61A Lecture 29

Monday, November 7

Homework: Huffman Encoding Trees

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Efficient encoding of strings as ones and zeros (bits).

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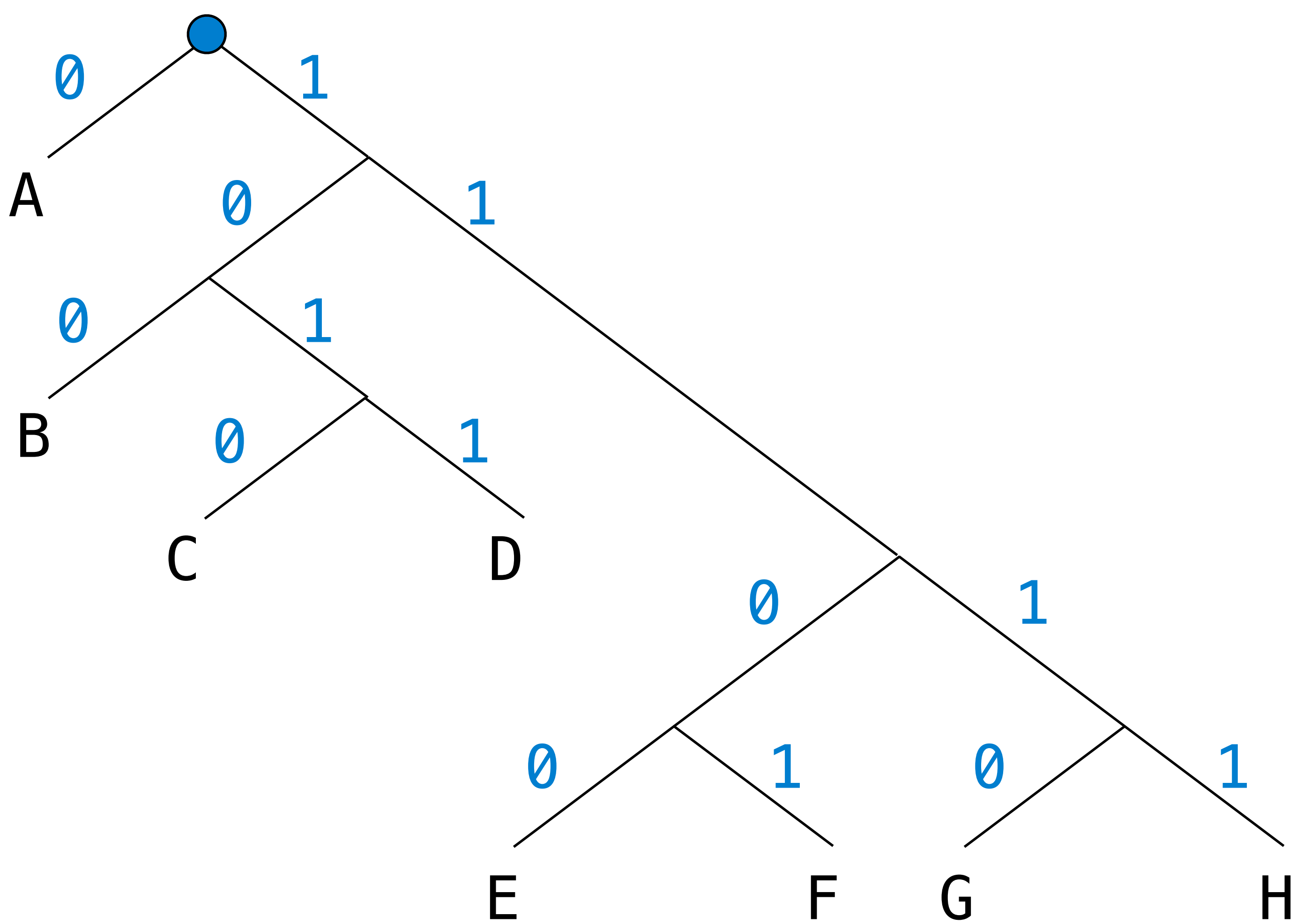

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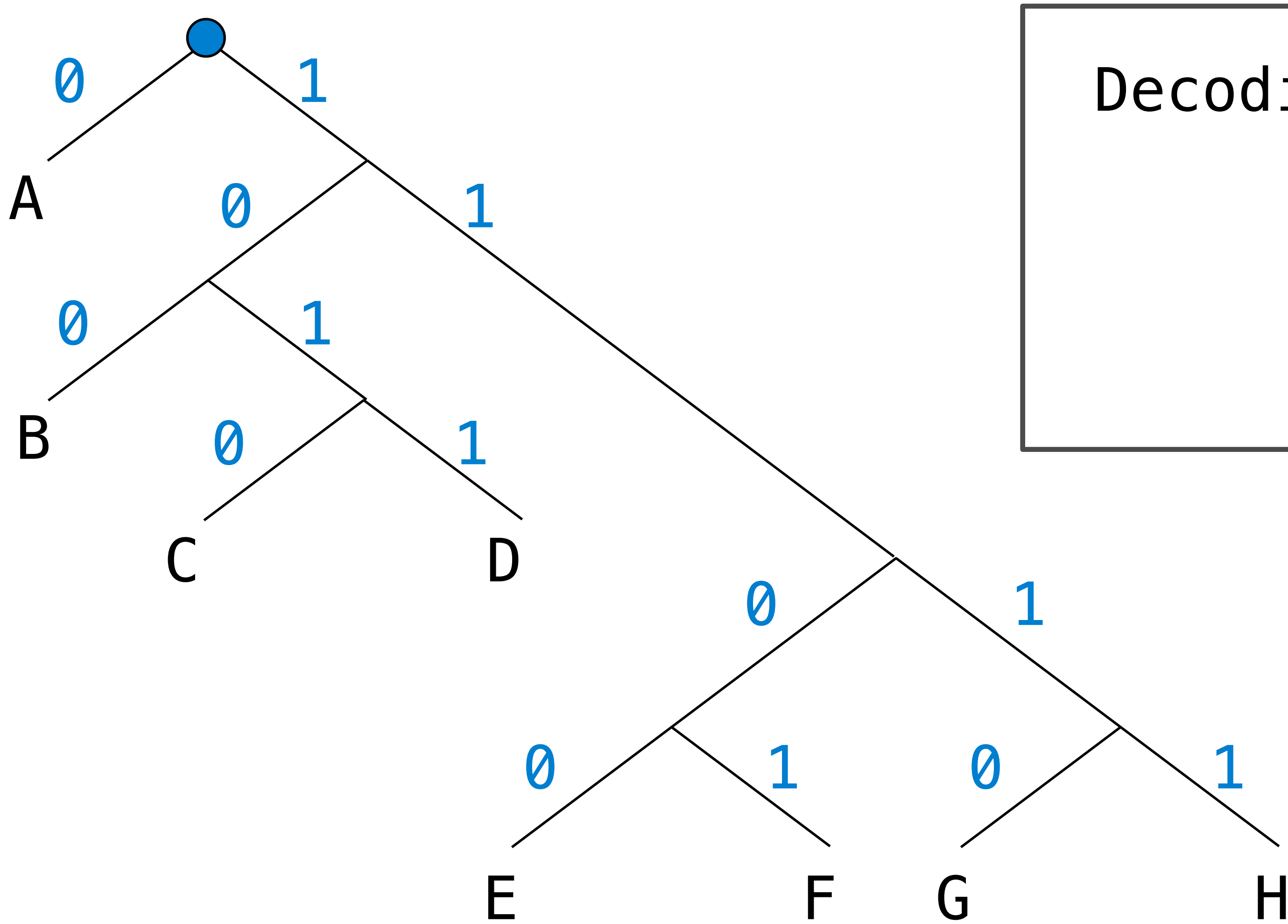

Decoding a sequence of bits:

Homework: Huffman Encoding Trees

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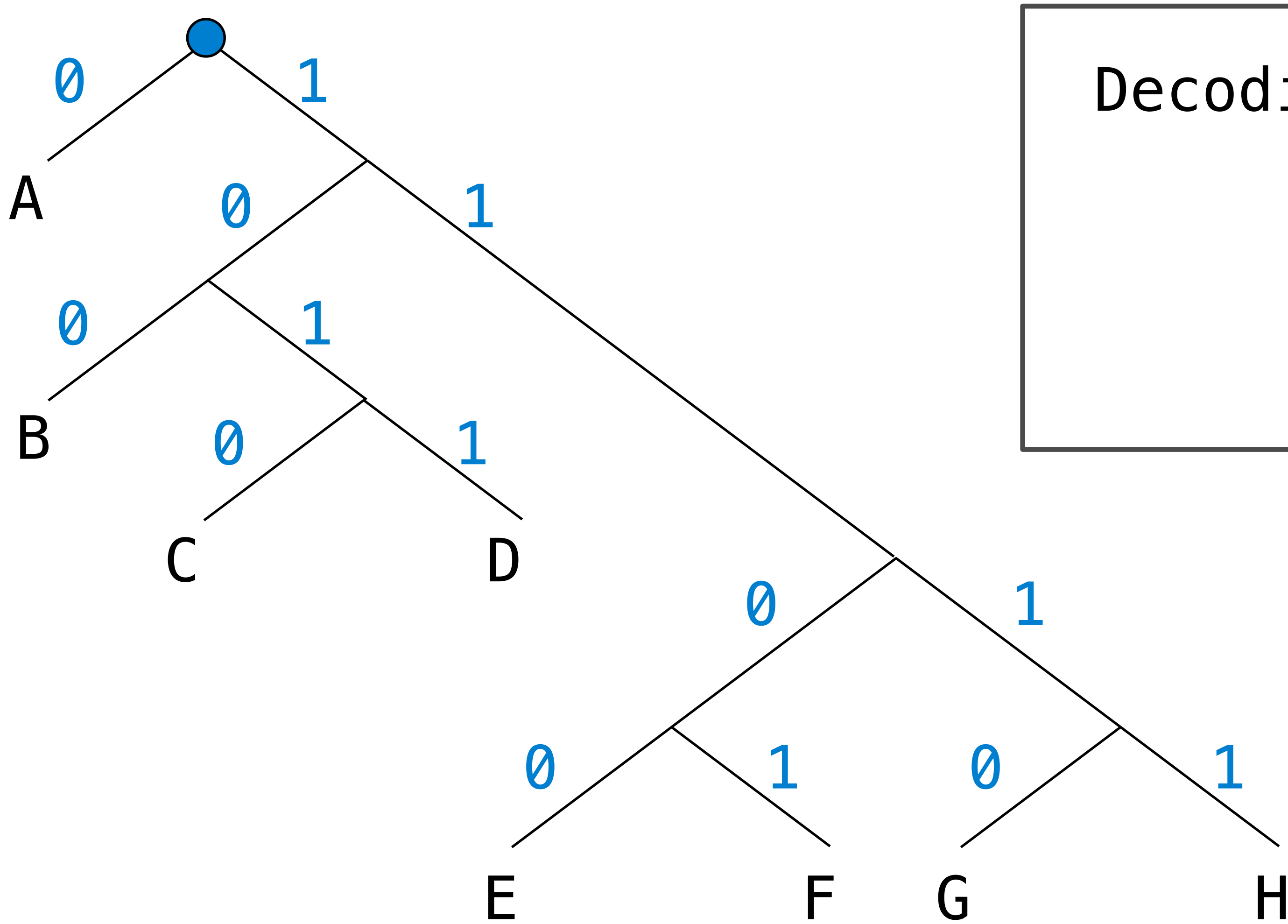

