Etymology

Verb
1. ram down - strike or drive against with a heavy impact; "ram the gate with a sledgehammer"; "pound on the door"
ram, pound
thrust - push forcefully; "He thrust his chin forward"
2. ram down - teach by drills and repetitionram down - teach by drills and repetition
beat in, drill in, hammer in
drill - teach by repetition

Latin

Etymology

From *con-* (“with, together”) + *pīlō* (“ram down”).

Pronunciation

- (Classical) IPA(key): /komˈpiː.loː/, [kɔmˈpiː.ɬoː]

Verb

compīlō (*present infinitive* **compīlāre**, *perfect active* **compīlāvī**, *supine* **compīlātum**); *first conjugation*

1. I snatch together and carry off; plunder, pillage, rob, steal.

https://en.wiktionary.org/wiki/compilo#Latin

Dictionary

English

Verb

compile (*third-person singular simple present* **compiles**, *present participle* **compiling**, *simple past and past participle* **compiled**)

1. (transitive) To put together; to assemble; to make by gathering things from various sources. *Samuel Johnson **compiled** one of the most influential dictionaries of the English language.*
2. (obsolete) To construct, build. quotations
3. (transitive, programming) To use a compiler to process source code and produce executable code. *After I **compile** this program I'll run it and see if it works.*
4. (intransitive, programming) To be successfully processed by a compiler into executable code. *There must be an error in my source code because it won't **compile**.*
5. (obsolete, transitive) To contain or comprise. quotations
6. (obsolete) To write; to compose.

https://en.wiktionary.org/wiki/compile

Etymology

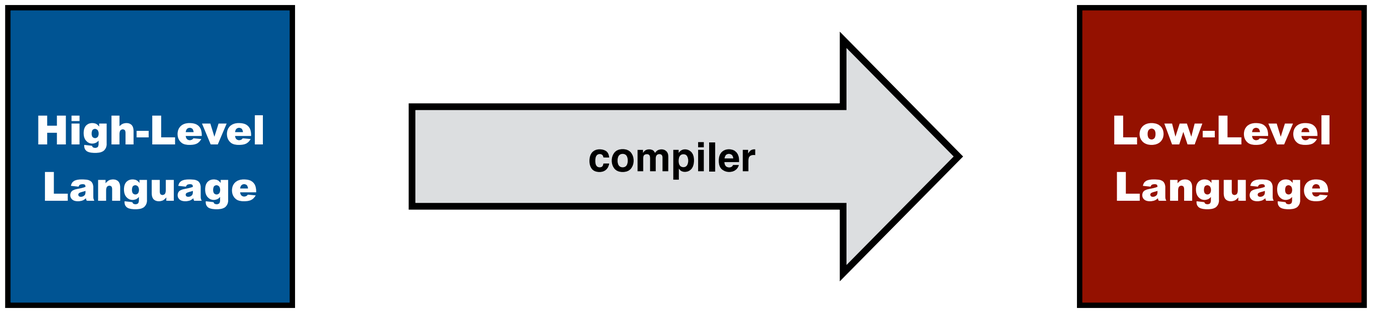
John McCarthy developed Lisp in 1958 at MIT. "Recursive Functions of Symbolic Expressions and Their Computation by Machine, Part I". Information Processing Language from 1955 or 1956, and already included many of the concepts, such as list-processing and recursion, which came to be used in Lisp.

> The first compiler was written by Grace Hopper, in 1952, for the A-0 System language. The term *compiler* was coined by Hopper.[1][2] The A-0 functioned more as a loader or linker than the modern notion of a compiler.

The FORTRAN team led by John W. Backus at IBM introduced the first commercially available compiler, in 1957, which took 18 person-years to create

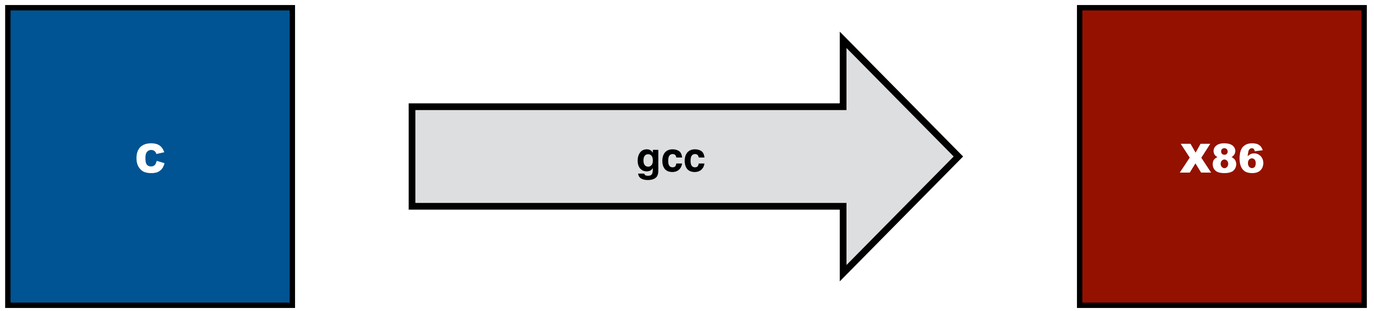
https://en.wikipedia.org/wiki/History_of_compiler_construction

Compiling = Translating



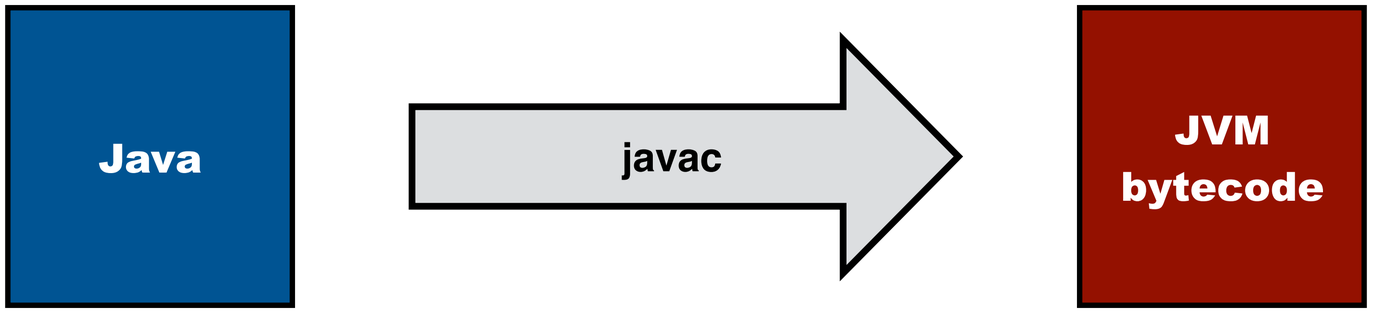
A compiler translates high-level programs to low-level programs

Compiling = Translating



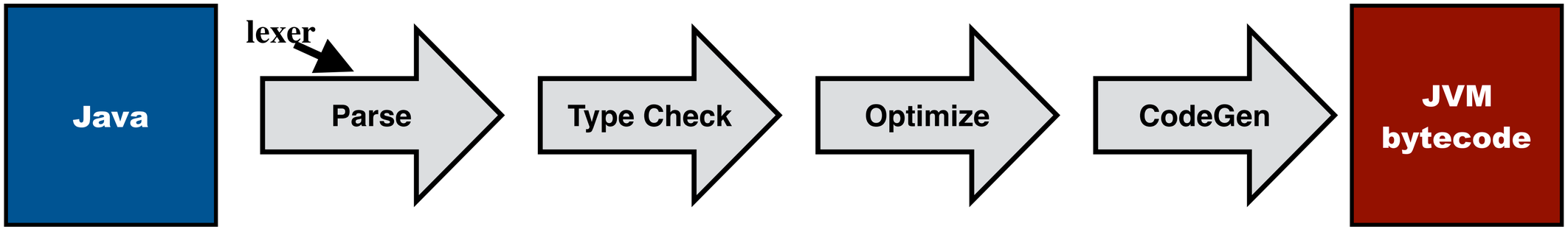
GCC translates C programs to object code for X86 (and other architectures)

