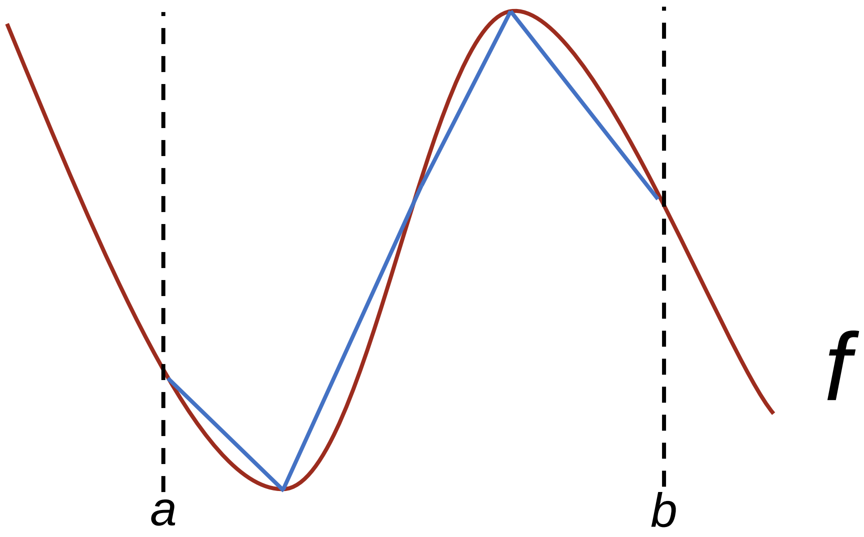
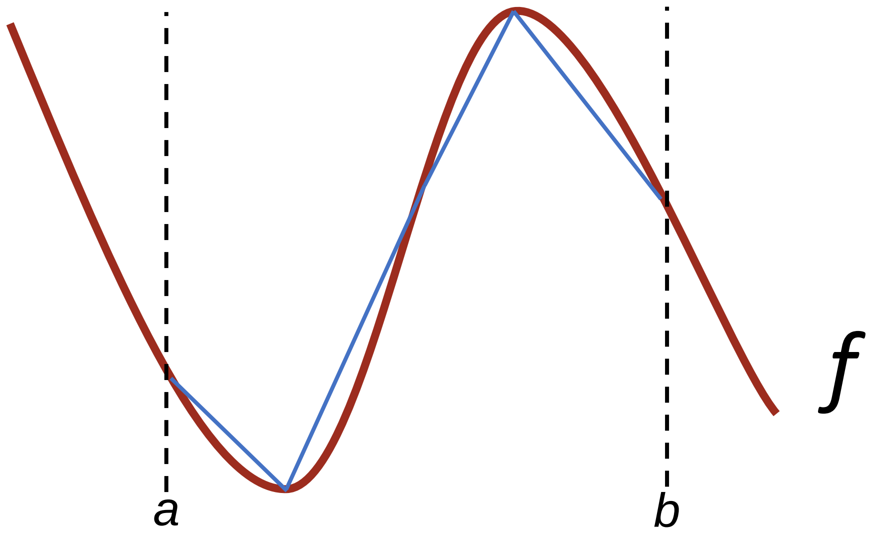


$$s = \int_a^b \sqrt{1 + \left(\frac{dy}{dx}\right)^2}\ dx$$

Another analogy: Where does the analogy faulter?

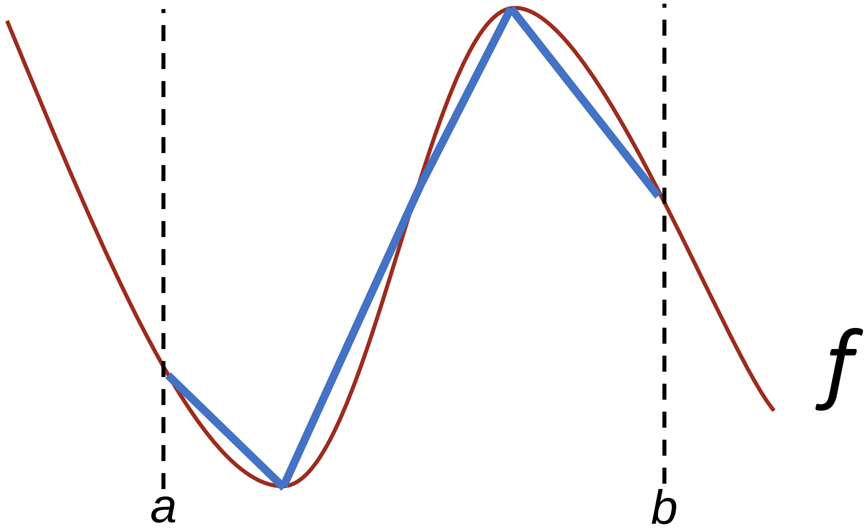


Another analogy: In the calculus problem, we seek *s*, the length of *f*.



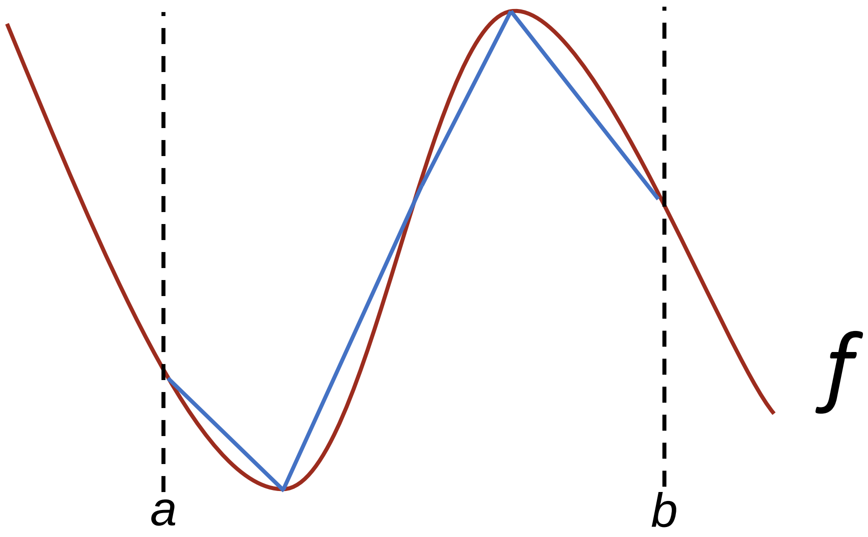
$$s = \int_a^b \sqrt{1 + \left(\frac{dy}{dx}\right)^2}\ dx$$

Another analogy: In the bee-bee problem, we seek the sum of the piece lengths.




```
# Output the sum of 1 through n.
print(n * (n + 1) // 2)
```

Another analogy: In general, they are only the same in the infinite limit.