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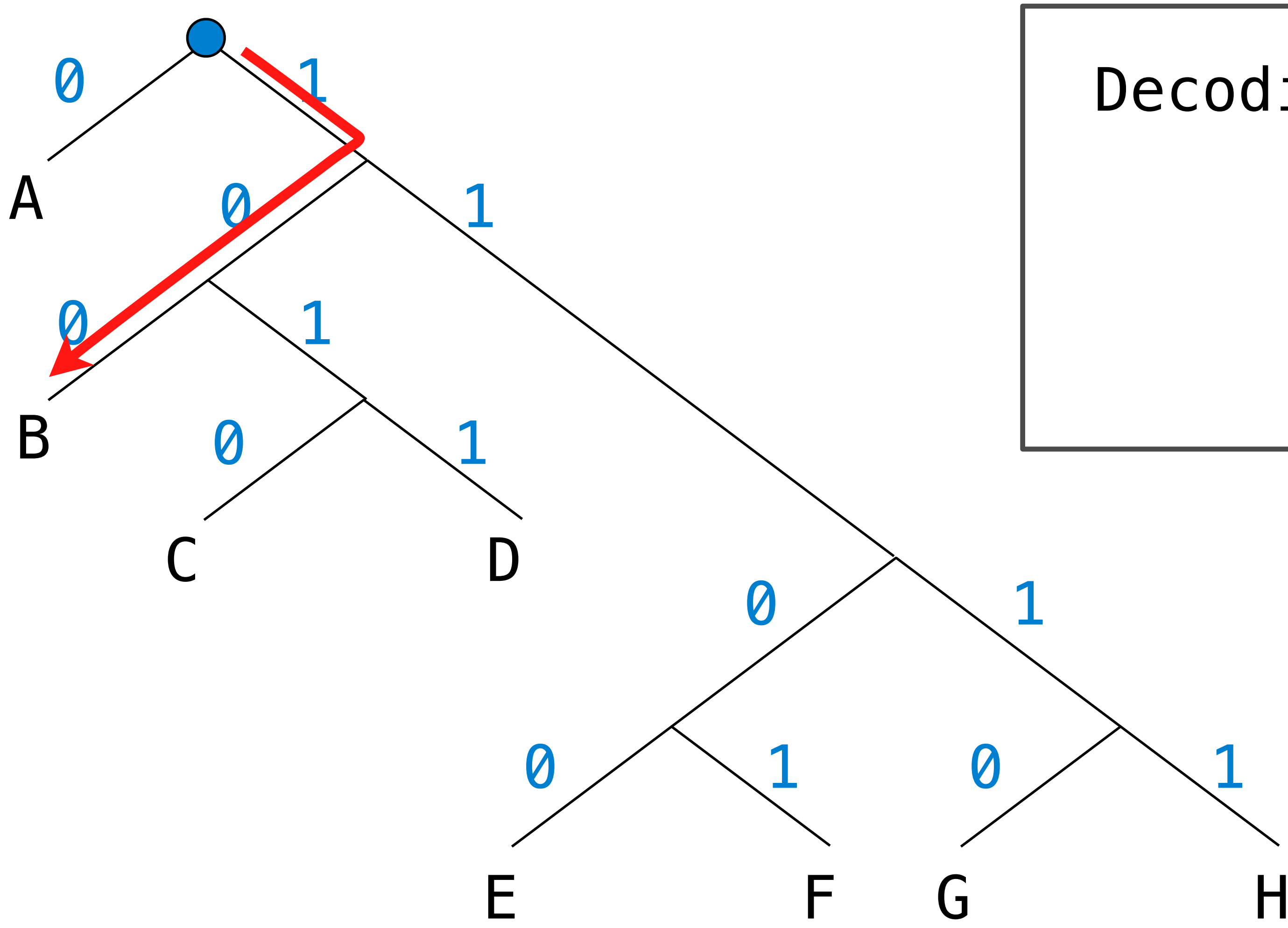

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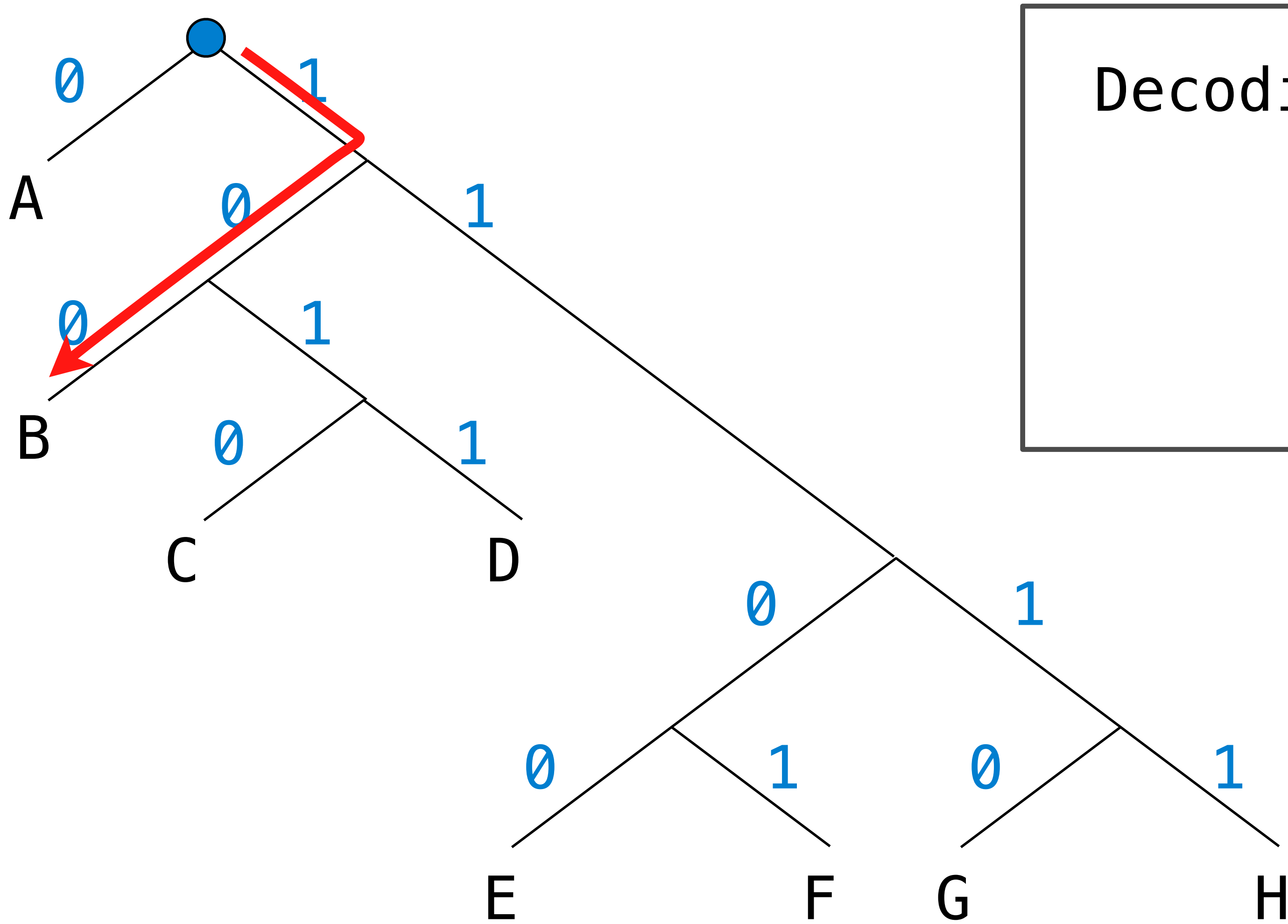

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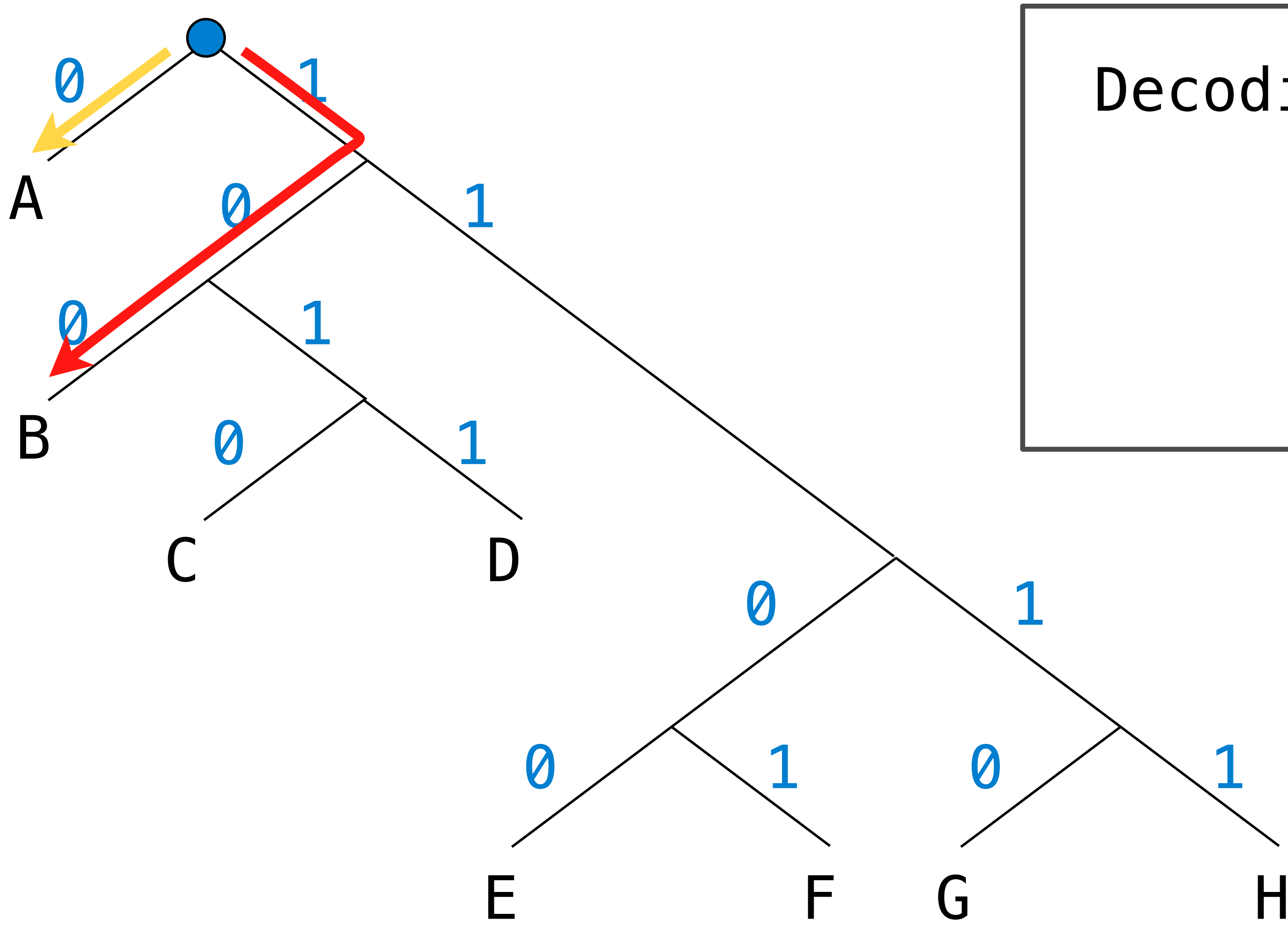