Compiling = Translating



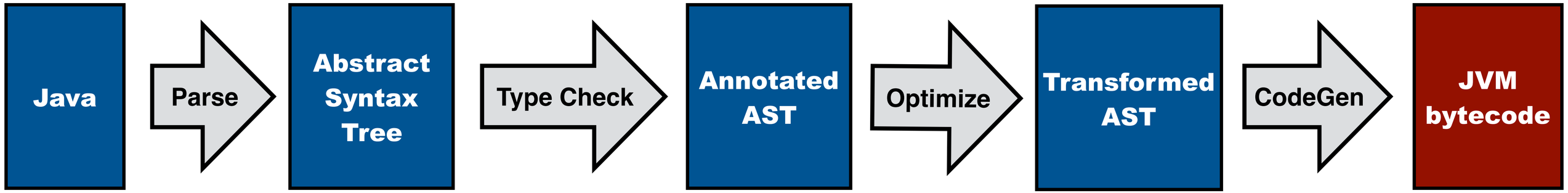
A Java compiler translates Java programs to bytecode instructions for Java Virtual Machine

Architecture: Multi-Pass Compiler



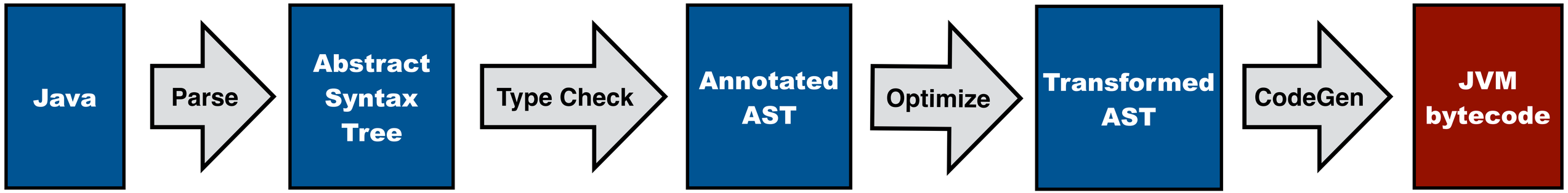
A modern compiler typically consists of sequence of stages or passes

Intermediate Representations



A compiler is a composition of a series of translations between intermediate languages

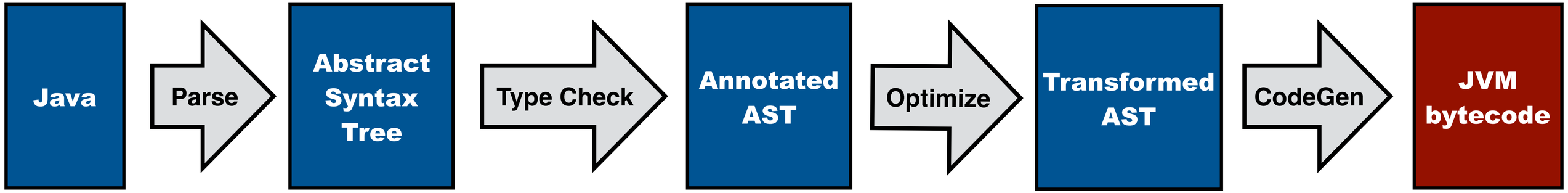
Compiler Components



Parser

- Reads in program text
- Checks that it complies with the syntactic rules of the language
- Produces an abstract syntax tree
- Represents the underlying (syntactic) structure of the program.

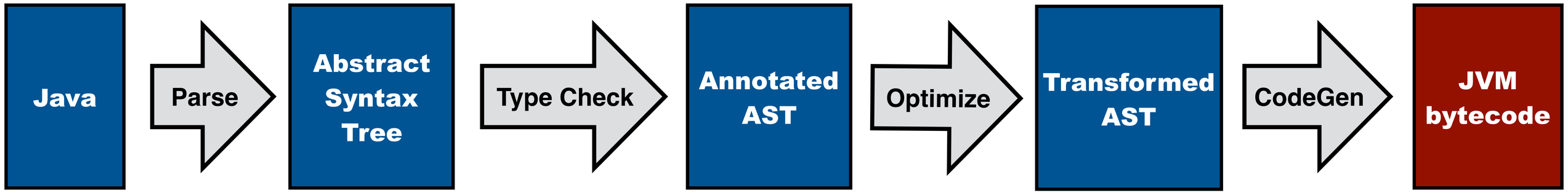
Compiler Components



Type checker

- Consumes an abstract syntax tree
- Checks that the program complies with the static semantic rules of the language
- Performs name analysis, relating uses of names to declarations of names
- Checks that the types of arguments of operations are consistent with their specification

Compiler Components

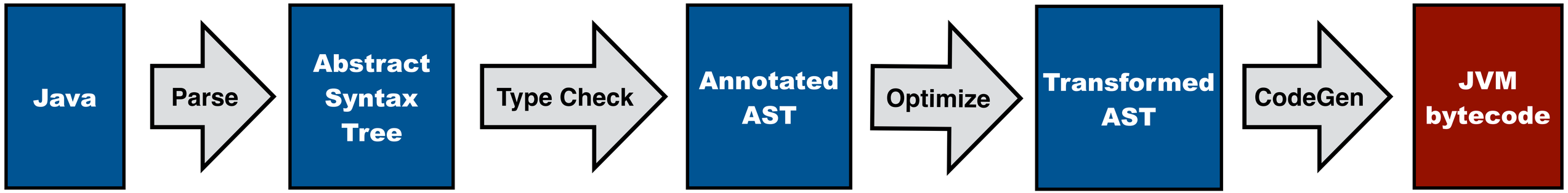


Optimizer

- Consumes a (typed) abstract syntax tree
- Applies transformations that improve the program in various dimensions
  - execution time
  - memory consumption
  - energy consumption.

Constant folding,
Constant propagation,
…

Compiler Components



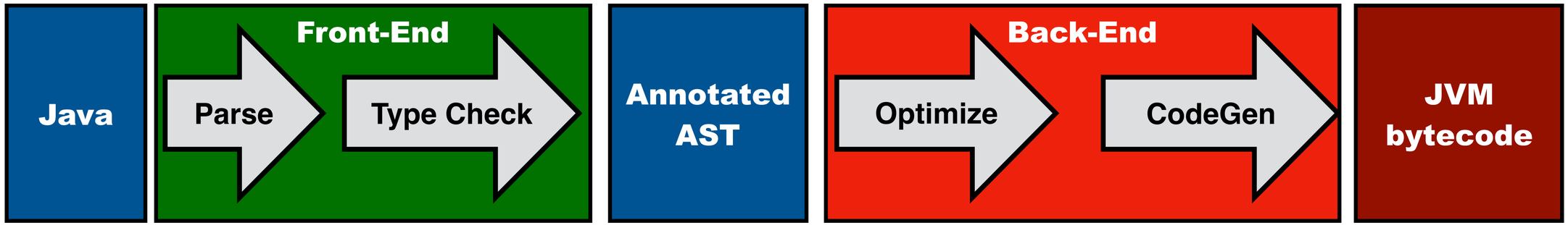
Code generator

- Transforms abstract syntax tree to instructions for a particular computer architecture
- aka instruction selection