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# Output the sum of 1 through n.
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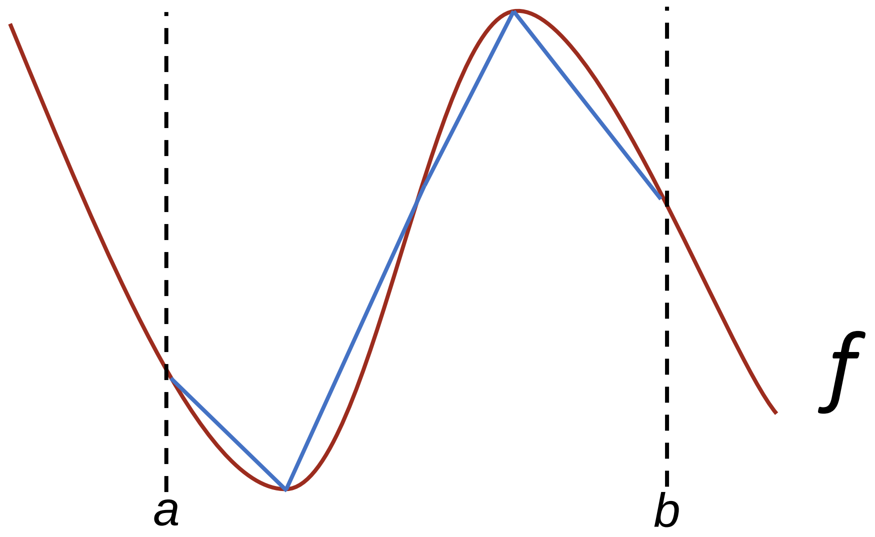
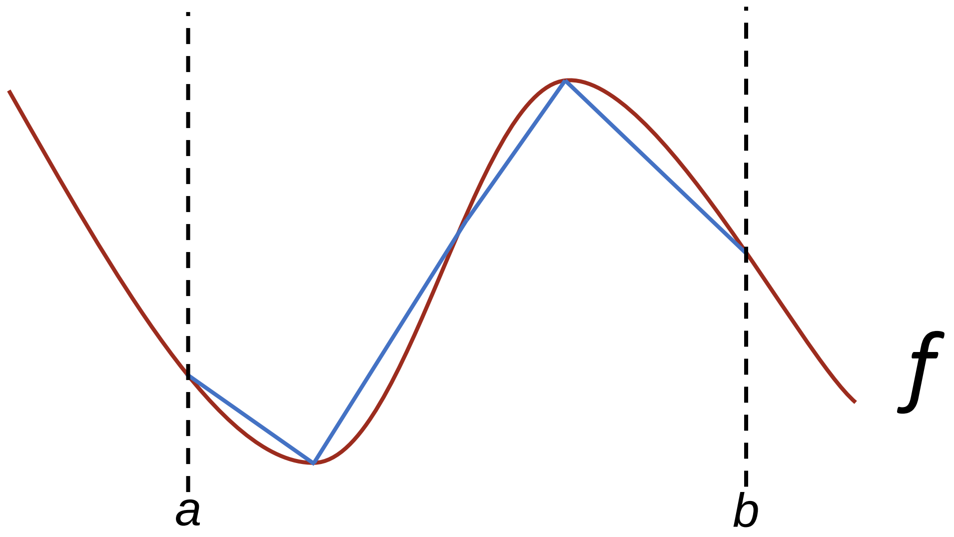
Another analogy: How can we unify the two disparate points of view?



Another analogy: By finding an instance of the problem where they are the same.



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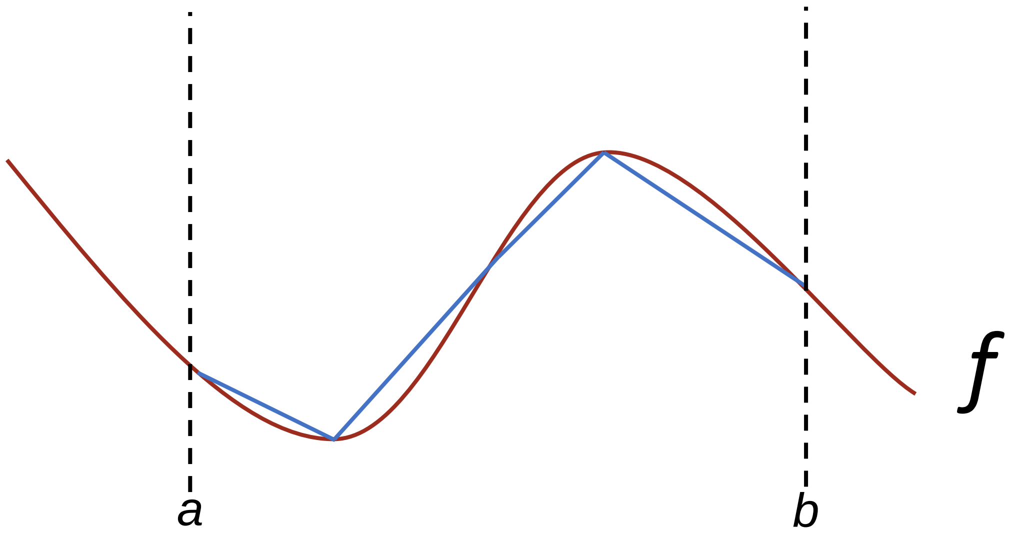

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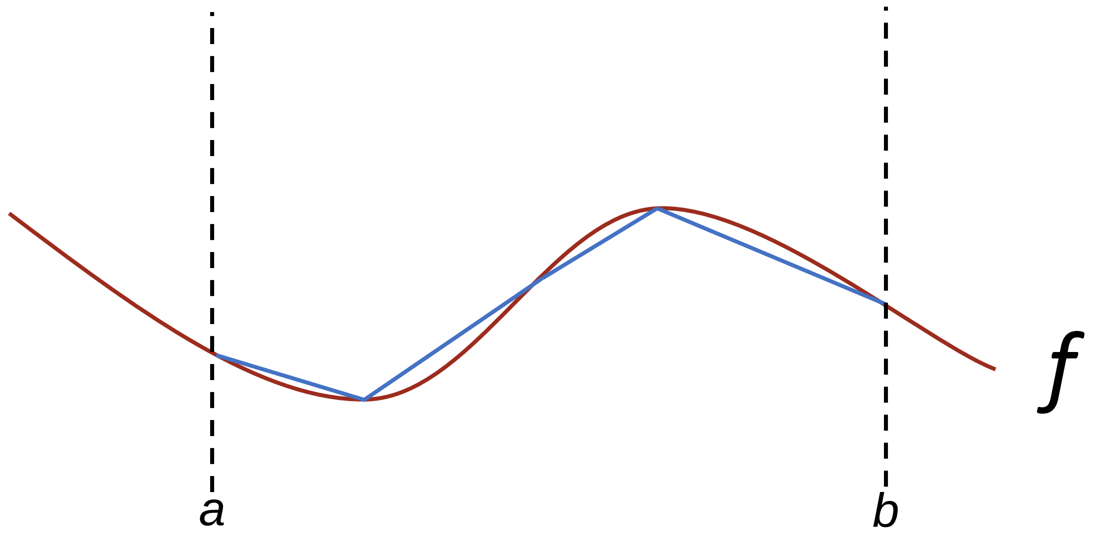