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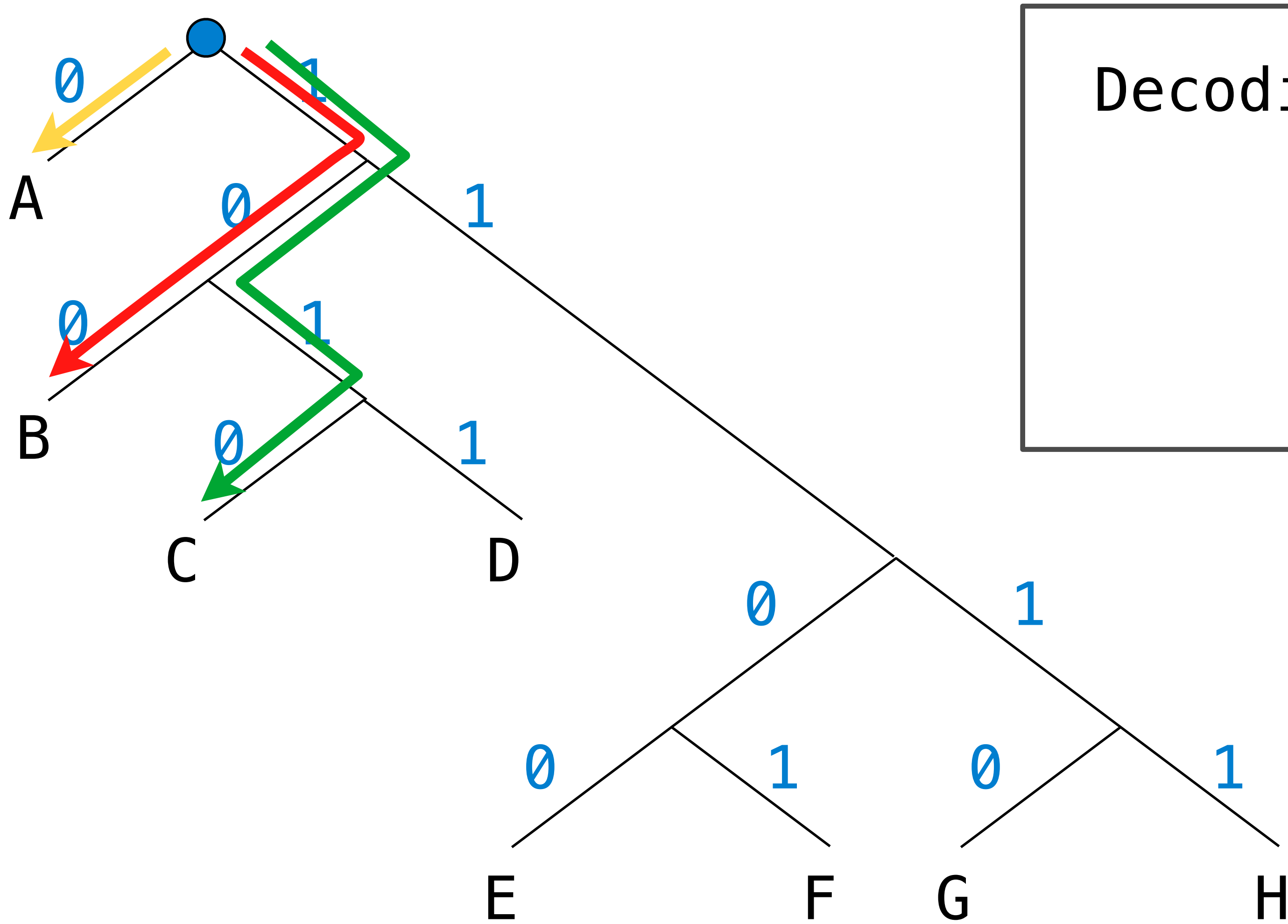

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B A C

Logo Refresher

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Data types: Words and sentences (immutable sequences)

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Syntactic forms: Call expressions, literals, and to-statements

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> output sum :x :x
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? print sum 10 difference 7 3
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? run [print sum 1 2]
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? to double :x
> output sum :x :x
> end