Register allocator

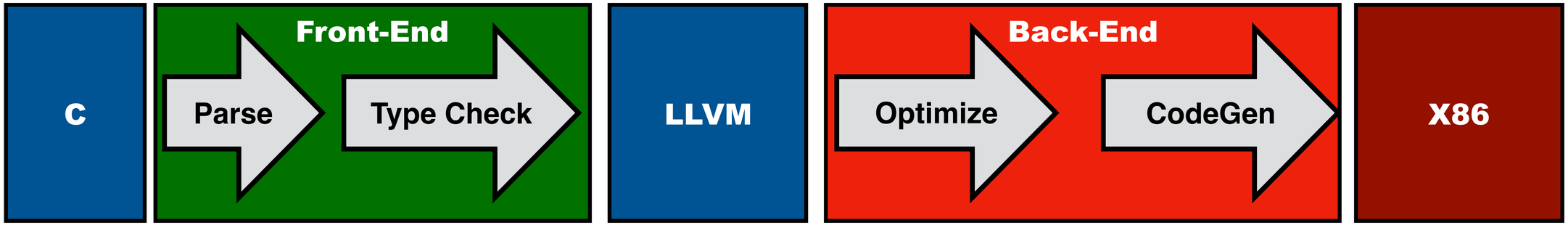
- Assigns physical registers to symbolic registers in the generated instructions

Compiler = Front-end + Back-End



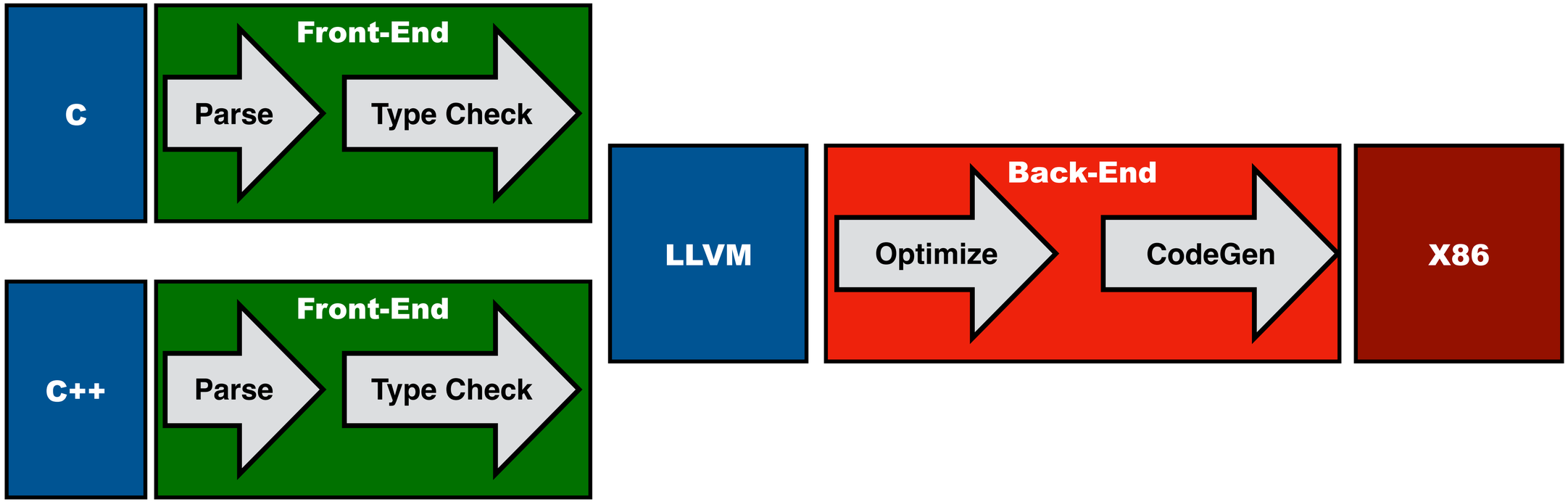
A compiler can typically be divided in a front-end (analysis) and a back-end (synthesis)

Compiler = Front-end + Back-End



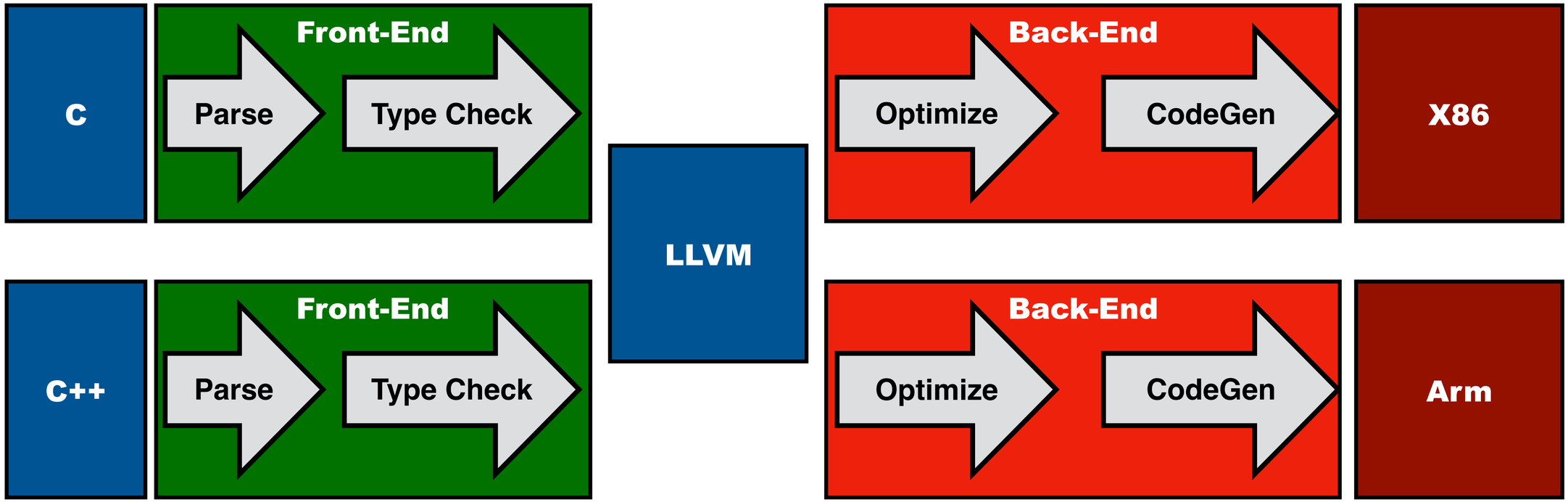
A compiler can typically be divided in a front-end (analysis) and a back-end (synthesis)

Repurposing Back-End



Repurposing: reuse a back-end for a different source language

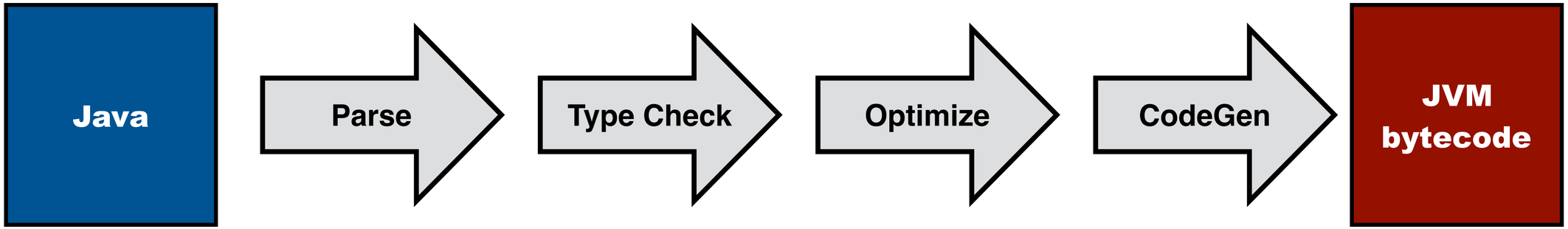
Retargeting Compiler



Retargeting: compile to different hardware architecture

What is a Compiler?