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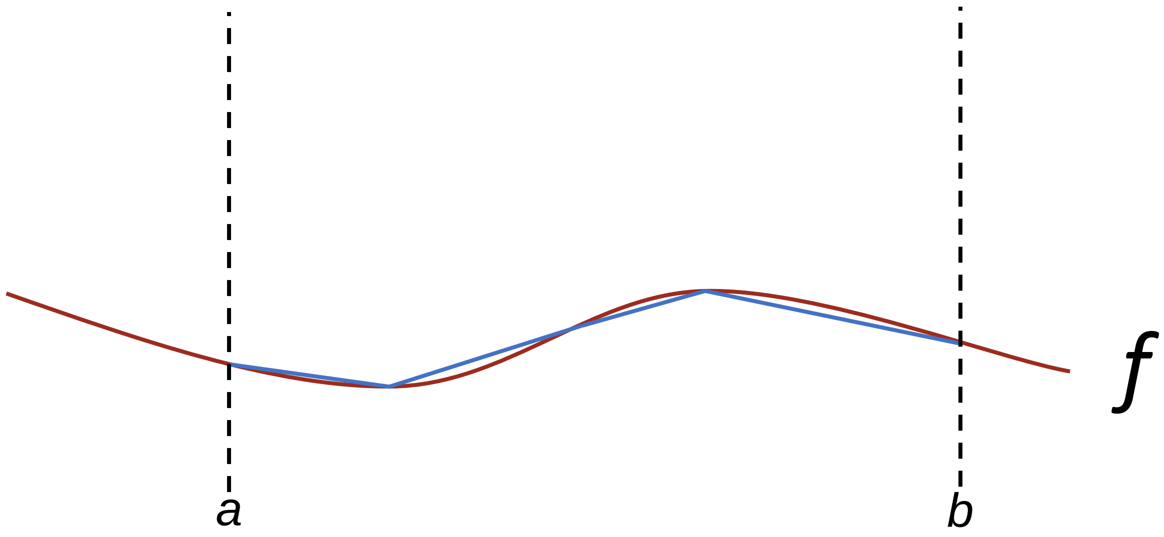

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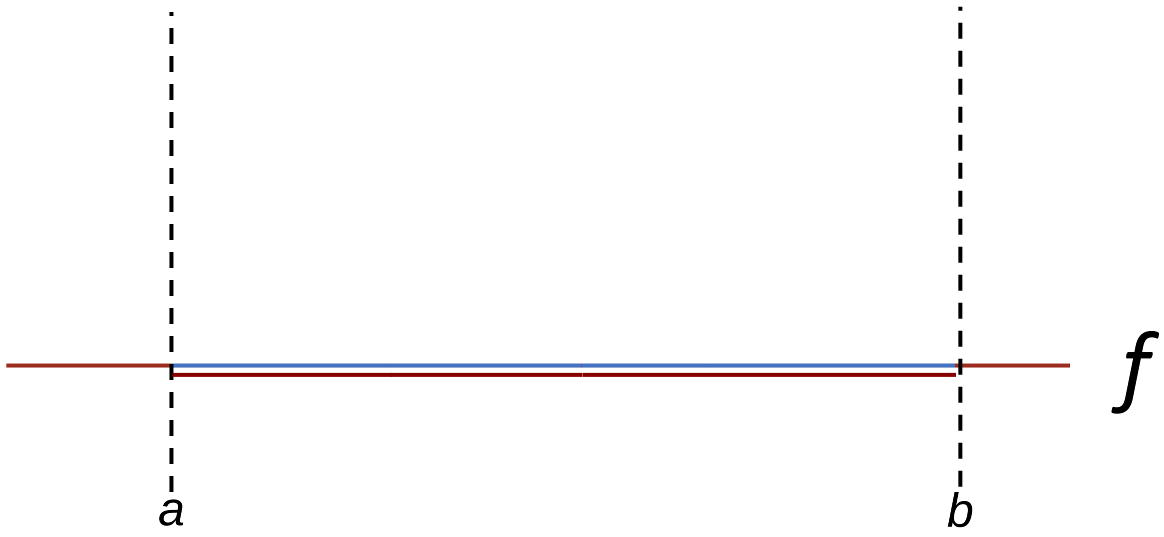

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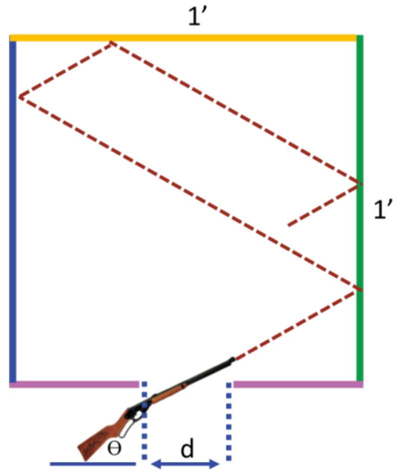

☞ **Solve a different problem, and use that solution to solve the original problem.**

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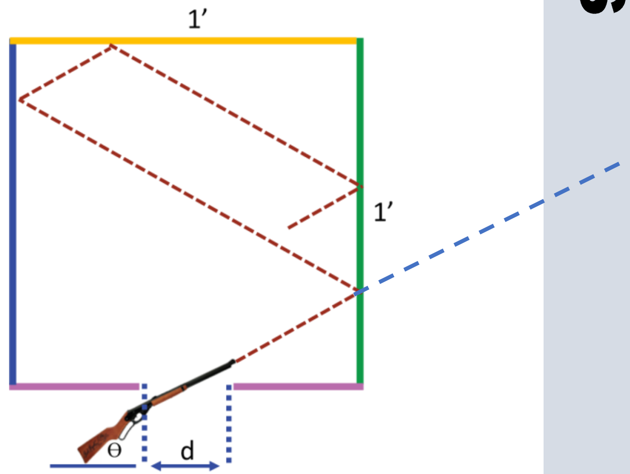

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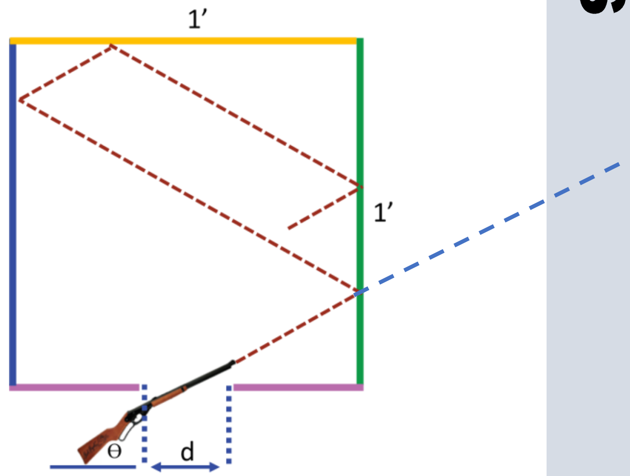

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Process:

☞ **Reduce errors.**

Process: Don’t make mistakes

- Hope for the best, but
- Plan for the worst.

☞ **Avoid debugging like the plague.**

Process: Find mistakes as soon as possible

☞ **Test programs incrementally.**

Process: Stay in control

- Hope for the best, but
- Plan for the worst.