? print double 4
8
```

Logo Interpreter Architecture

Logo Interpreter Architecture

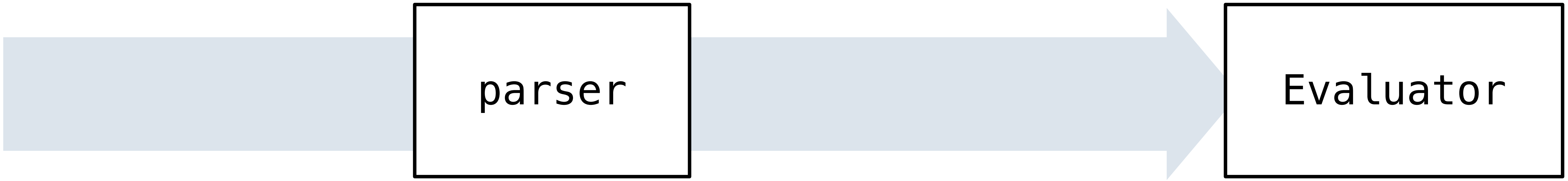
`parser`

Logo Interpreter Architecture

parser

Evaluator

Logo Interpreter Architecture



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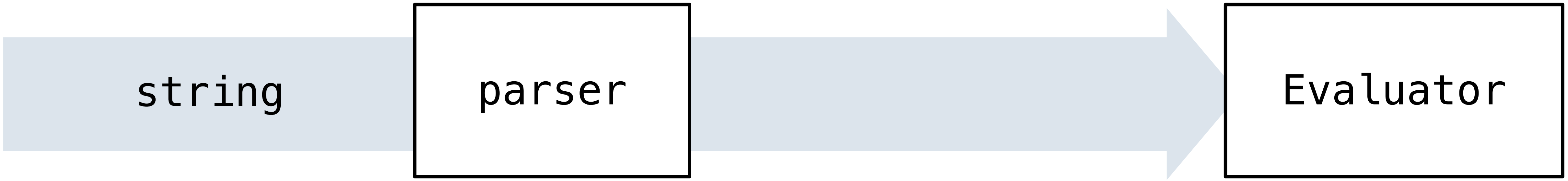

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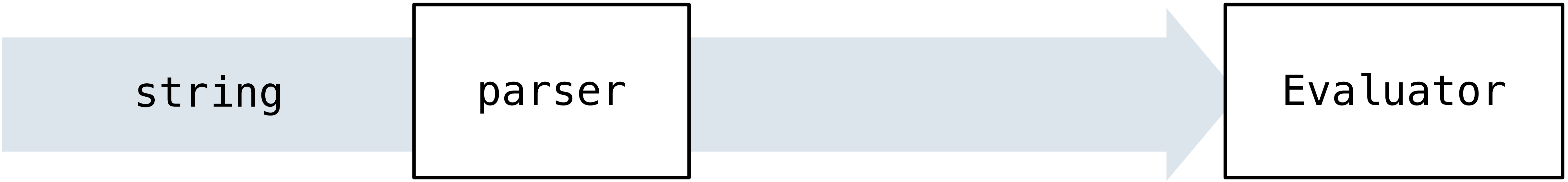

`'run [print sum 1 2]'`

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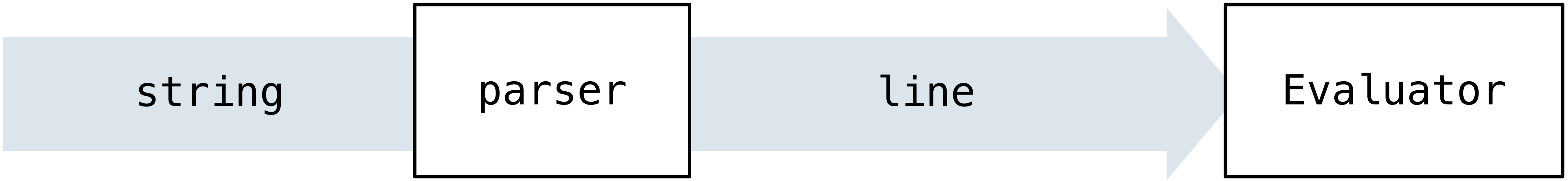


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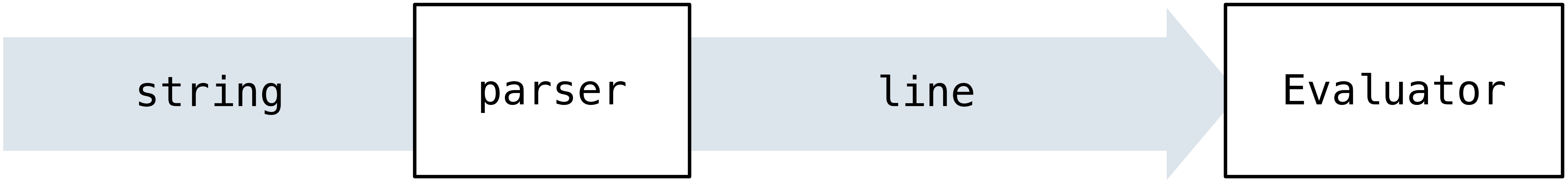


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Logo Interpreter Architecture


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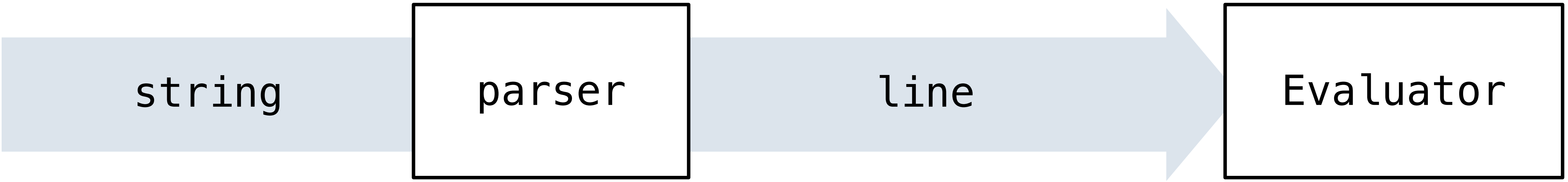

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Logo Interpreter Architecture


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The Parser creates nested sentences, but **does not** build full expression trees for nested call expressions

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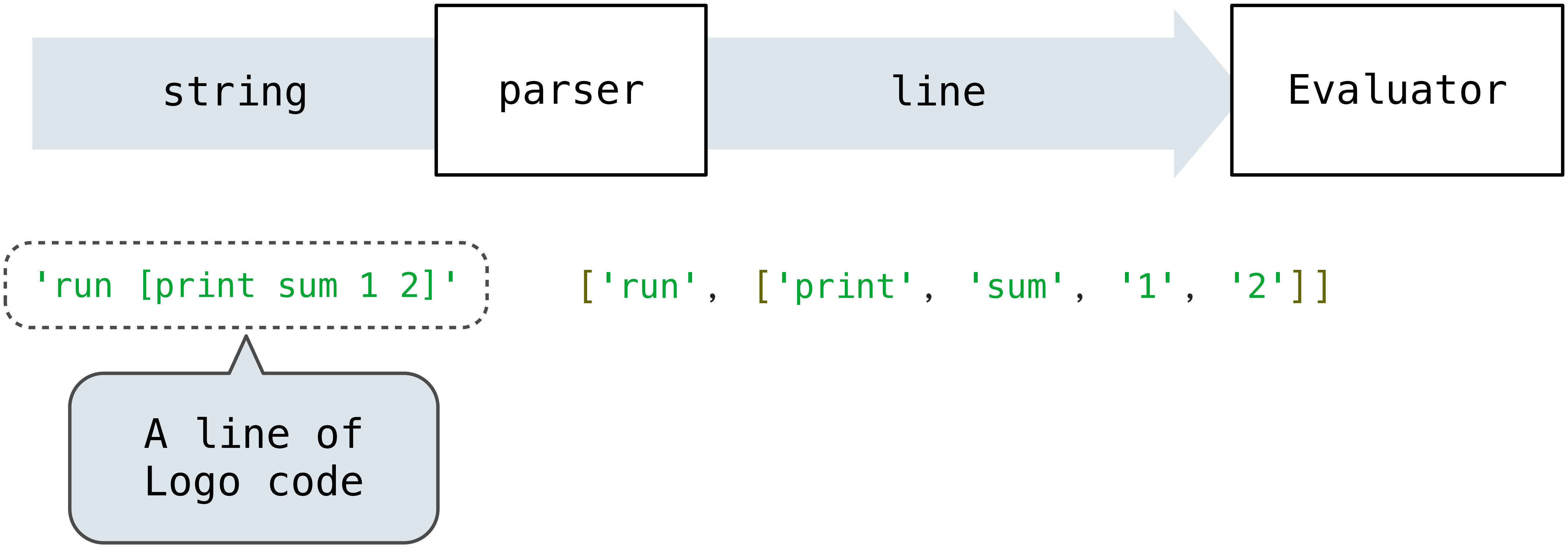

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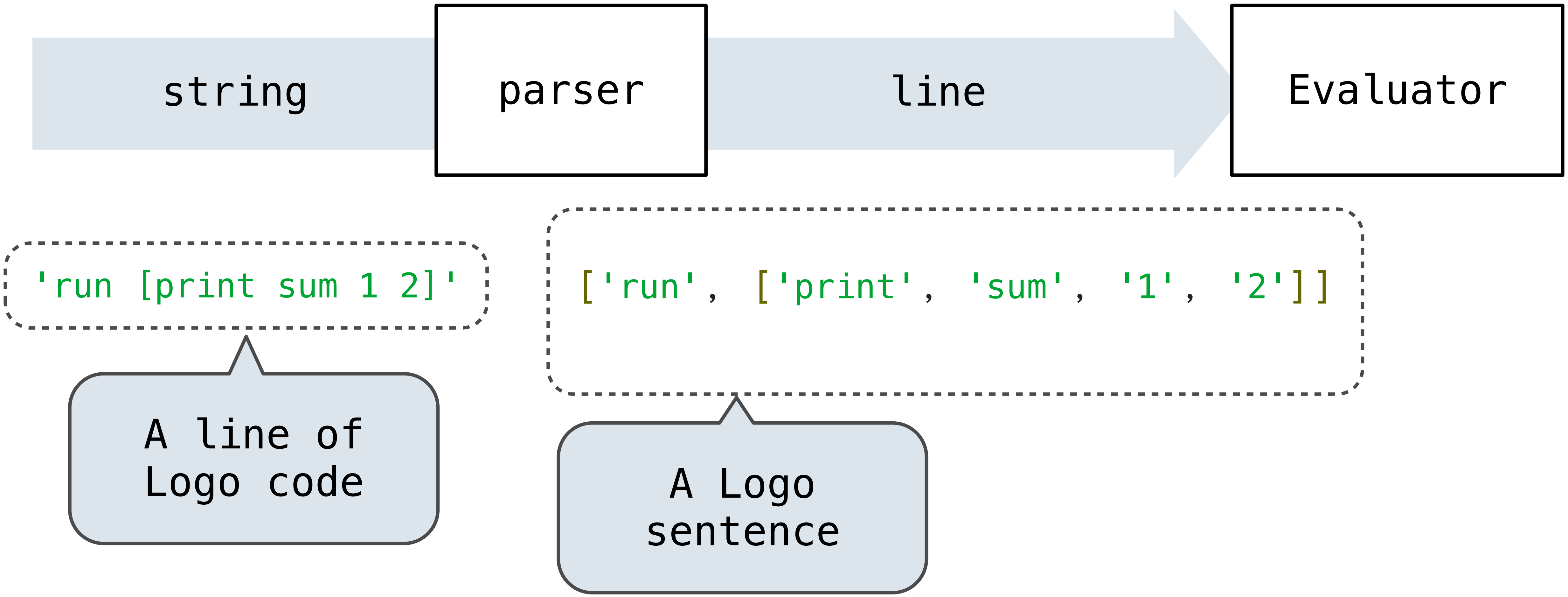

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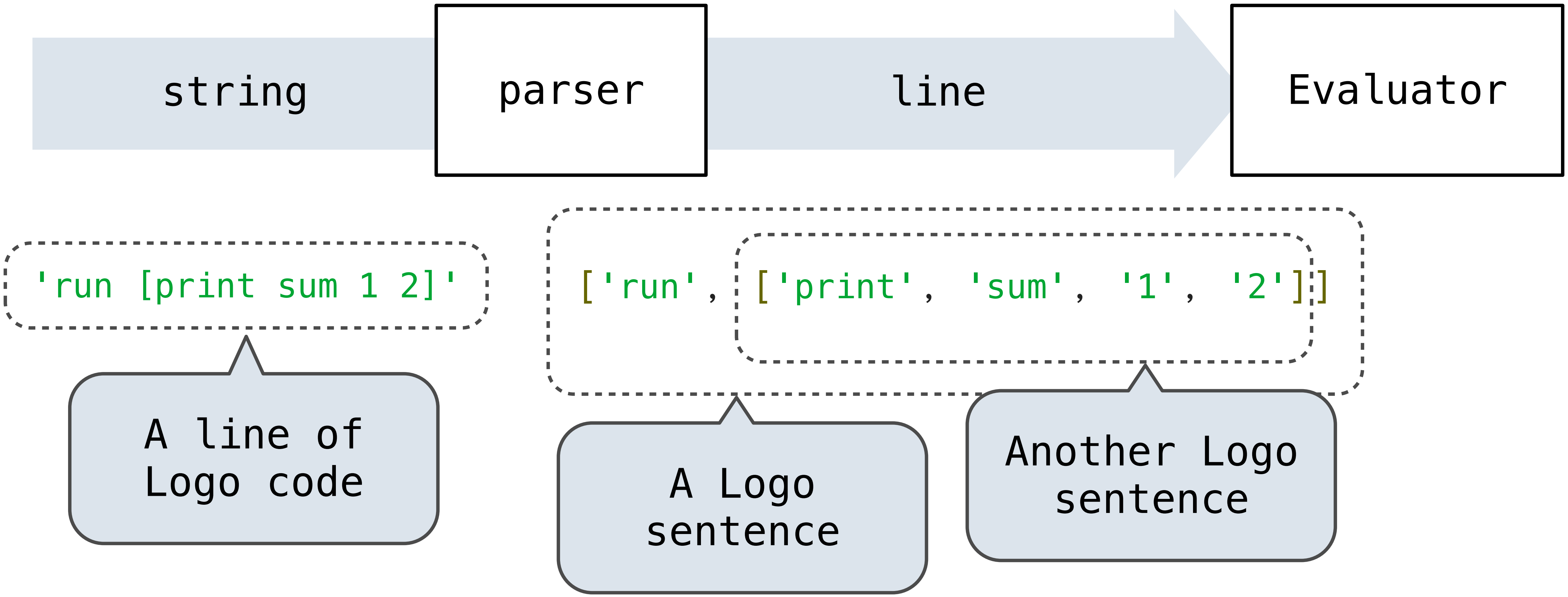

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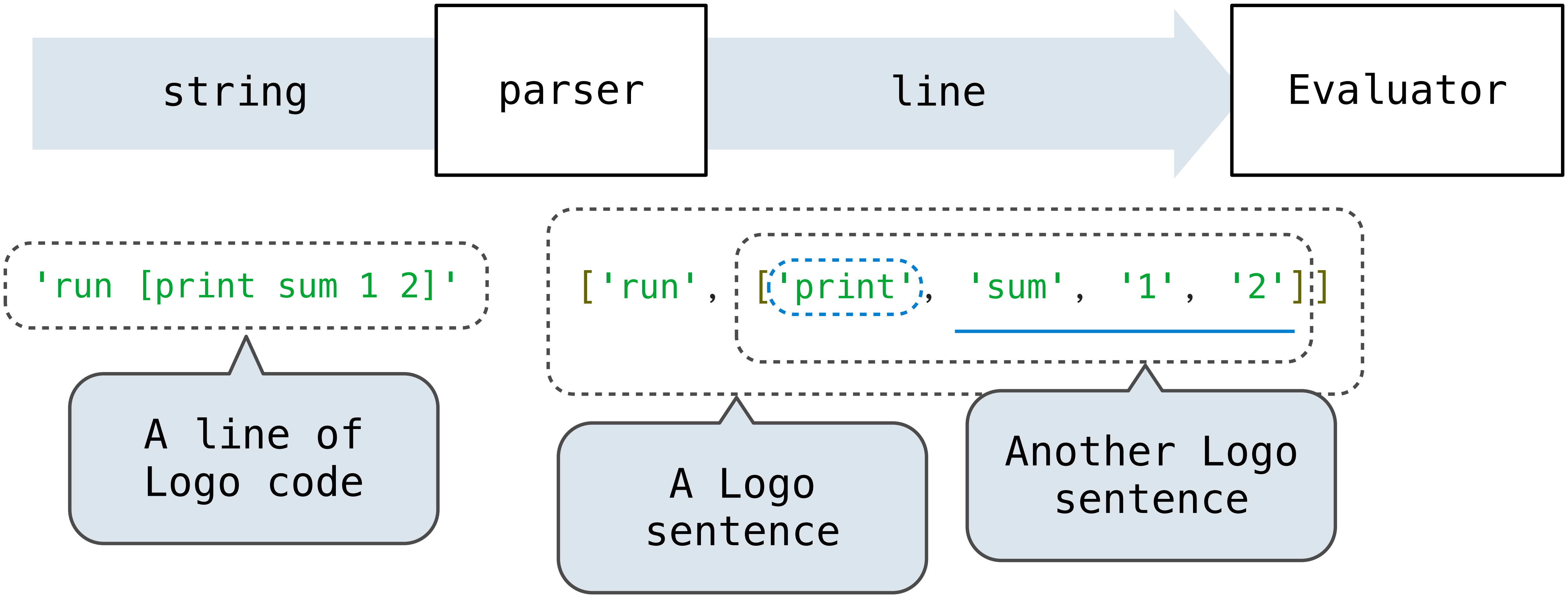

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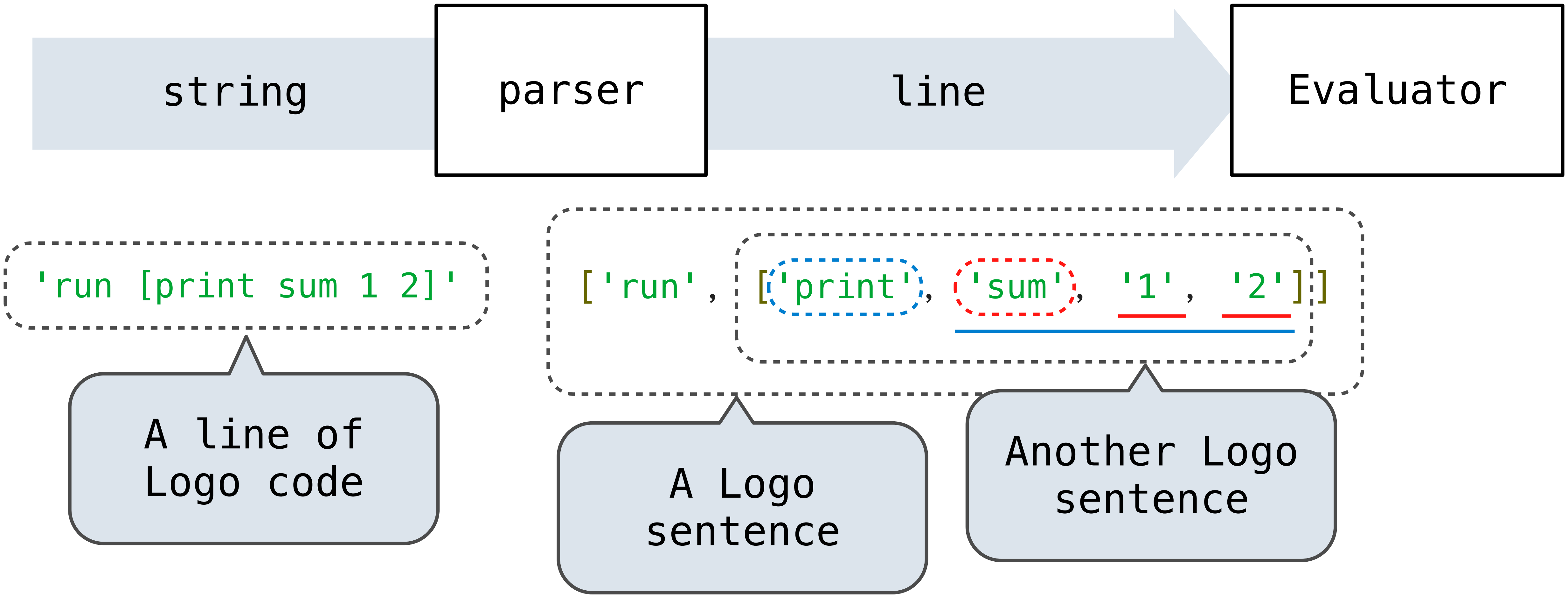