A bunch of components for translating programs



Compiler Construction = Building Variants of Java?

Types of Compilers (1)

Compiler

– translates high-level programs to machine code for a computer

Bytecode compiler

– generates code for a virtual machine

Just-in-time compiler

– defers (some aspects of) compilation to run time

Source-to-source compiler (transpiler)

– translate between high-level languages

Cross-compiler

– runs on different architecture than target architecture

Types of Compilers (2)

Interpreter

- directly executes a program (although prior to execution program is typically transformed)

Hardware compiler

- generate configuration for FPGA or integrated circuit

De-compiler

- translates from low-level language to high-level language

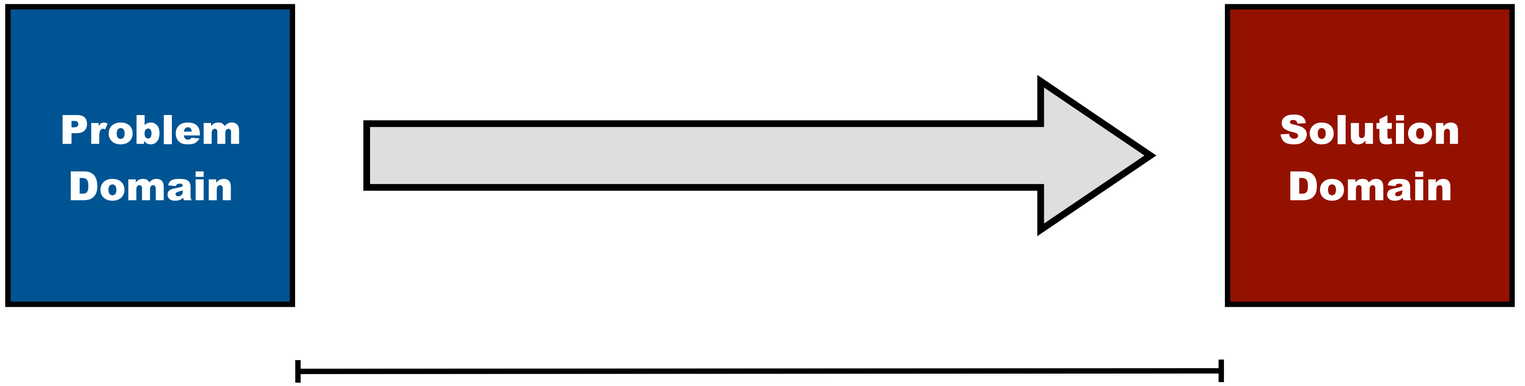
Why Compilers?

Programming = Instructing Computer

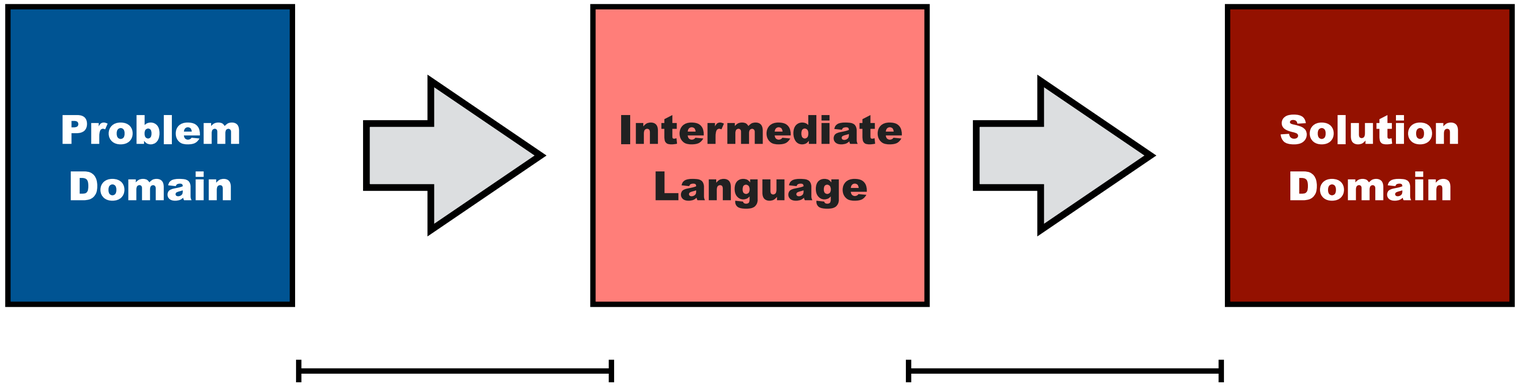
- fetch data from memory
- store data in register
- perform basic operation on data in register
- fetch instruction from memory
- update the program counter
- etc.

"*Computational thinking* is the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer—human or machine—can effectively carry out."

Jeanette M. Wing. Computational Thinking Benefits Society.
In Social Issues in Computing. January 10, 2014.
http://socialissues.cs.toronto.edu/index.html



Programming is expressing intent



linguistic abstraction | liNG'gwistik ab'strakSHən |

noun

1. a programming language construct that captures a programming design pattern
   - *the linguistic abstraction saved a lot of programming effort*
   - *he introduced a linguistic abstraction for page navigation in web programming*
2. the process of introducing linguistic abstractions
   - *linguistic abstraction for name binding removed the algorithmic encoding of name resolution*

From Instructions to Expressions

```
mov &a, &c
add &b, &c
mov &a, &t1
sub &b, &t1
and &t1,&c
```

```
c   = a
c  += b
t1  = a
t1 -= b
c  &= t1
```

```
c = (a + b) & (a - b)
```

Source: http://sites.google.com/site/arch1utep/home/course_outline/translating-complex-expressions-into-assembly-language-using-expression-trees

From Calling Conventions to Procedures

```
calc:
 push eBP              ; save old frame pointer
 mov eBP,eSP           ; get new frame pointer
 sub eSP,localsize     ; reserve place for locals
 .
 .                     ; perform calculations, leave result in AX
 .
 mov eSP,eBP           ; free space for locals
 pop eBP               ; restore old frame pointer
 ret paramsize         ; free parameter space and return
```

```
push eAX              ; pass some register result
push byte[eBP+20]     ; pass some memory variable (FASM/TASM syntax)
push 3                ; pass some constant
call calc             ; the returned result is now in eAX
```

http://en.wikipedia.org/wiki/Calling_convention

Due to the small number of architectural registers, the x86 calling conventions mostly pass arguments on the stack, while the return value (or a pointer to it) is passed in a register.

```
def f(x)={ ... }
```

```
f(e1)
```