☞ **Never be (very) lost. Don't stray far from a correct (albeit, partial) program.**

Process: End-to-end correctness of subproblems

```
/* Input a maze of arbitrary size, or output “malformed input” and stop if the
   input is improper. Input format: TBD. */
/* Compute a direct path through the maze, if one exists. */
/* Output the direct path found, or “unreachable” if there is none. Output
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/* Compute a direct path through the maze, if one exists. */
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⇩ provide simple diagnostic output

⇩

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Process: End-to-end correctness of subproblems

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`/* Compute a` ~~`direct`~~ `path through the maze, if one exists. */`

provide simple diagnostic output

☞ **Never be (very) lost. Don't stray far from a correct (albeit, partial) program.**

Process: Undo if necessary

☞ **Don’t be wedded to code. Revise and rewrite when you discover a better way.**

Process: Stepwise refinement

☞ **Program top-down, outside-in.**

Example: Print the integer part of the square root of an integer `n≥0`.

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```

Q. Where did n come from?

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Q. Where did n come from?

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- A2. It is assumed to already contain a value ≥ 0.

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/* Given n≥0, output the Integer Square Root of n. */    1
```

Q. Where did n come from?

- A1. It is a program variable.
- A2. It is assumed to already contain a value ≥ 0.
- A3. We are only asked to write a program segment.

☞ **Make sure you understand the problem.**

Example

```
/* Given n≥0, output the Integer Square Root of n. */
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Q. Can’t we just do this using a few library routines?

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```
/* Given n≥0, output the Integer Square Root of n. */
   System.out.println( Math.floor( Math.sqrt(n) ) );
```
2

Q. Can’t we just do this using a few library routines?

- A. Yes.

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- A. Yes.
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- So, we amend our problem statement.

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/* Given n≥0, output the Integer Square Root of n. */
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☞ **Master stylized code patterns, and use them.**

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Example

Example

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/* Given n≥0, output the Integer Square Root of n. */
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1

```
/* Compute. */
/* Use. */
```

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```
/* Given n≥0, output the Integer Square Root of n. */
```

1

```
/* Compute r. */
/* Use r. */
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☞ **Specify how individual program steps will cooperate with one another.**

```
/* Given n≥0, output the Integer Square Root of n. */
   /* Let r be the integer part of the square root of n≥0. */
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☞ **If you "smell a loop", write it down.**

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```

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Example

☞ **Decide first whether an iteration is indeterminate (use while) or determinate (use for).**

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2

```
/* Indeterminate iteration */
   int k = start;
   while ( condition ) k++;
```

```
/* Determinate iteration */
   for (int k=start; k<=limit; k++) compute
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Which?

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3

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3

☞ **There is no shame in reasoning with concrete examples.**

Example

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3

☞ **Elaborate the expected input/output mapping explicitly.**

Example

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   /* Let r be the integer part of the square root of n≥0. */
      int r = 0;
      while ( condition ) r++;
   System.out.println( r );
```

3

r	r*r	n
0	0	0

☞ **Elaborate the expected input/output mapping explicitly.**

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3	9	9, 10, 11, 12, 13, 14, 15

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- 4, 5, 6, 7, or 8.

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What is special about 9?
- It is the square of 3.

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But what is special about 3?

- It is one more than 2, the value of r.

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☞ **Alternate between concrete reasoning and abstract reasoning.**

```
/* Given n≥0, output the Integer Square Root of n. */
   /* Let r be the integer part of the square root of n≥0. */
      int r = 0;
      while ( (r+1)*(r+1) ____ n ) r++;
   System.out.println( r );
```

4

r	r*r	n
0	0	0
1	1	1, 2, 3
2	4	4, 5, 6, 7, 8
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```
4

Elaborate and eliminate choices

☞ **Alternate between concrete reasoning and abstract reasoning.**

Example

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```
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Elaborate and eliminate choices for the relation

==, != No. Given r, must be true for many n, and false for many n.

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/* Given n≥0, output the Integer Square Root of n. */
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   System.out.println( r );
```
4

Elaborate and eliminate choices for the relation

==, !=	No. Given r, must be true for many n, and false for many n.
>, >=	No. Must keep going for little r and big n.

☞ **Alternate between concrete reasoning and abstract reasoning.**

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/* Given n≥0, output the Integer Square Root of n. */
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   System.out.println( r );
```
4

Elaborate and eliminate choices for the relation

==, !=	No. Given r, must be true for many n, and false for many n.
>, >=	No. Must keep going for little r and big n.
<	No. Must keep going for “equal n” case.

☞ **Alternate between concrete reasoning and abstract reasoning.**

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/* Given n≥0, output the Integer Square Root of n. */
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==, !=	No. Given r, must be true for many n, and false for many n.
>, >=	No. Must keep going for little r and big n.
<	No. Must keep going for “equal n” case.
<=	Yes.

☞ **Alternate between concrete reasoning and abstract reasoning.**

Example

Example

```
/* Given n≥0, output the Integer Square Root of n. */
   /* Let r be the integer part of the square root of n≥0. */
      int r = 0;
      while ( (r+1)*(r+1) <= n ) r++;
   System.out.println( r );
```

5

Elaborate and eliminate choices for the relation

==, !=	No. Given r, must be true for many n, and false for many n.
>, >=	No. Must keep going for little r and big n.
<	No. Must keep going for “equal n” case.
<=	Yes.

☞ **Alternate between concrete reasoning and abstract reasoning.**

Example

```
/* Given n≥0, output the Integer Square Root of n. */
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      int r = 0;
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   System.out.println( r );
```

5

Pragmatics

We developed a code fragment in isolation, and ignored several practical questions:

A. Where will the integer n come from?
B. In what packaging will we run the code fragment?
C. What, if any, additional details must be addressed before the program can run?

We refer to these matters as “Pragmatics”.

```
/* Output the Integer Square Root of an integer input. */
   /* Obtain an integer n≥0 from the user. */
   /* Given n≥0, output the Integer Square Root of n. */
      /* Let r be the integer part of the square root of n≥0. */
         int r = 0;
         while ( (r+1)*(r+1) <= n ) r++;
      System.out.println( r );
```

6

Pragmatics

We developed a code fragment in isolation, and ignored several practical questions:

A. Where will the integer n come from?
   Obtain the integer value of n interactively from the user.

```
/* Output the Integer Square Root of an integer input. */
   /* Obtain an integer n≥0 from the user. */
      int n = in.nextInt();
   /* Given n≥0, output the Integer Square Root of n. */
      /* Let r be the integer part of the square root of n≥0. */
         int r = 0;
         while ( (r+1)*(r+1) <= n ) r++;
      System.out.println( r );
```


Pragmatics

We developed a code fragment in isolation, and ignored several practical questions:

A. Where will the integer n come from?
Obtain the integer value of n interactively from the user.

```
import java.util.Scanner;
class boilerplate {
   static Scanner in = new Scanner(System.in);
   static void main() {
      /* Output the Integer Square Root of an integer input. */
         /* Obtain an integer n≥0 from the user. */
            int n = in.nextInt();
         /* Given n≥0, output the Integer Square Root of n. */
            /* Let r be the integer part of the square root of n≥0. */
               int r = 0;
               while ( (r+1)*(r+1) <= n ) r++;
            System.out.println( r );
      } /* main */
   } /* boilerplate */
```

7

Pragmatics

We developed a code fragment in isolation, and ignored several practical questions:

B. In what context will we run the finished code?
   As the body of a method named `main`, which is inside a class called `boilerplate`.