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Tracking Positions in Lines

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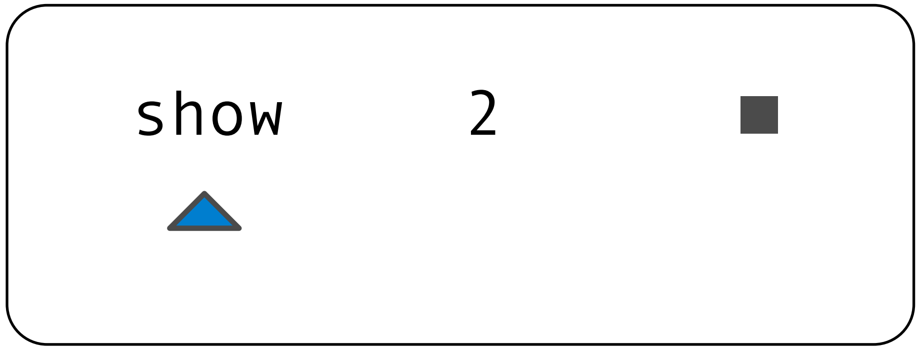

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>>> buf.current
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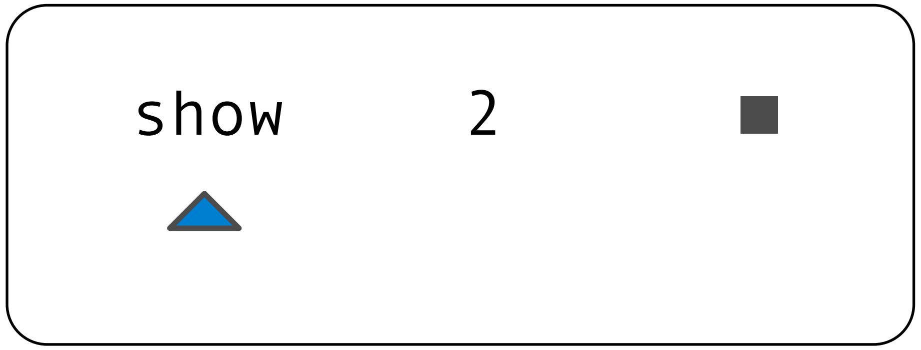

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```

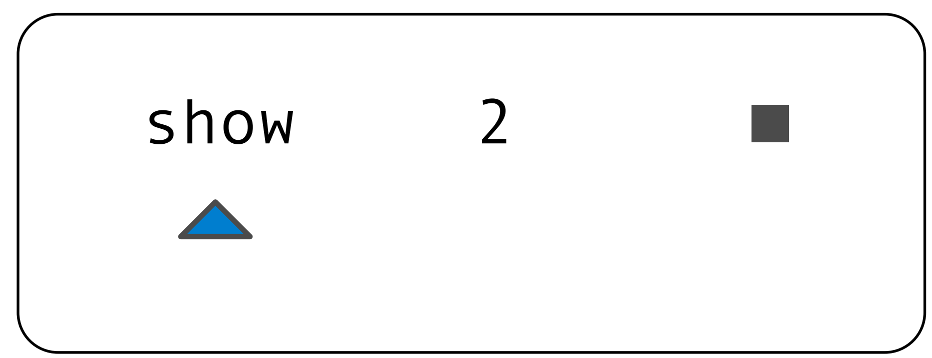

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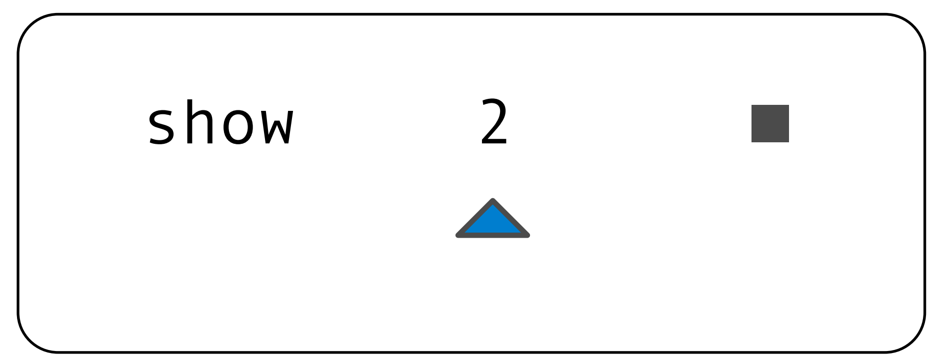

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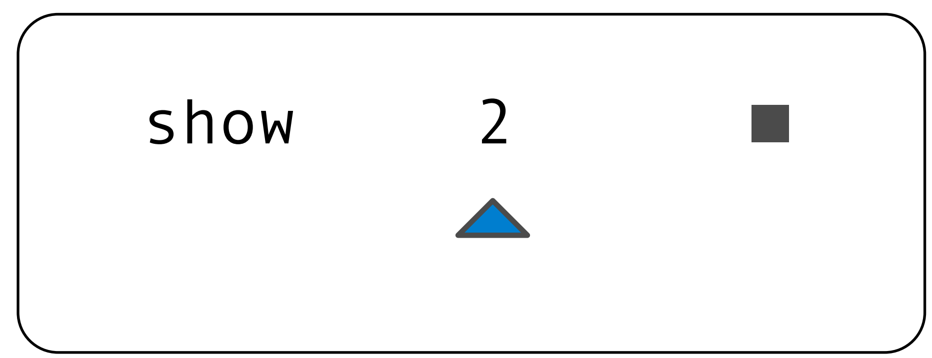

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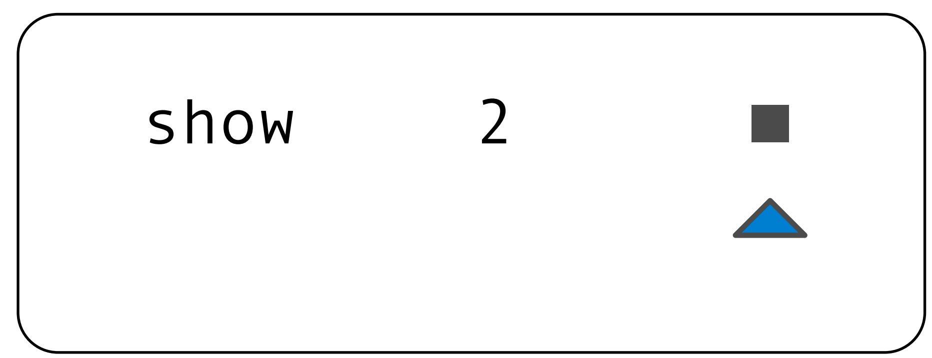

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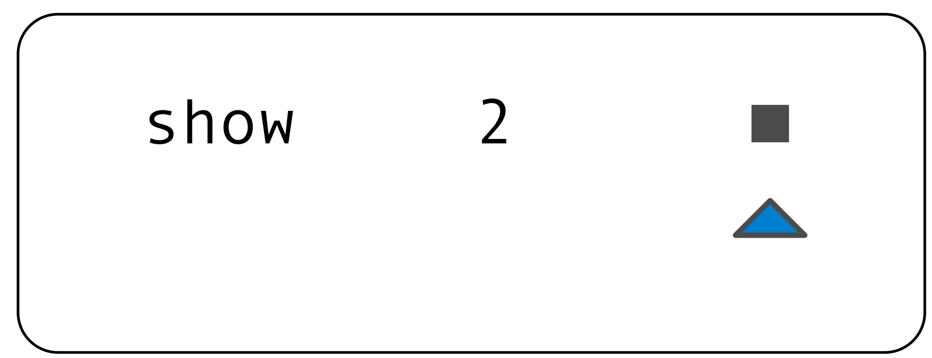

Demo

Evaluating Lines

Evaluating Lines

`Evaluating a line of Logo involves evaluating each expression`

Evaluating Lines

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Evaluate a line

`eval_line`

Evaluating Lines

Evaluating a line of Logo involves evaluating each expression

Evaluate a line — `eval_line`

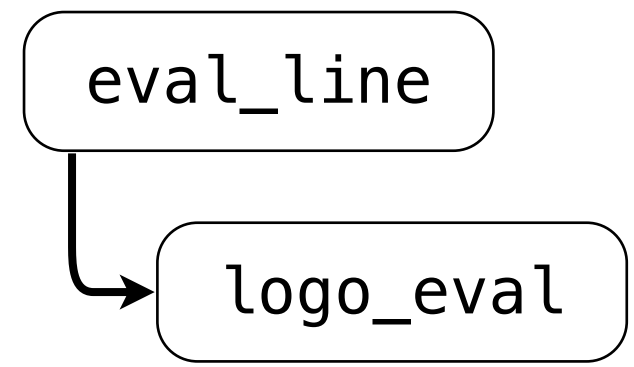
Evaluate the next expression — `logo_eval`

Evaluating Lines

Evaluating a line of Logo involves evaluating each expression

Evaluate a line

Evaluate the
next expression



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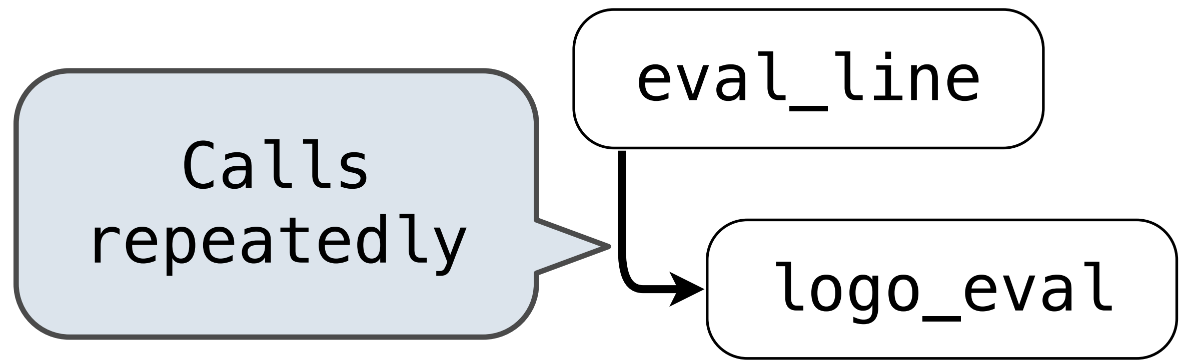

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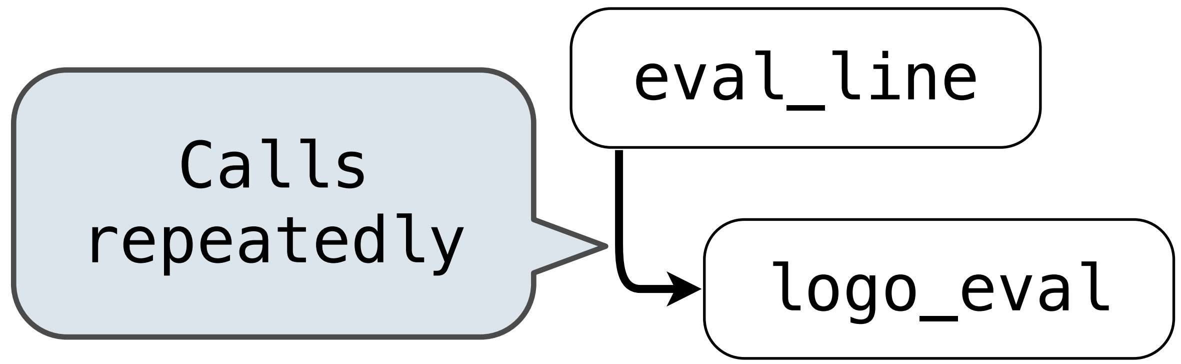