function definition and call in Scala

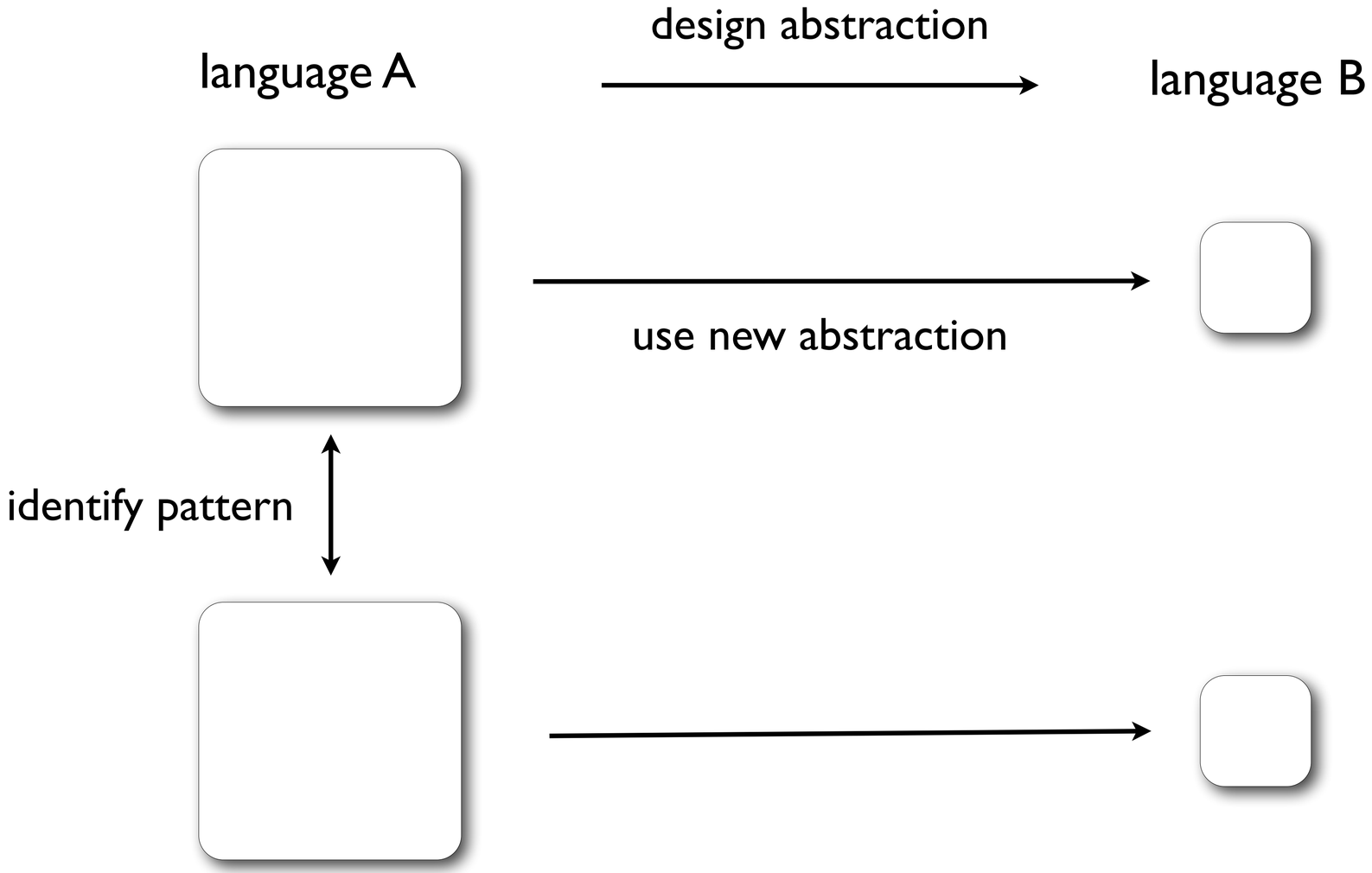
From Malloc to Garbage Collection

```
/* Allocate space for an array with ten elements of type int. */
int *ptr = (int*)malloc(10 * sizeof (int));
if (ptr == NULL) {
    /* Memory could not be allocated, the program
       should handle the error here as appropriate. */
} else {
    /* Allocation succeeded.  Do something.  */
    free(ptr);  /* We are done with the int objects,
                   and free the associated pointer. */
    ptr = NULL; /* The pointer must not be used again,
                   unless re-assigned to using malloc again. */
}
```

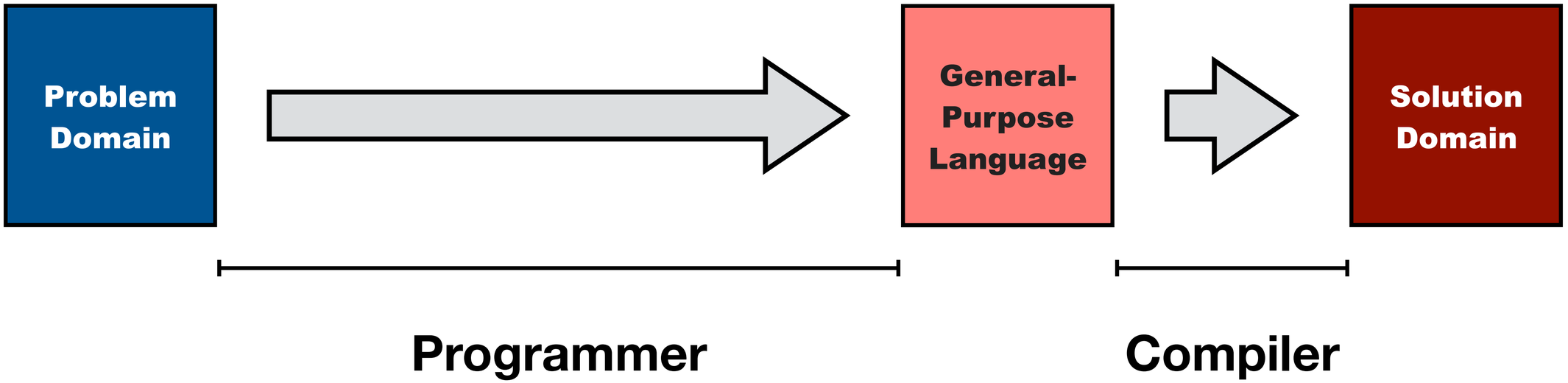
http://en.wikipedia.org/wiki/Malloc

```
int [] = new int[10];
/* use it; gc will clean up (hopefully) */
```

Linguistic Abstraction



Compiler Automates Work of Programmer



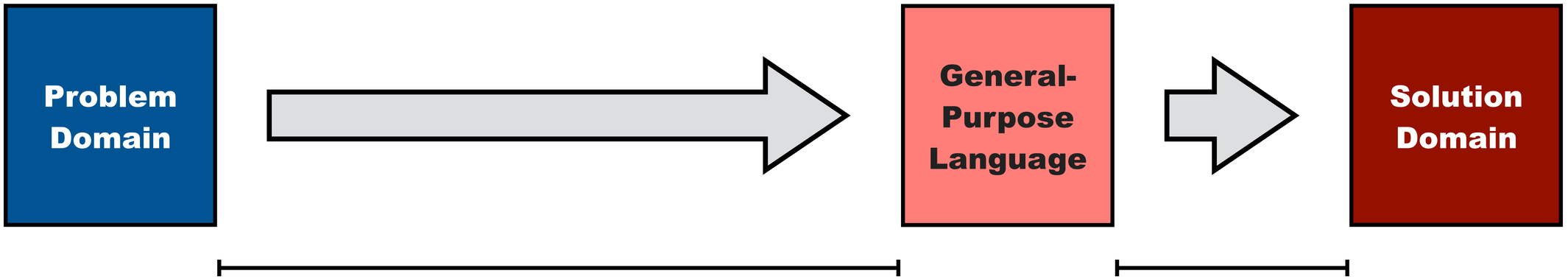
Compilers for modern high-level languages

- Reduce the gap between problem domain and program
- Support programming in terms of computational concepts instead of machine concepts
- Abstract from hardware architecture (portability)
- Protect against a range of common programming errors