```
import java.util.Scanner;
class boilerplate {
   static Scanner in = new Scanner(System.in);
   static void main() {
      /* Output the Integer Square Root of an integer input. */
         /* Obtain an integer n≥0 from the user. */
            int n = in.nextInt();
         /* Given n≥0, output the Integer Square Root of n. */
            /* Let r be the integer part of the square root of n≥0. */
               int r = 0;
               while ( (r+1)*(r+1) <= n ) r++;
            System.out.println( r );
      } /* main */
   } /* boilerplate */
```

8

Pragmatics

We developed a code fragment in isolation, and ignored several practical questions:

C. What, if any, additional details must be addressed before the program can run?
None. The program is ready to run.

Pragmatics

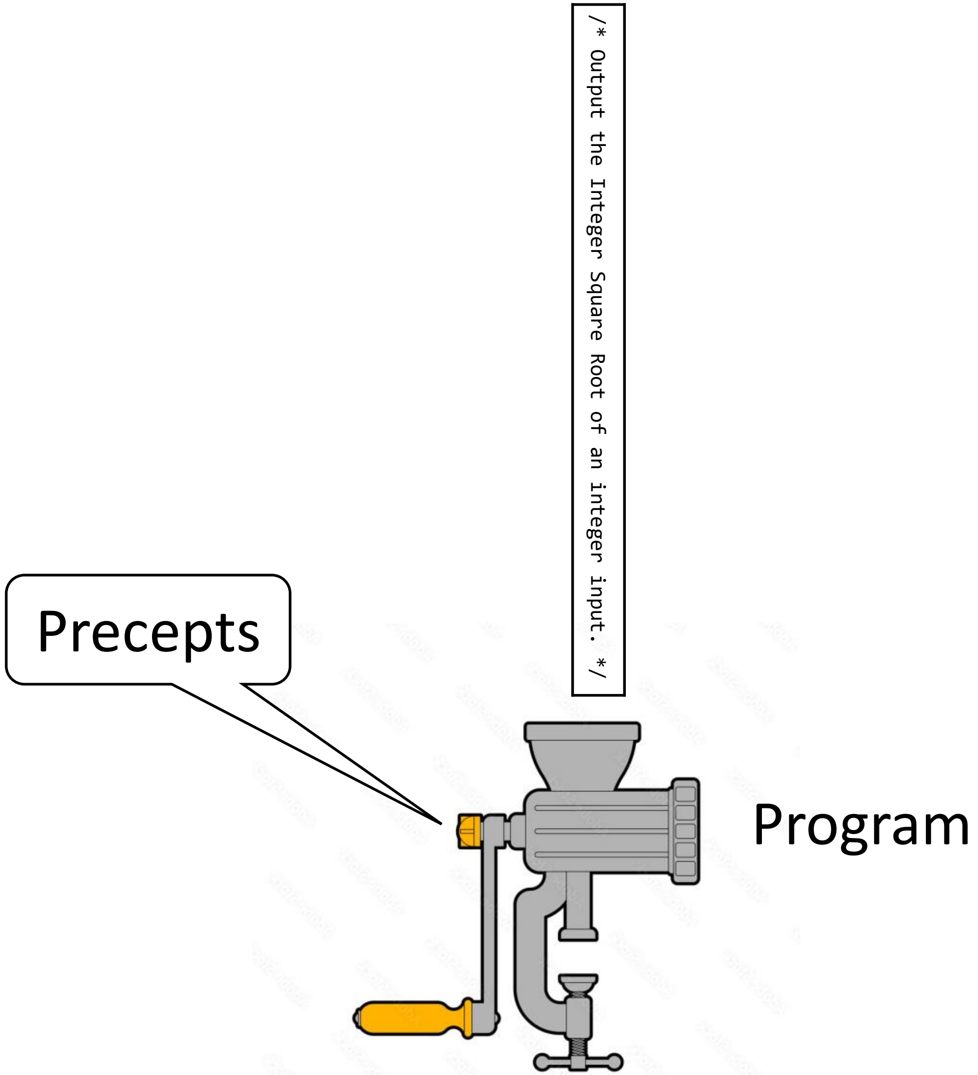
Pragmatics

```
/* Output the Integer Square Root of an integer input. */
```

YOU

Program

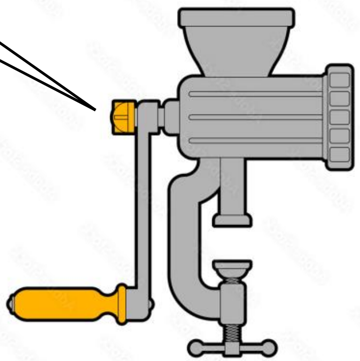
Pragmatics


/* Output the Integer Square Root of an integer input. */
Precepts
Program

Pragmatics

```
/* Output the Integer Square Root of an integer input. */
```

Precepts



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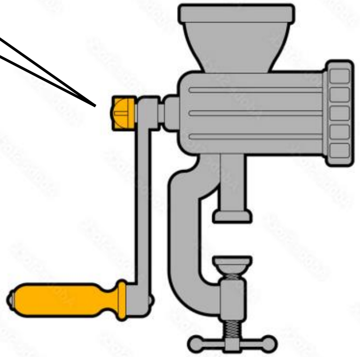
```

8

Pragmatics

/* Output the Integer Square Root of an integer input. */

Precepts



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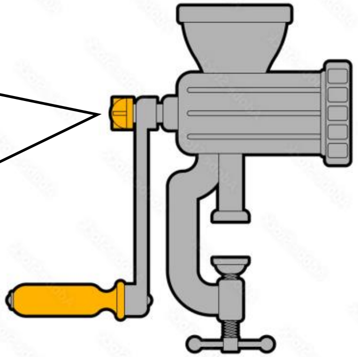
Input

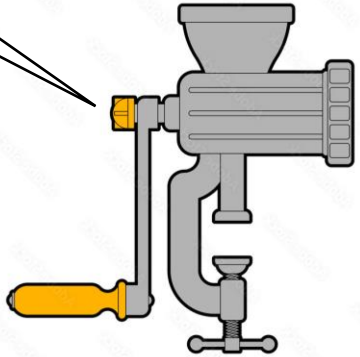


Output

Pragmatics

/* Output the Integer Square Root of an integer input. */

Precepts



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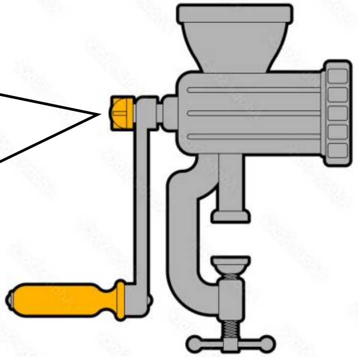
8