```
? print 1 print 2
1
2
```

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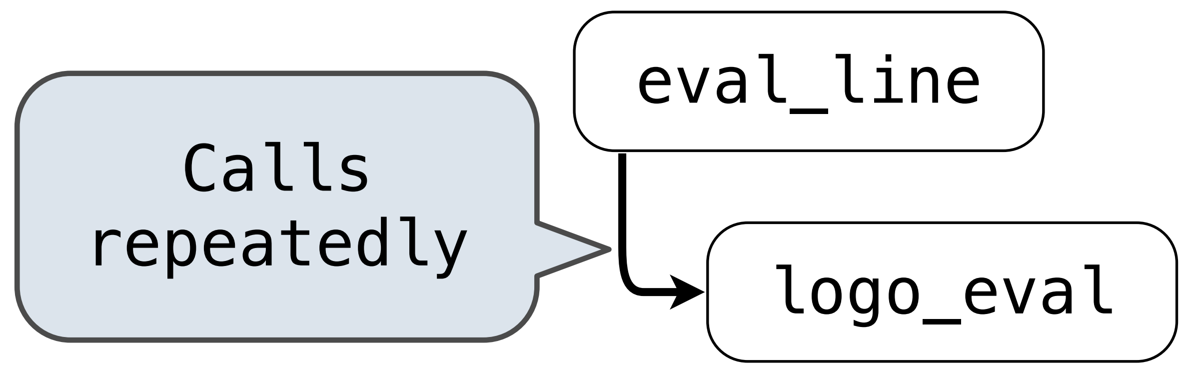


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logo_eval	Argument	Effect
first call		
second call		

Evaluating Lines

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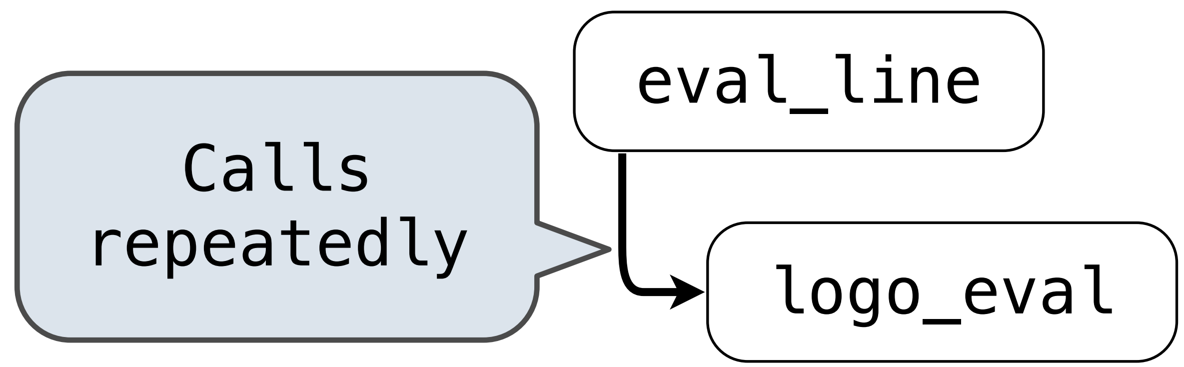


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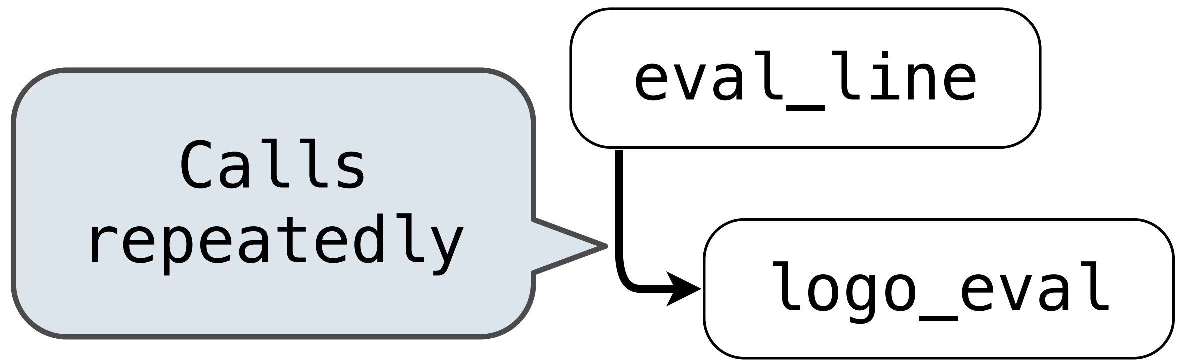


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logo_eval	**Argument**	**Effect**
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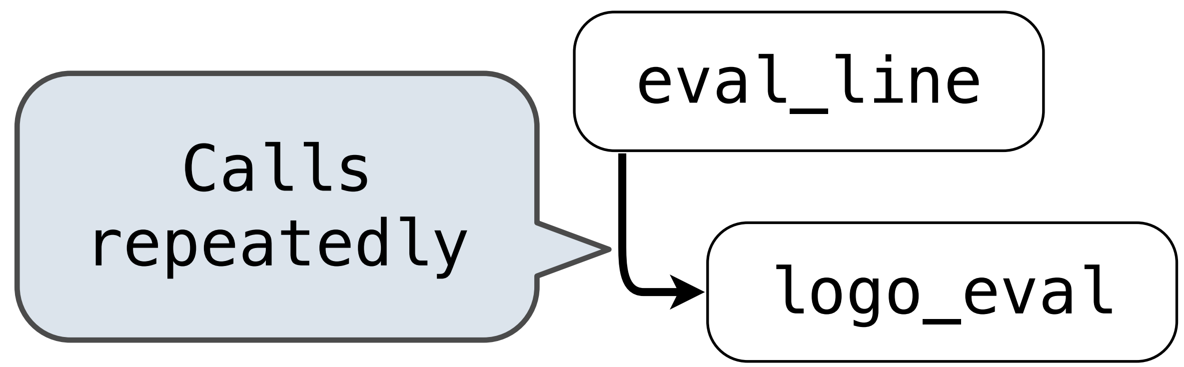


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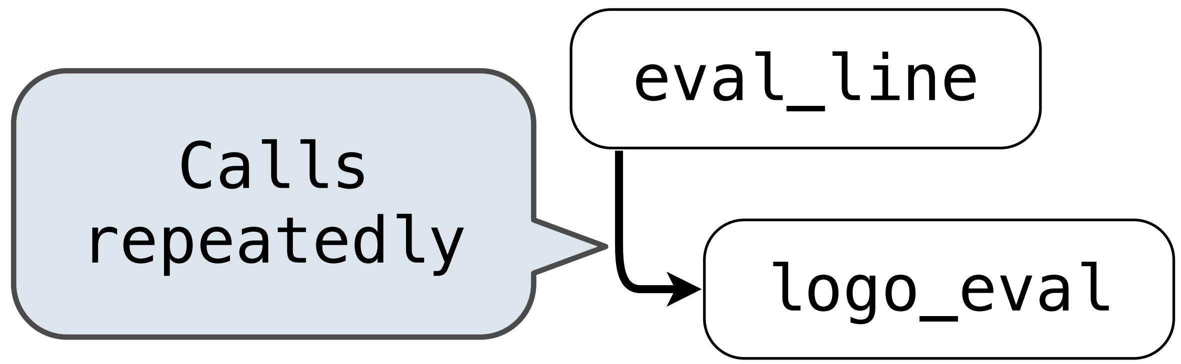


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logo_eval	Argument	Effect
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Logo Evaluation

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- A **quoted expression** evaluates to the text of the quotation, which is a string without the preceding quote. Sentences are quoted and evaluate to themselves.
- A **call expression** is evaluated with apply_procedure.

The expression form can be inferred from the first token