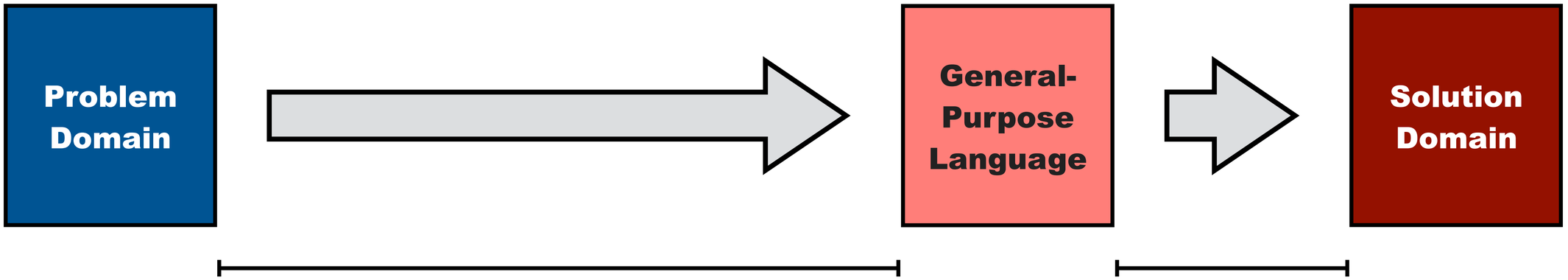
Domain-Specific Languages

TU Delft

Domains of Computation

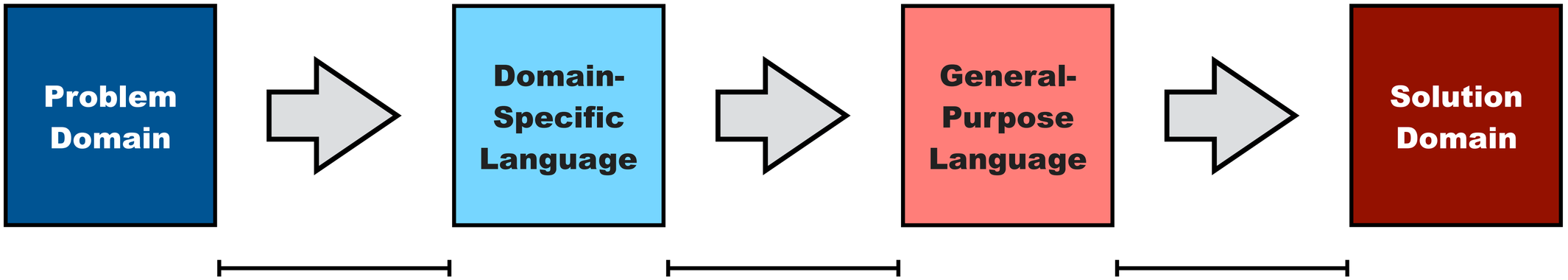


- Systems programming
- Embedded software
- Web programming
- Enterprise software
- Database programming
- Distributed programming
- Data analytics
- ...



"A programming language is low level when its programs require attention to the irrelevant"

Alan J. Perlis. Epigrams on Programming.
SIGPLAN Notices, 17(9):7-13, 1982.



Domain-specific language (DSL)

noun

1. a programming language that provides notation, analysis, verification, and optimization specialized to an application domain
2. result of linguistic abstraction beyond general-purpose computation

Language Design Methodology

Domain Analysis

- What are the features of the domain?

Language Design

- What are adequate linguistic abstractions?
- Coverage: can language express everything in the domain?
  - often the domain is unbounded; language design is making choice what to cover
- Minimality: but not more
  - allowing too much interferes with multi-purpose goal

Semantics

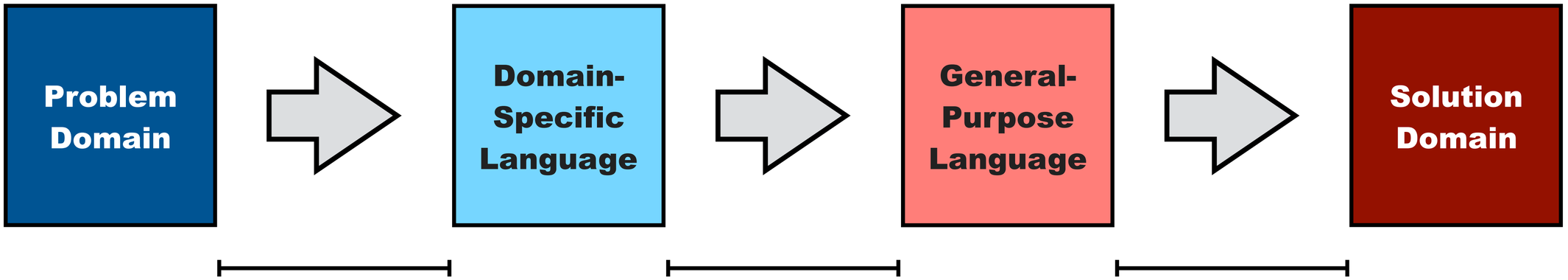
- What is the semantics of such definitions?
- How can we verify the correctness / consistency of language definitions?

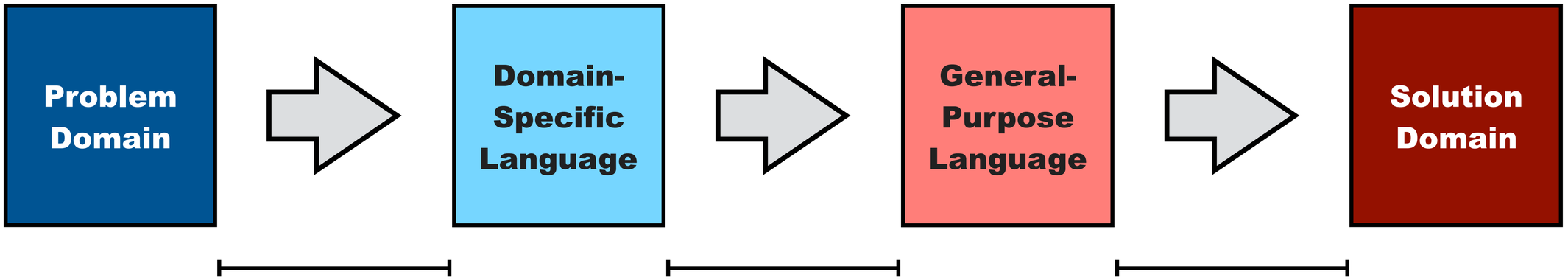
Implementation

- How do we derive efficient language implementations from such definitions?