7

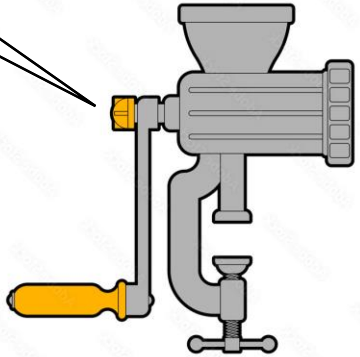


Output

Pragmatics

Precepts

`/* Output the Integer Square Root of an integer input. */`



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            System.out.println( r );
      } /* main */
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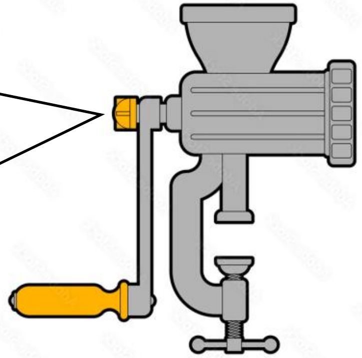
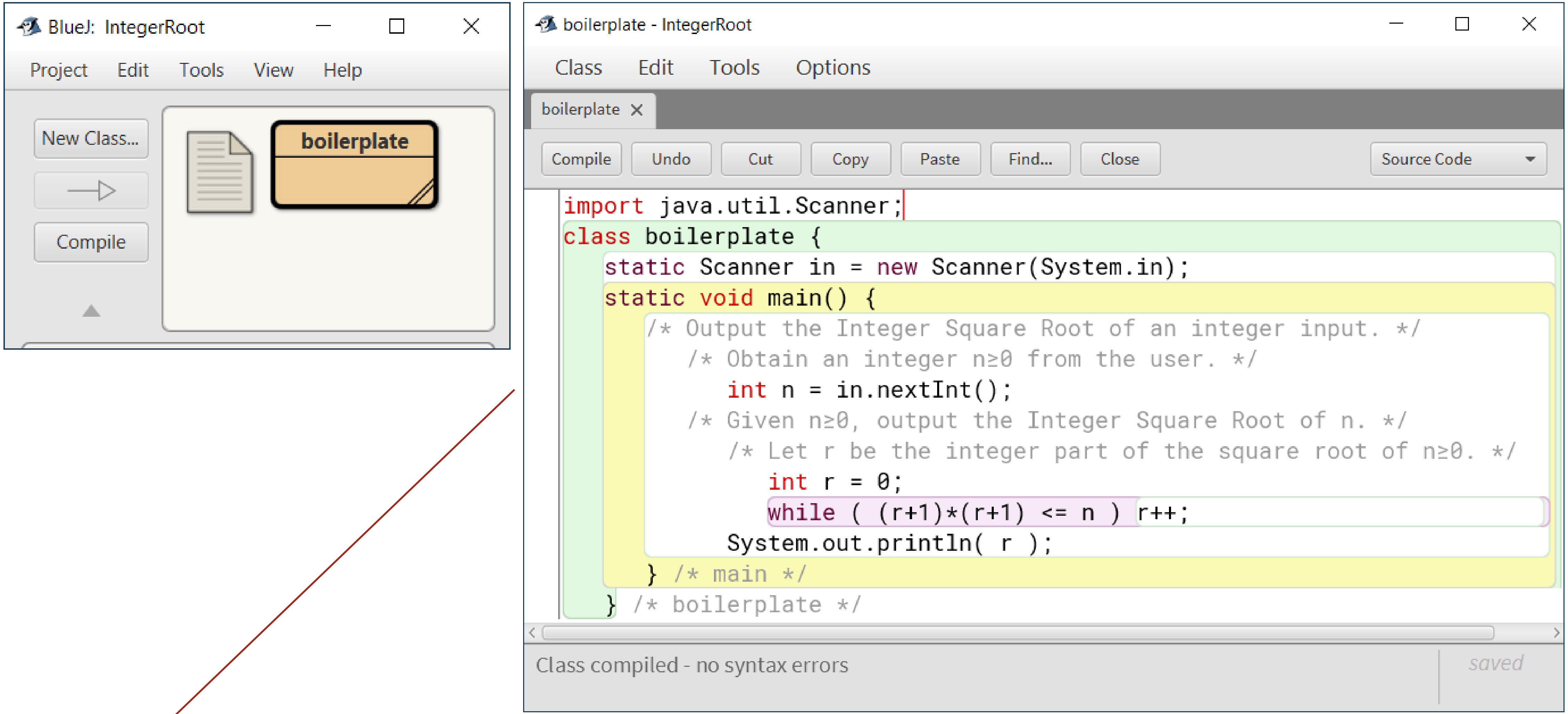
```

7