```
def logo_eval(line, env):
    """Evaluate the first expression in a line."""
    token = line.pop()
    if isprimitive(token):
        return token
    elif isvariable(token):
```

Logo Evaluation

The logo_eval function dispatches on expression form:

- A **primitive expression** is a word that can be interpreted as a number, True, or False. Primitives are self evaluating.
- A **variable** is looked up in the current environment.
- A **procedure definition** creates a new user-defined procedure.
- A **quoted expression** evaluates to the text of the quotation, which is a string without the preceding quote. Sentences are quoted and evaluate to themselves.
- A **call expression** is evaluated with apply_procedure.

The expression form can be inferred from the first token

```
def logo_eval(line, env):
    """Evaluate the first expression in a line."""
    token = line.pop()
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        ...
```

Evaluating Call Expressions

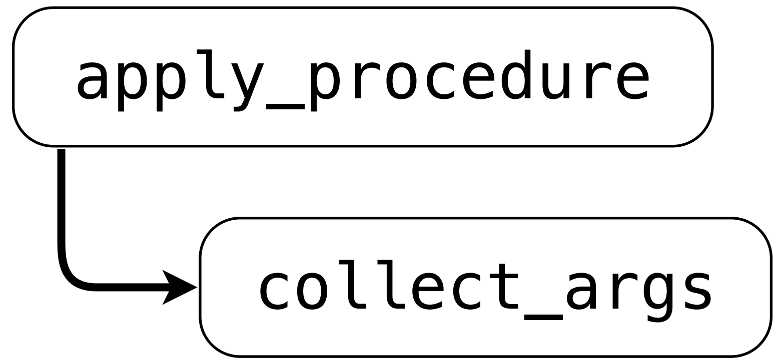
Evaluating Call Expressions

Apply a named procedure `apply_procedure`

Evaluating Call Expressions

Apply a named procedure

Evaluate *n* operands

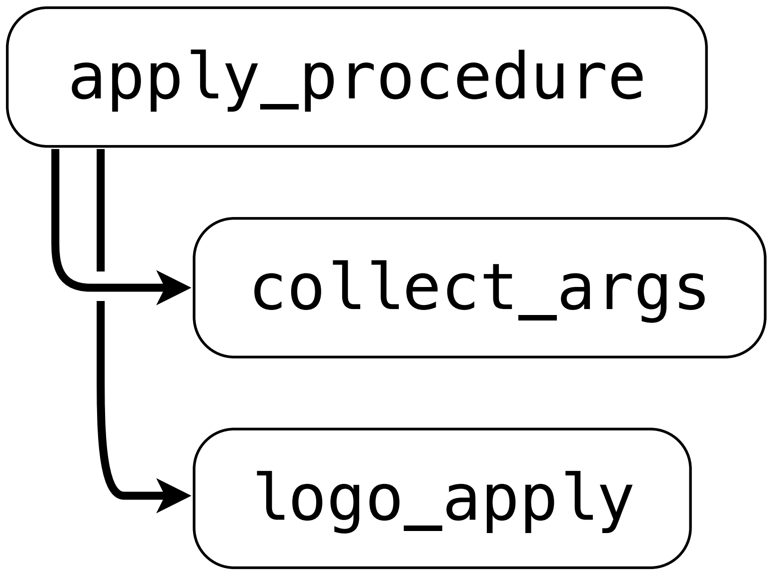


Evaluating Call Expressions

Apply a named procedure

Evaluate *n* operands

Apply a procedure to
a sequence of arguments



Evaluating Call Expressions

Apply a named procedure

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Apply a procedure to
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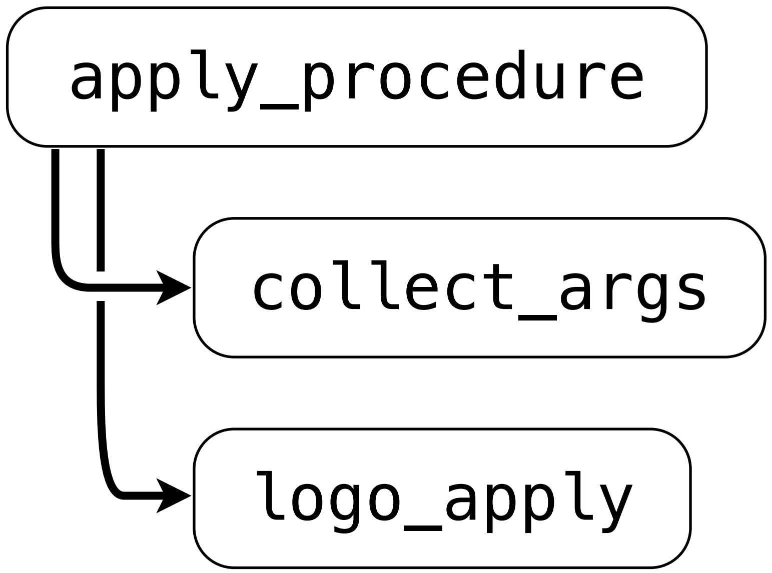

Return the output value

Evaluating Call Expressions

Apply a named procedure

Evaluate *n* operands

Apply a procedure to
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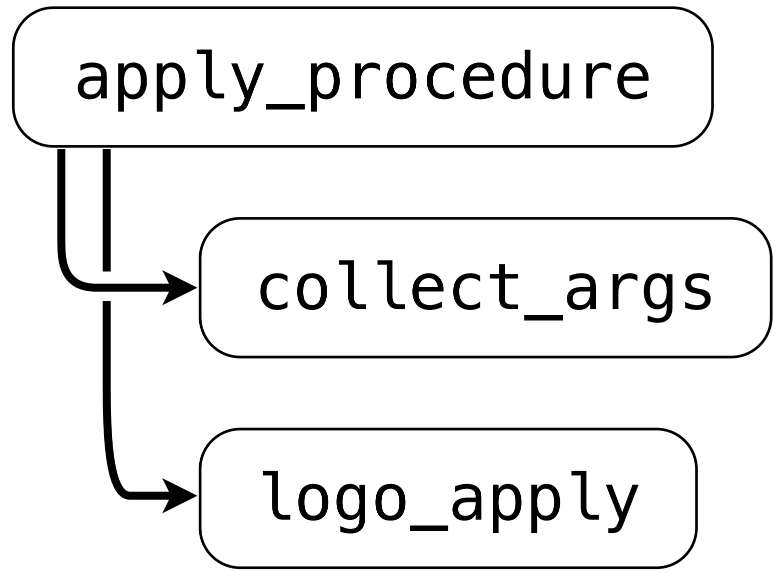


Return the output value

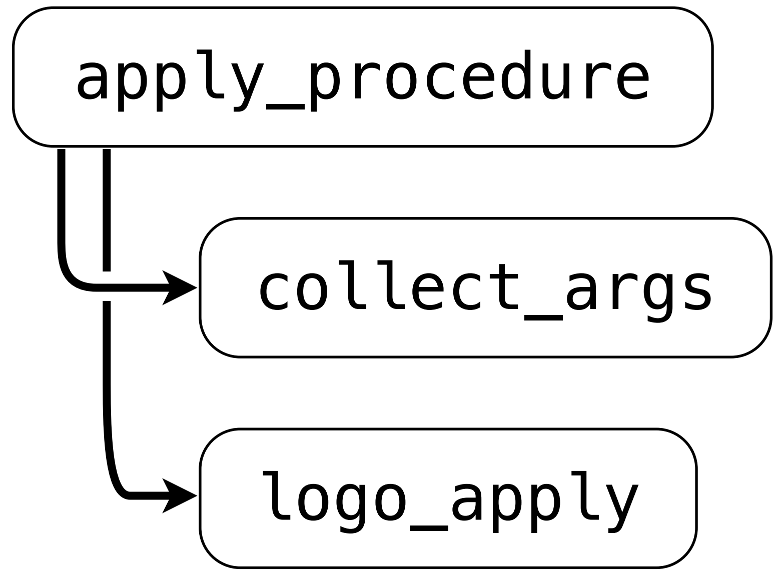
Return *n* arguments

Evaluating Call Expressions

Apply a named procedure

Evaluate *n* operands

Apply a procedure to
a sequence of arguments



Return the output value

Return *n* arguments

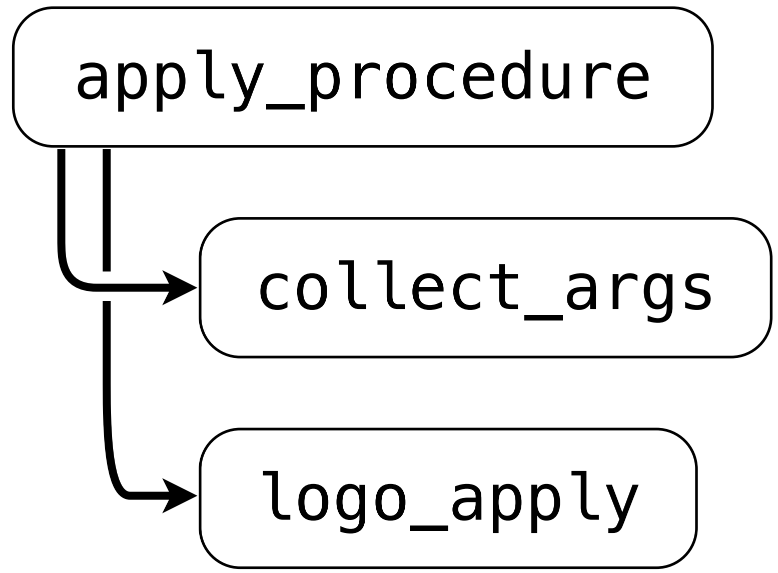
Return the output value

Evaluating Call Expressions

Apply a named procedure

Evaluate n operands

Apply a procedure to
a sequence of arguments



Return the output value

Return n arguments

Return the output value

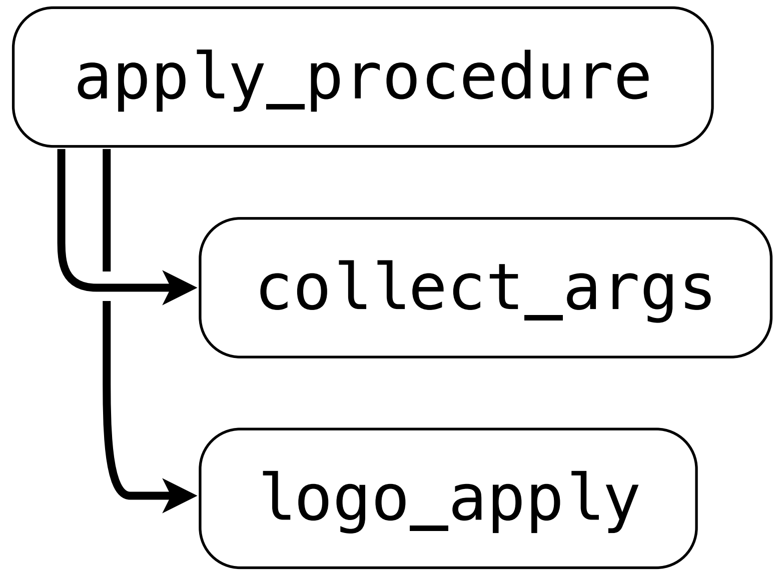
```
[ print >> 2 ]
```

Evaluating Call Expressions

Apply a named procedure

Evaluate *n* operands

Apply a procedure to
a sequence of arguments



Return the output value

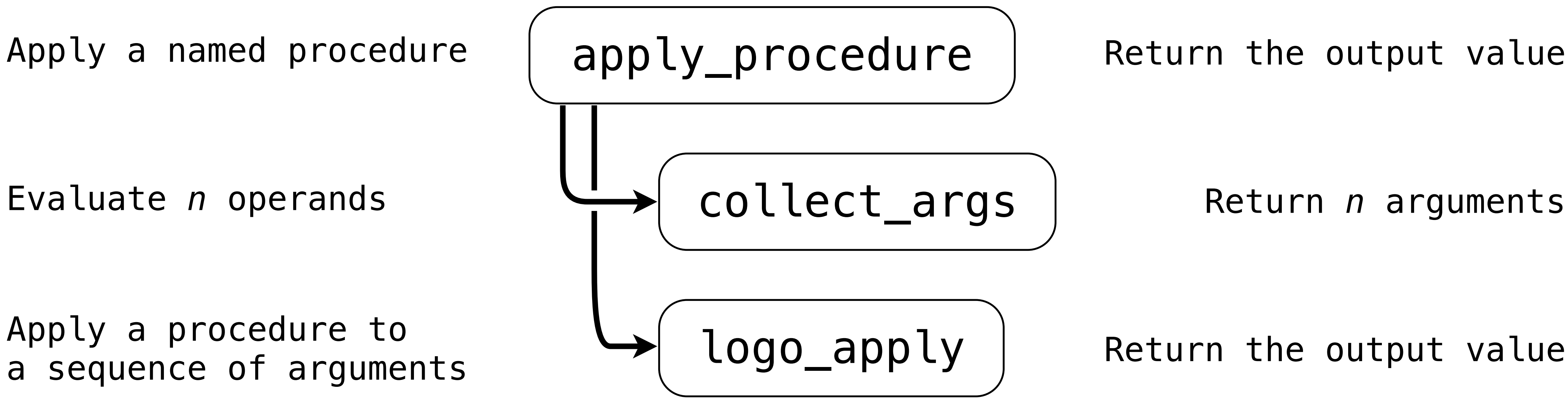
Return *n* arguments

Return the output value

```
[ print >> 2 ]
```

Popped by logo_eval

Evaluating Call Expressions




```
[ print >> 2 ]
```

Popped by logo_eval

1. Collect 1 argument via logo_eval (collect_args)

Evaluating Call Expressions

Apply a named procedure — **apply_procedure** — Return the output value

Evaluate *n* operands — **collect_args** — Return *n* arguments

Apply a procedure to a sequence of arguments — **logo_apply** — Return the output value

```
[ print >> 2 ]
```

Popped by logo_eval

```
[ print, 2 >> ]
```

1. Collect 1 argument via logo_eval (collect_args)

Evaluating Call Expressions

Apply a named procedure — **apply_procedure** — Return the output value

Evaluate *n* operands — **collect_args** — Return *n* arguments

Apply a procedure to a sequence of arguments — **logo_apply** — Return the output value

```
[ print >> 2 ]
```

Popped by logo_eval

```
[ print, 2 >> ]
```

Popped by logo_eval also (recursive call)

1. Collect 1 argument via logo_eval (collect_args)

Evaluating Call Expressions

Apply a named procedure — `apply_procedure` — Return the output value

Evaluate *n* operands — `collect_args` — Return *n* arguments

Apply a procedure to a sequence of arguments — `logo_apply` — Return the output value

```
[ print >> 2 ]
```

Popped by logo_eval

```
[ print, 2 >> ]
```

Popped by logo_eval also (recursive call)

1. Collect 1 argument via logo_eval (collect_args)

2. Apply print procedure to the argument '2' (logo_apply)

Procedures

Procedures

```
class Procedure():
```

Procedures

```
class Procedure():
    def __init__(self, name, arg_count, body, isprimitive=False,
                 needs_env=False, formal_params=None):
```

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class Procedure():
    def __init__(self, name, arg_count, body, isprimitive=False,
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        self.name = name
        self.arg_count = arg_count
        self.body = body
        self.isprimitive = isprimitive
        self.needs_env = needs_env
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Procedures

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def logo_apply(proc, args):
    """Apply a Logo procedure to a list of arguments."""
```

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def logo_apply(proc, args):
    """Apply a Logo procedure to a list of arguments."""
    if proc.isprimitive:
        return proc.body(*args)
```

Procedures

```python
class Procedure():
    def __init__(self, name, arg_count, body, isprimitive=False,
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        self.name = name
        self.arg_count = arg_count
        self.body = body
        self.isprimitive = isprimitive
        self.needs_env = needs_env
        self.formal_params = formal_params