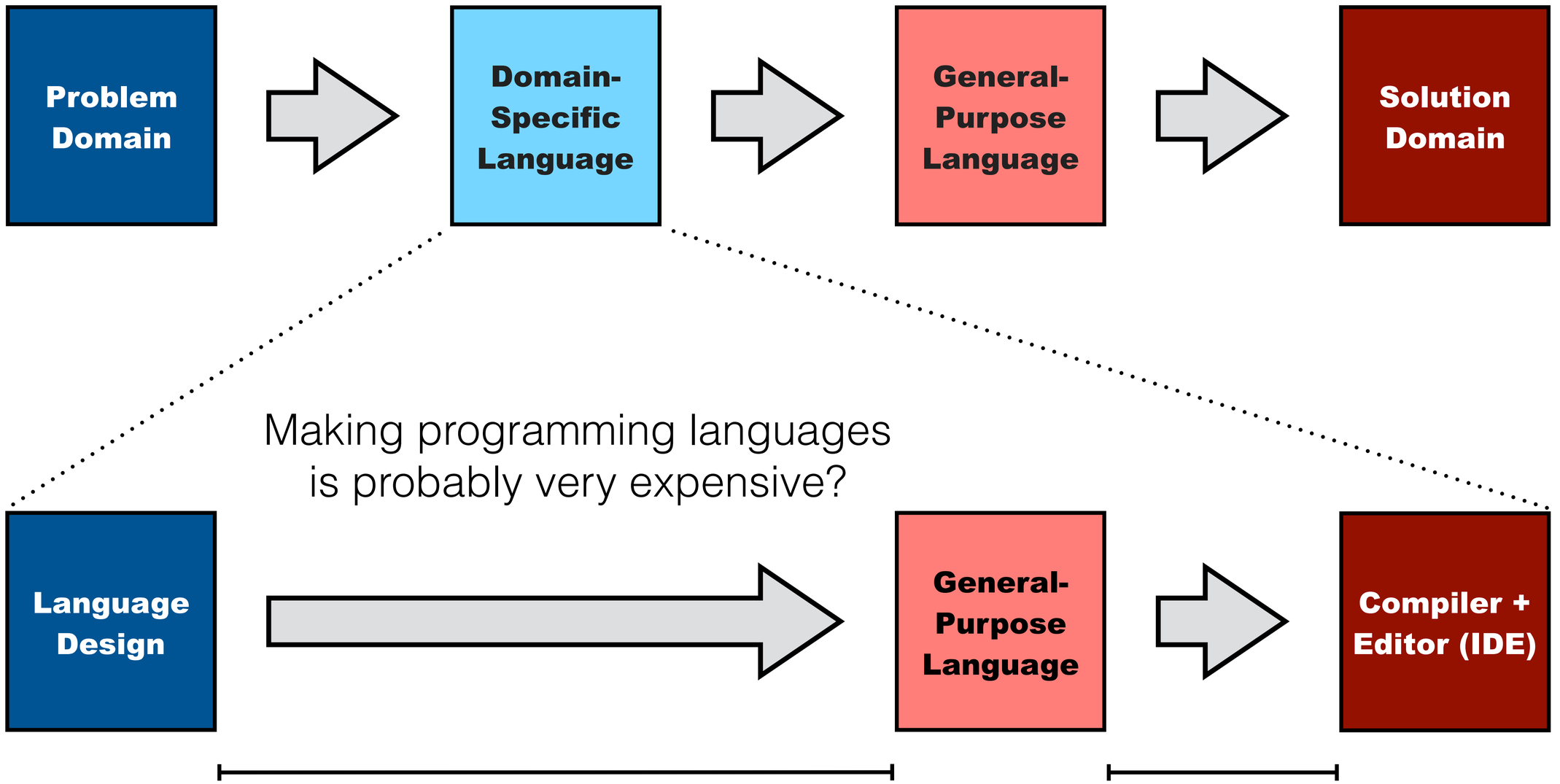
Evaluation

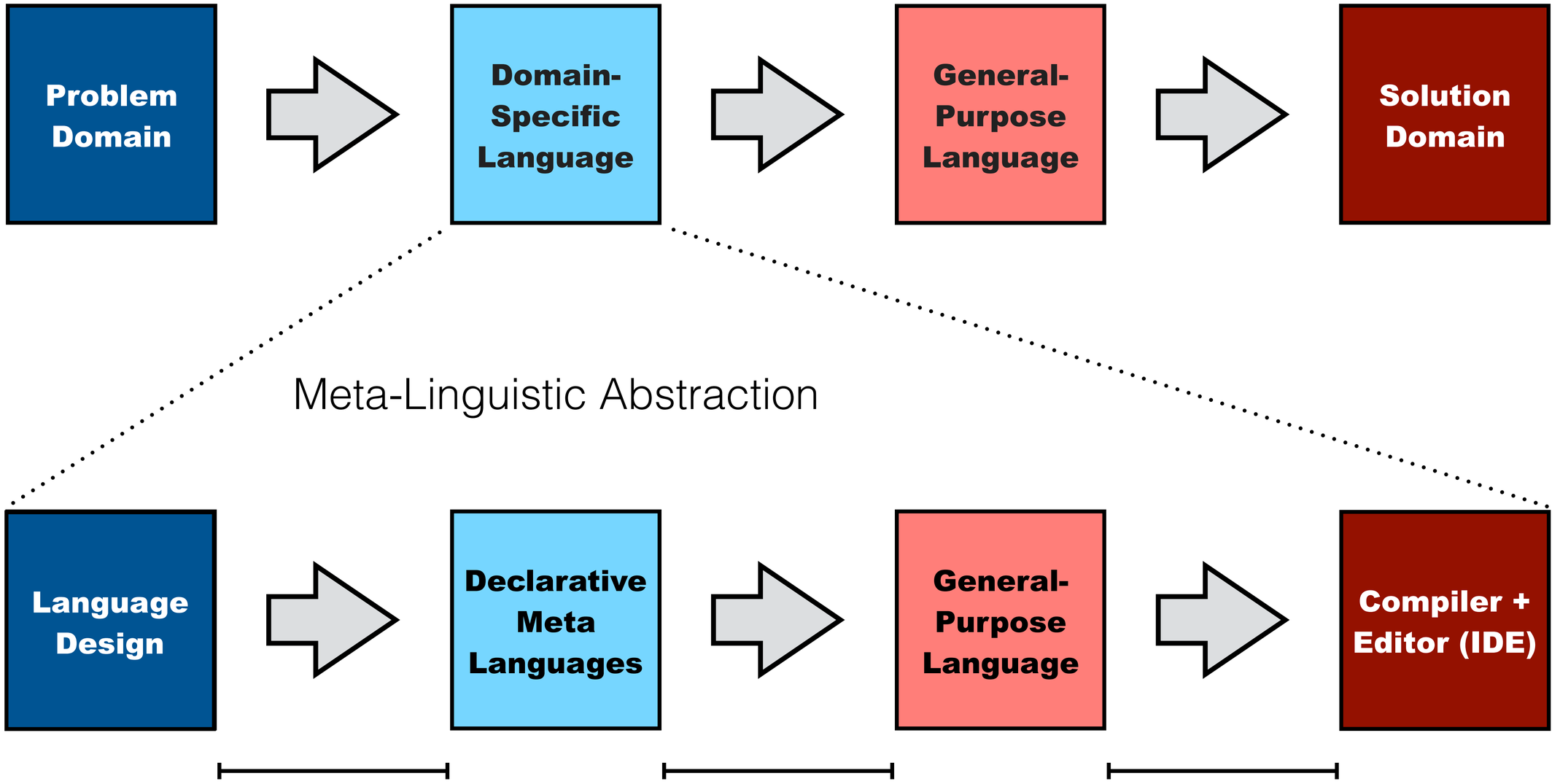
- Apply to new and existing languages to determine adequacy