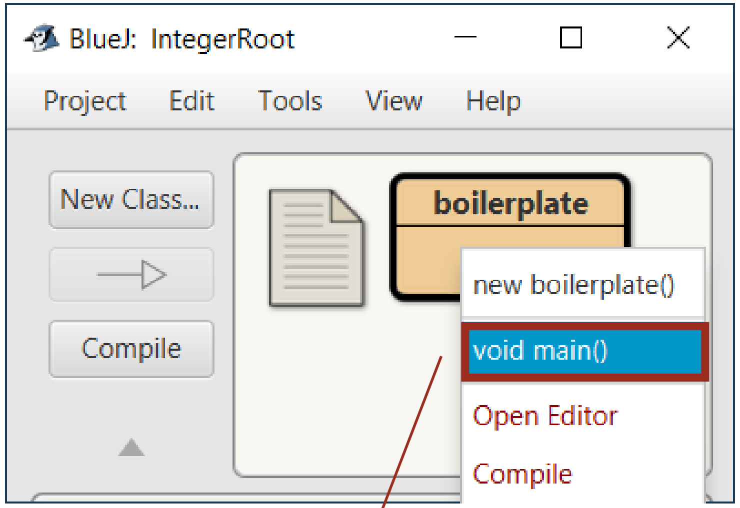


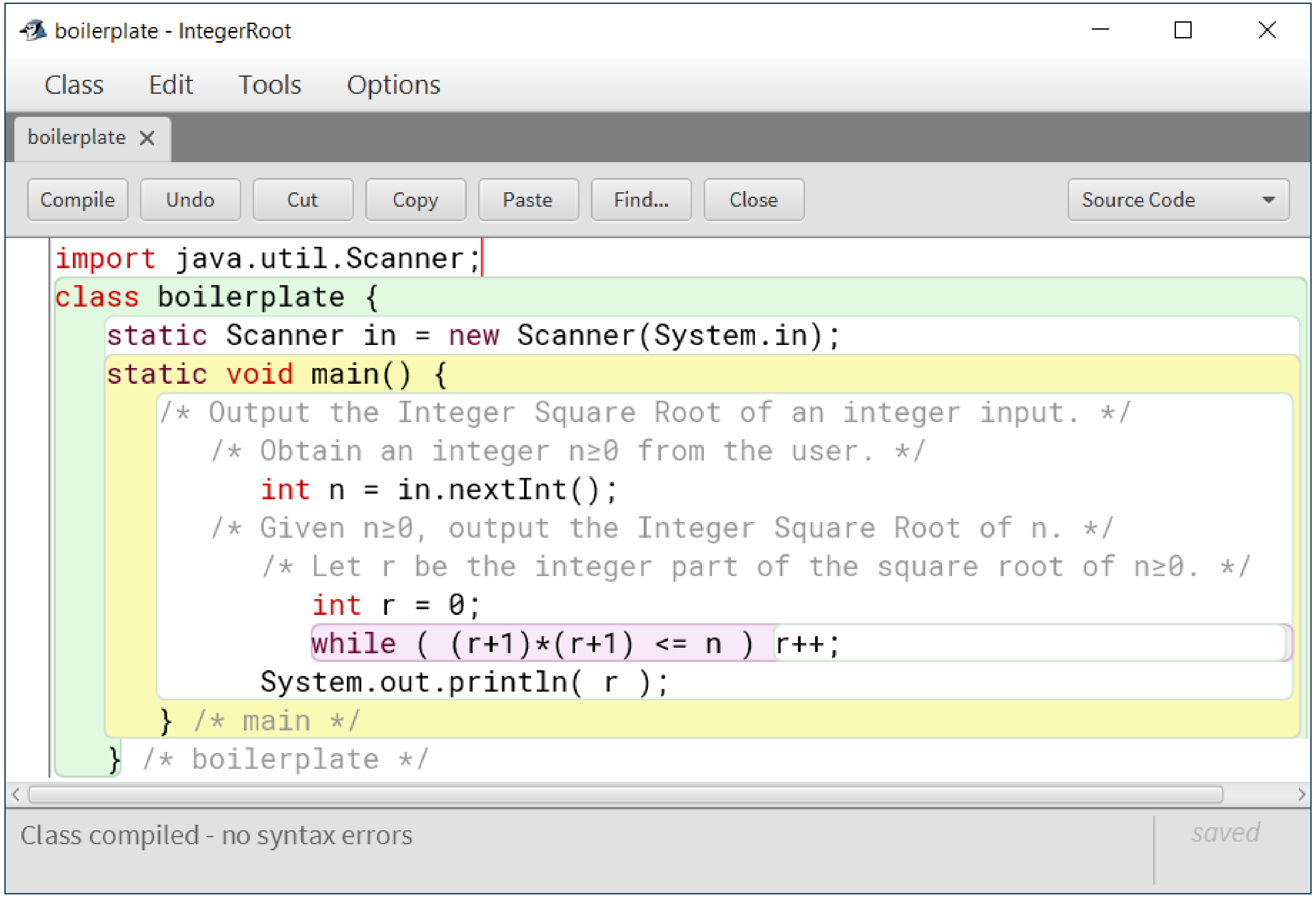
2



Code is typically edited and executed in an Integrated Development Environment (IDE), for example, BlueJ.

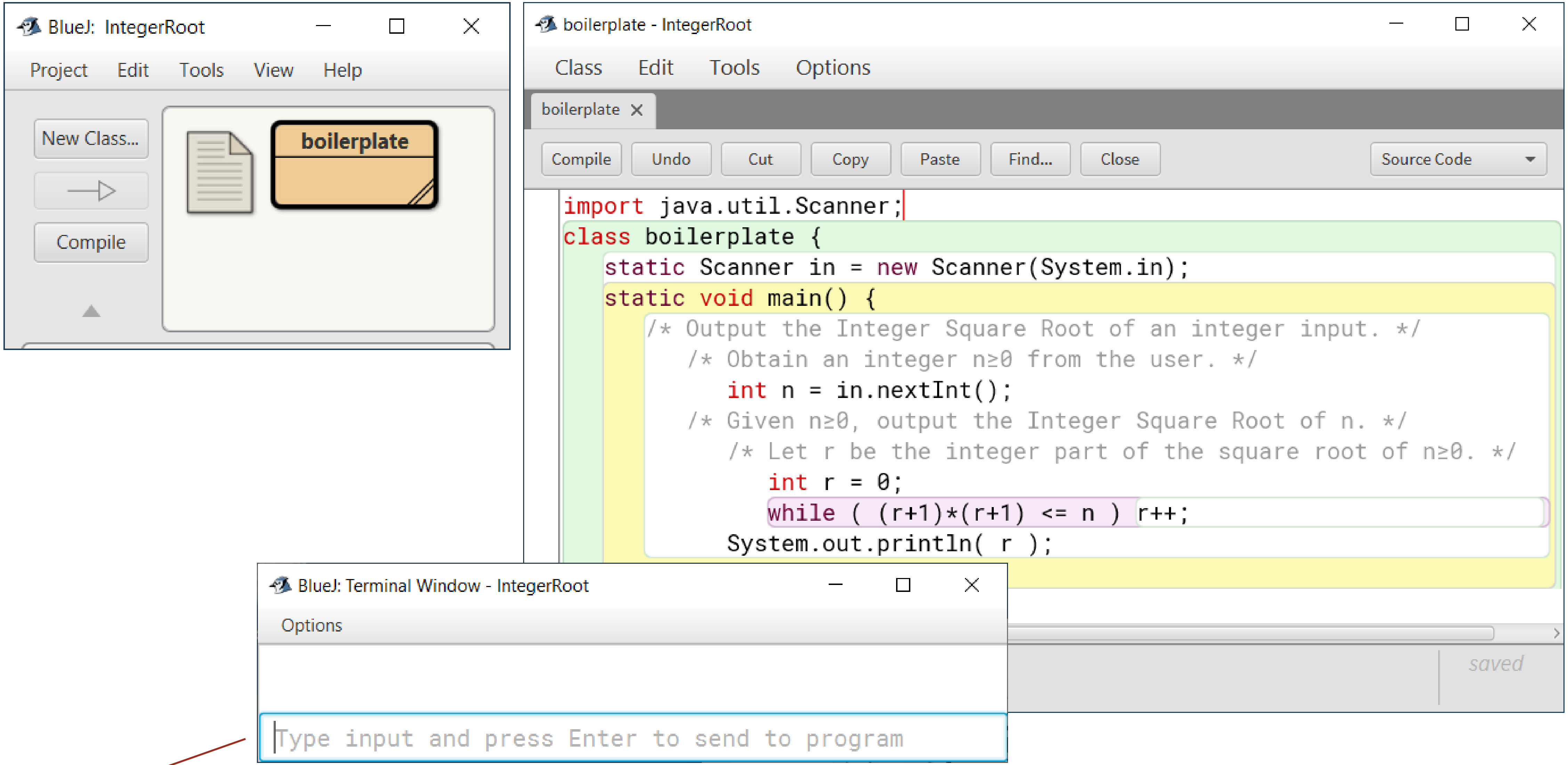
Pragmatics





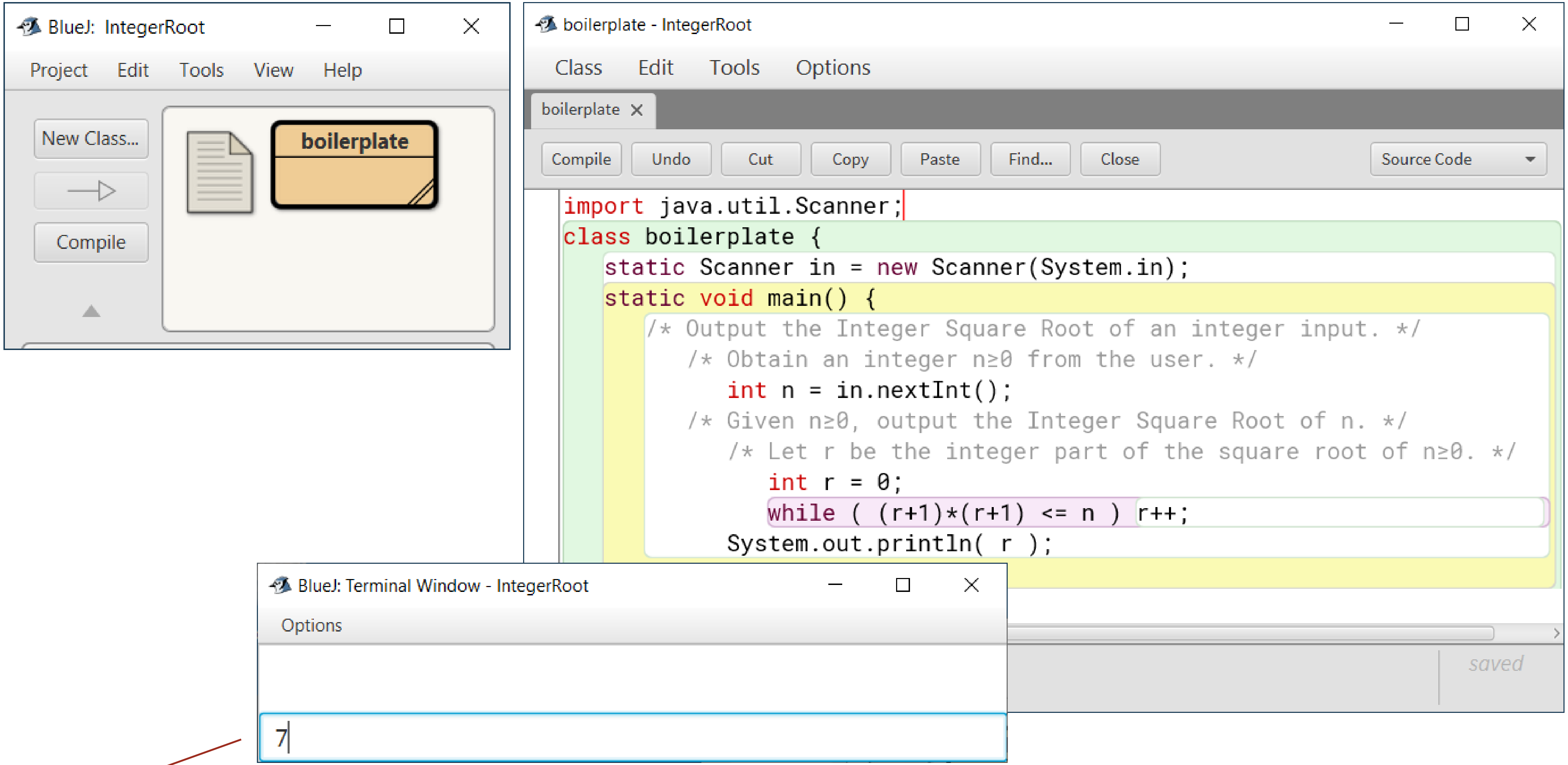
We can right-click in the Project Window to request program execution.

Pragmatics



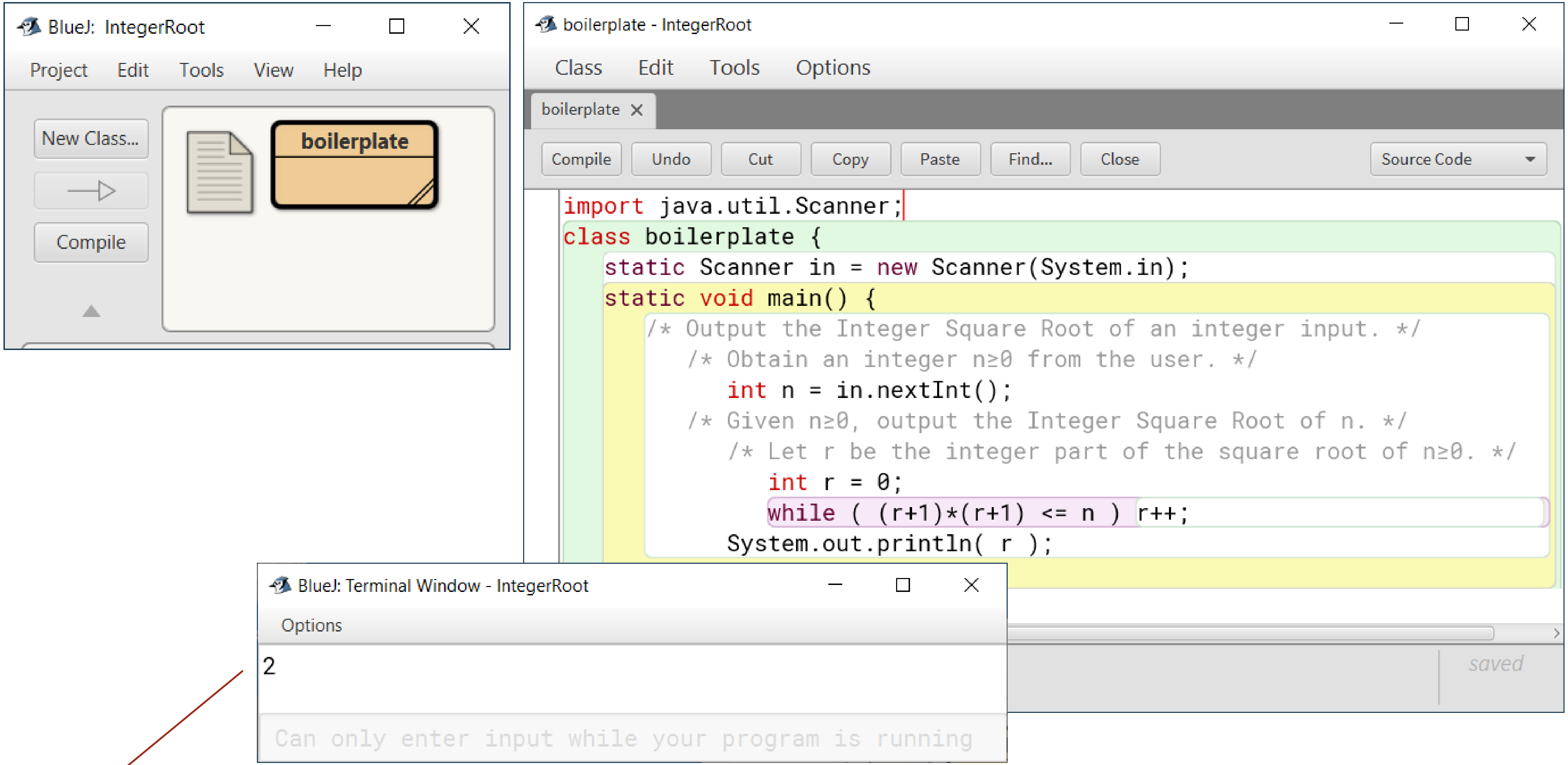
The Terminal Window then appears, requesting an input.

Pragmatics



We enter “7”.

Pragmatics



The program responds with “2”, and then completes its execution.

Summary

Goals

Elements of methodology

- Precepts, Patterns, Analysis, Process

Core programming-language constructs

- (almost all that we will need)

Illustrated the approach with a complete example