Problem Domain
Domain-Specific Language
General-Purpose Language
Solution Domain

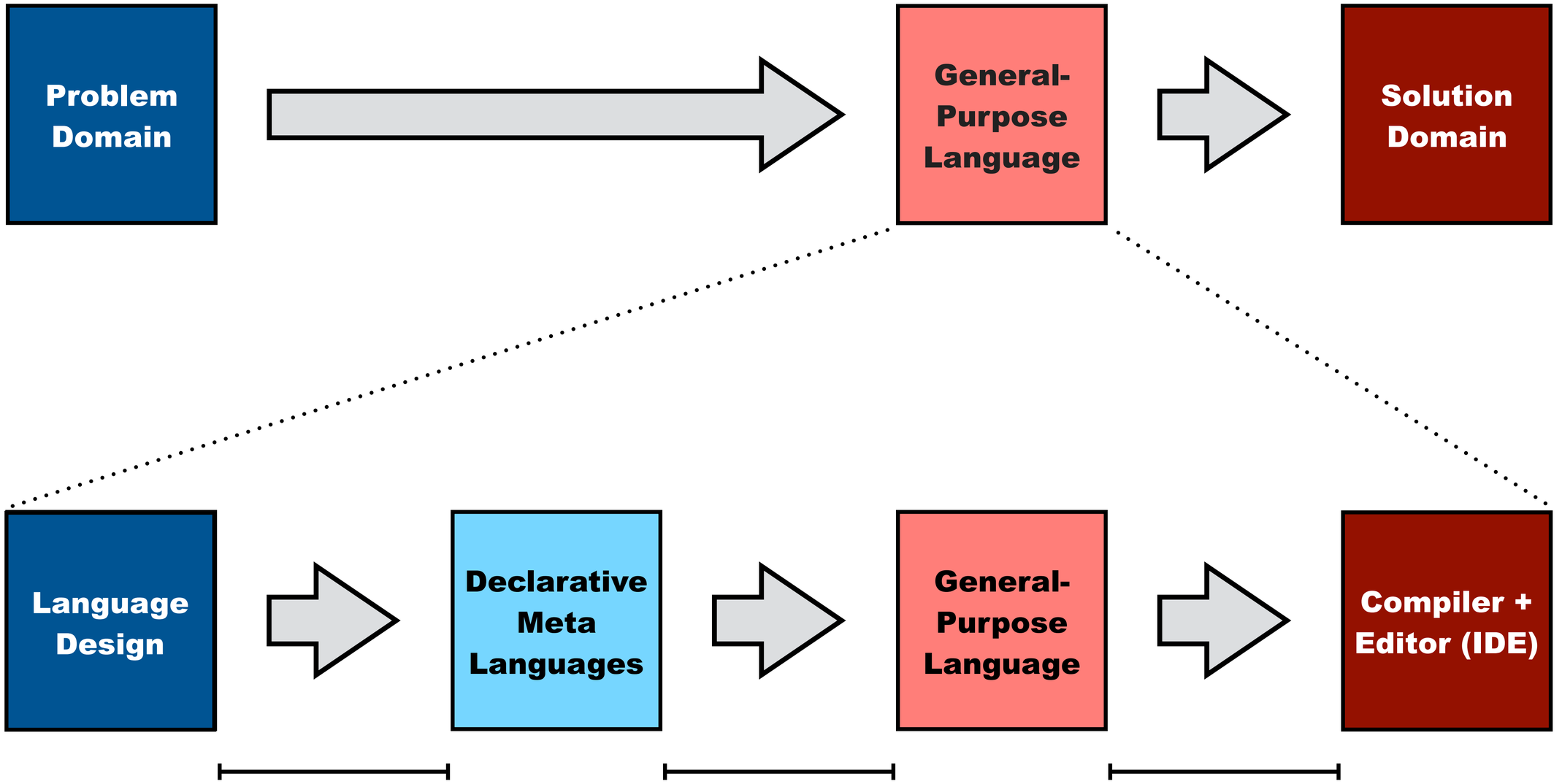


Making programming languages
is probably very expensive?


Problem Domain
Domain-Specific Language
General-Purpose Language
Solution Domain
Making programming languages is probably very expensive?
Language Design
General-Purpose Language
Compiler + Editor (IDE)

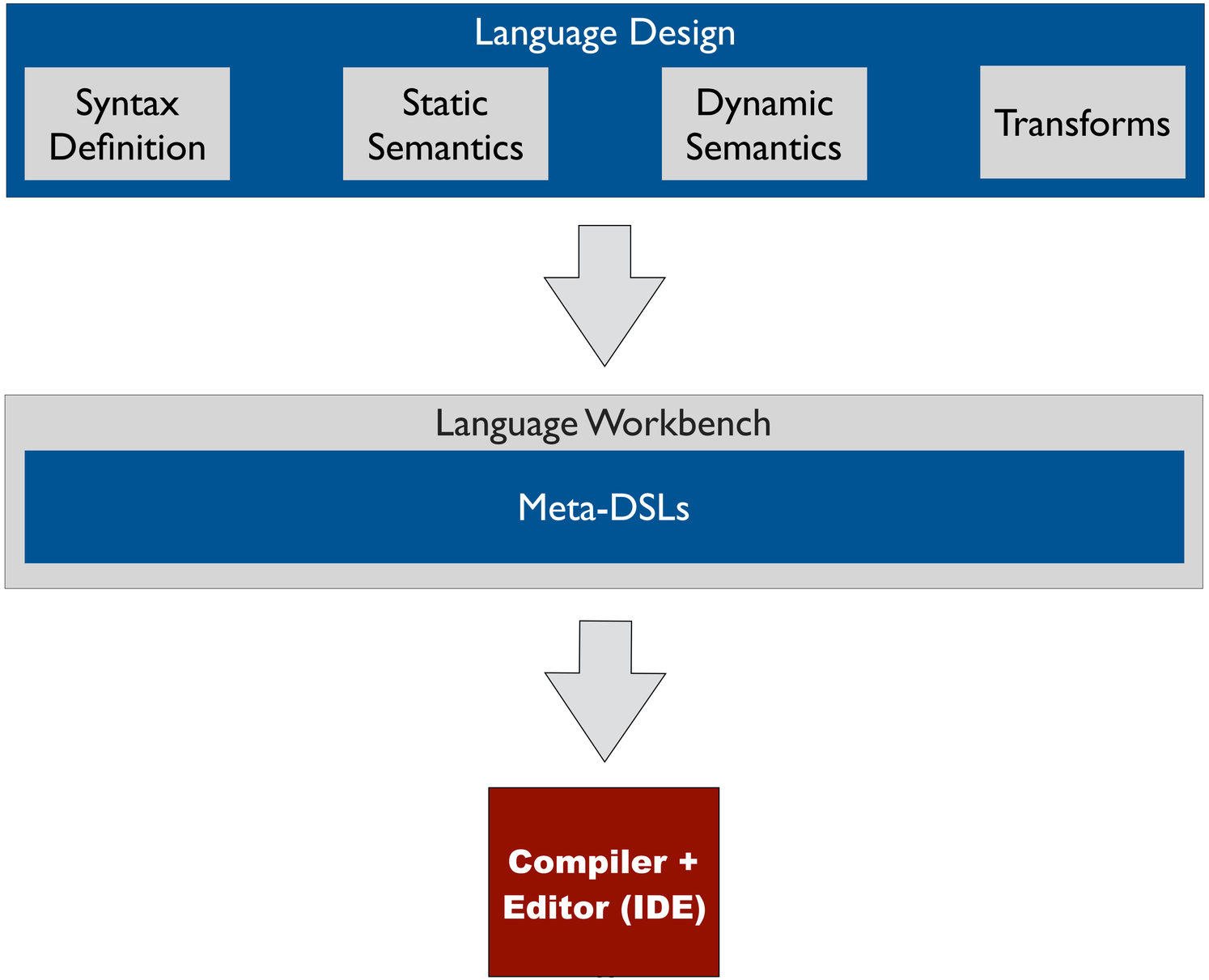


Applying compiler construction to the domain of compiler construction



That also applies to the definition of (compilers for) general purpose languages


Language Design
Declarative Meta Languages
Compiler + Editor (IDE)


Language Design
Syntax Definition
Static Semantics
Dynamic Semantics
Transforms
Language Workbench
Meta-DSLs
Compiler + Editor (IDE)

Declarative Language Definition

Objective

- A workbench supporting design and implementation of programming languages

Approach

- Declarative multi-purpose domain-specific meta-languages

Meta-Languages

- Languages for defining languages

Domain-Specific

- Linguistic abstractions for domain of language definition (syntax, names, types, …)

Multi-Purpose

- Derivation of interpreters, compilers, rich editors, documentation, and verification from single source

Declarative

- Focus on what not how; avoid bias to particular purpose in language definition

Separation of Concerns

Representation

- Standardized representation for <aspect> of programs
- Independent of specific object language

Specification Formalism

- Language-specific declarative rules
- Abstract from implementation concerns

Language-Independent Interpretation

- Formalism interpreted by language-independent algorithm
- Multiple interpretations for different purposes
- Reuse between implementations of different languages