def logo_apply(proc, args):
    """Apply a Logo procedure to a list of arguments."""
    if proc.isprimitive:
        return proc.body(*args)
    else:
        """Apply a user-defined procedure"""
```
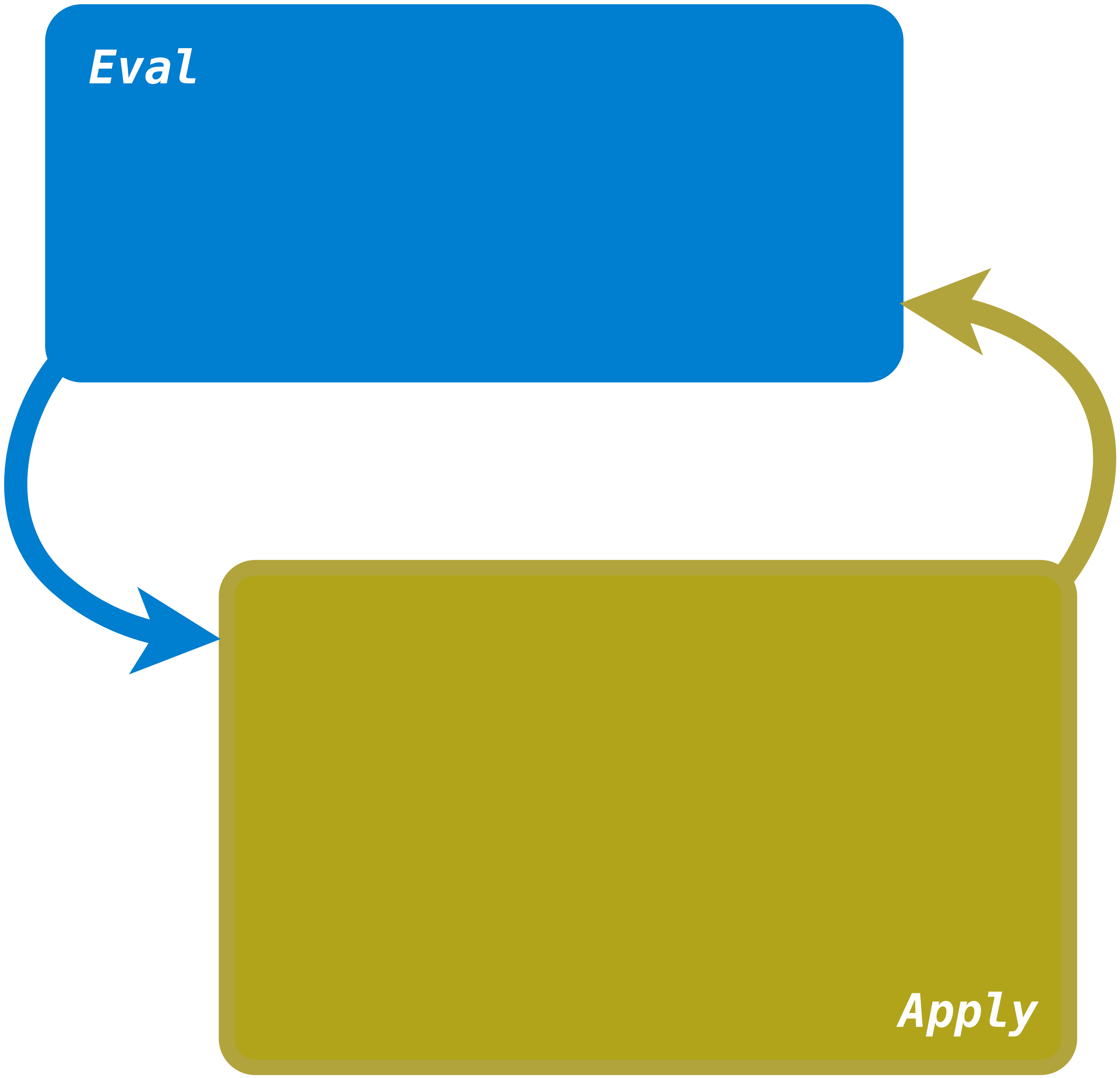
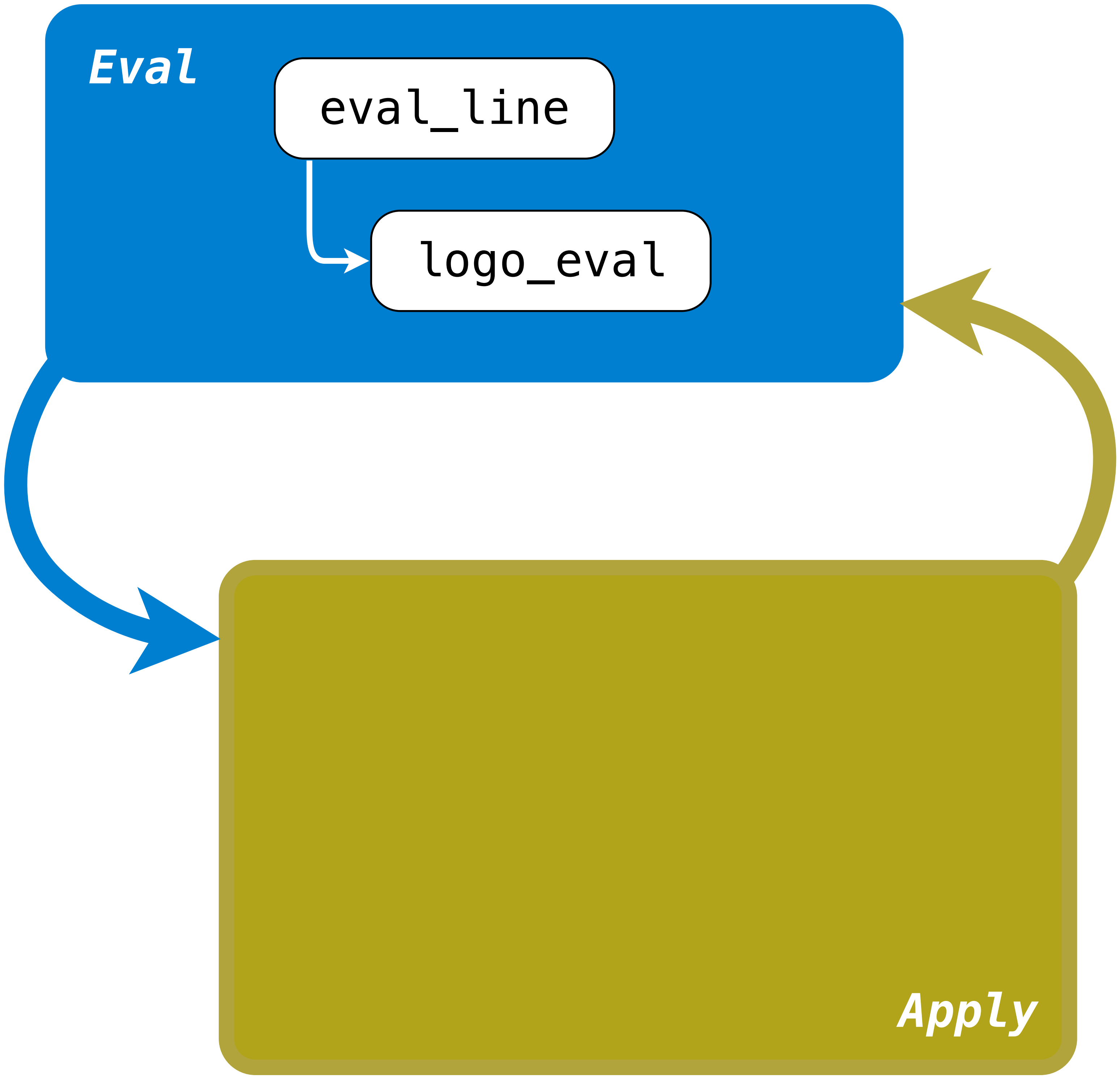
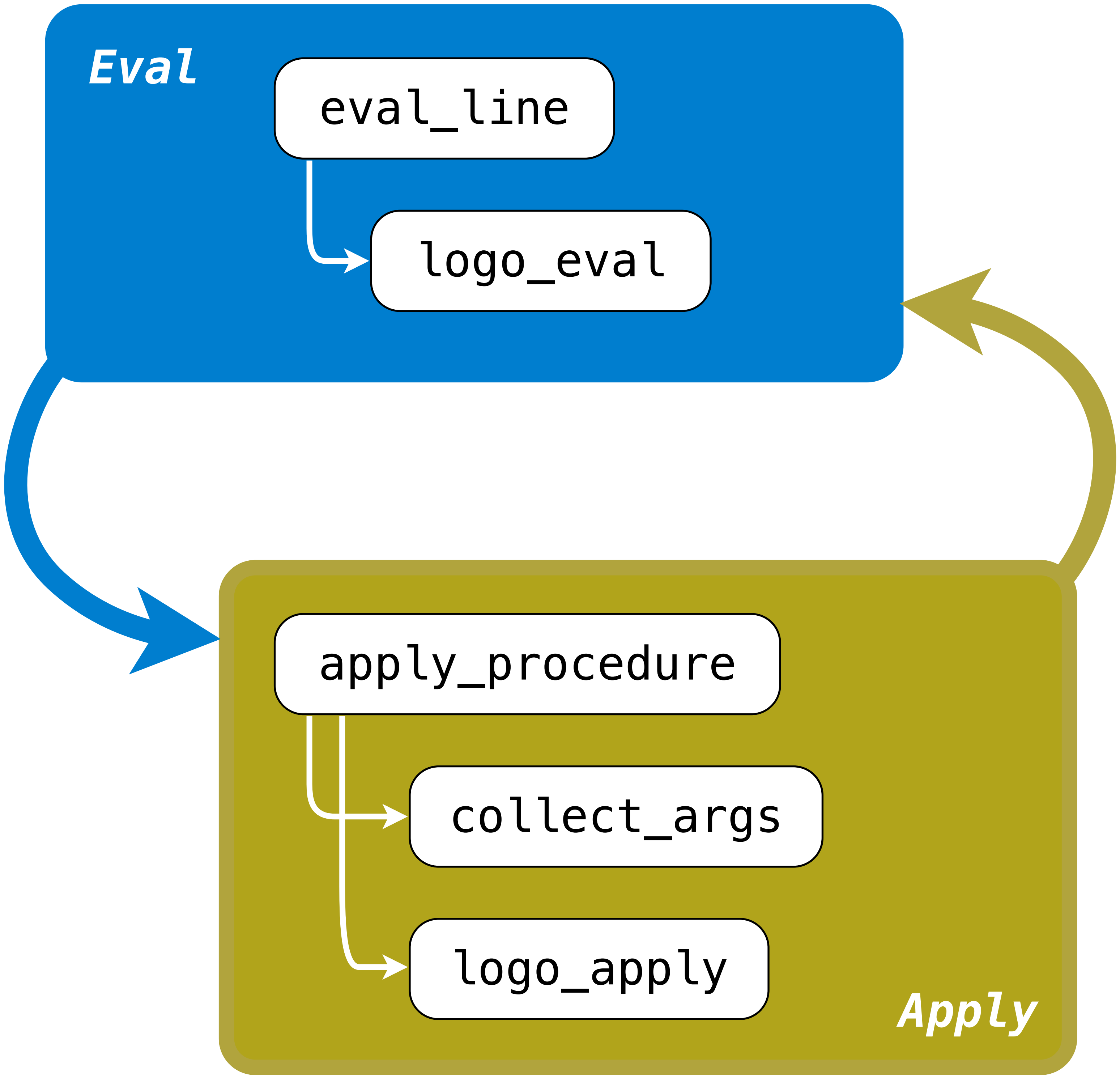

Logo Interpreter



Logo Interpreter



Logo Interpreter

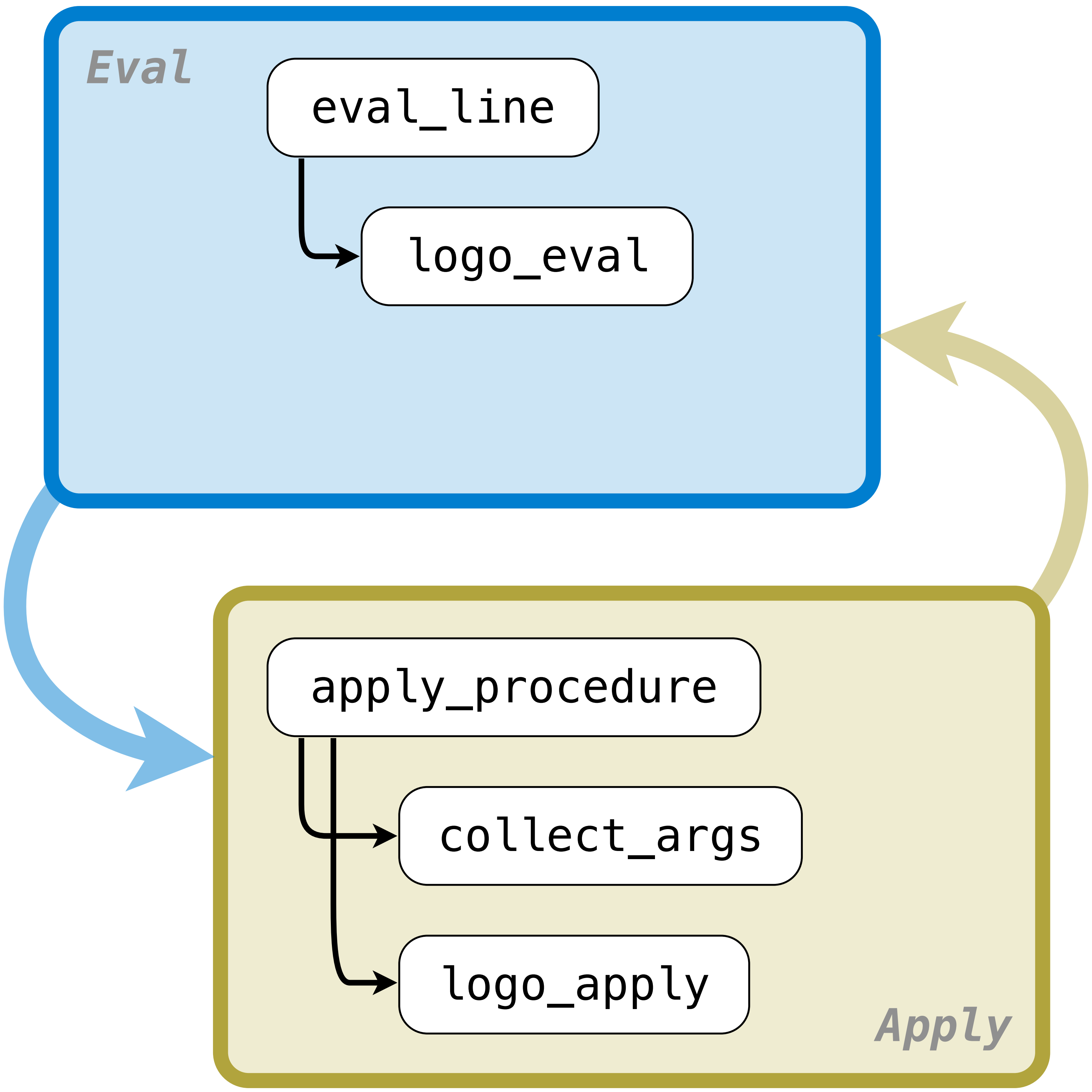


Eval/Apply in Lisp 1.5

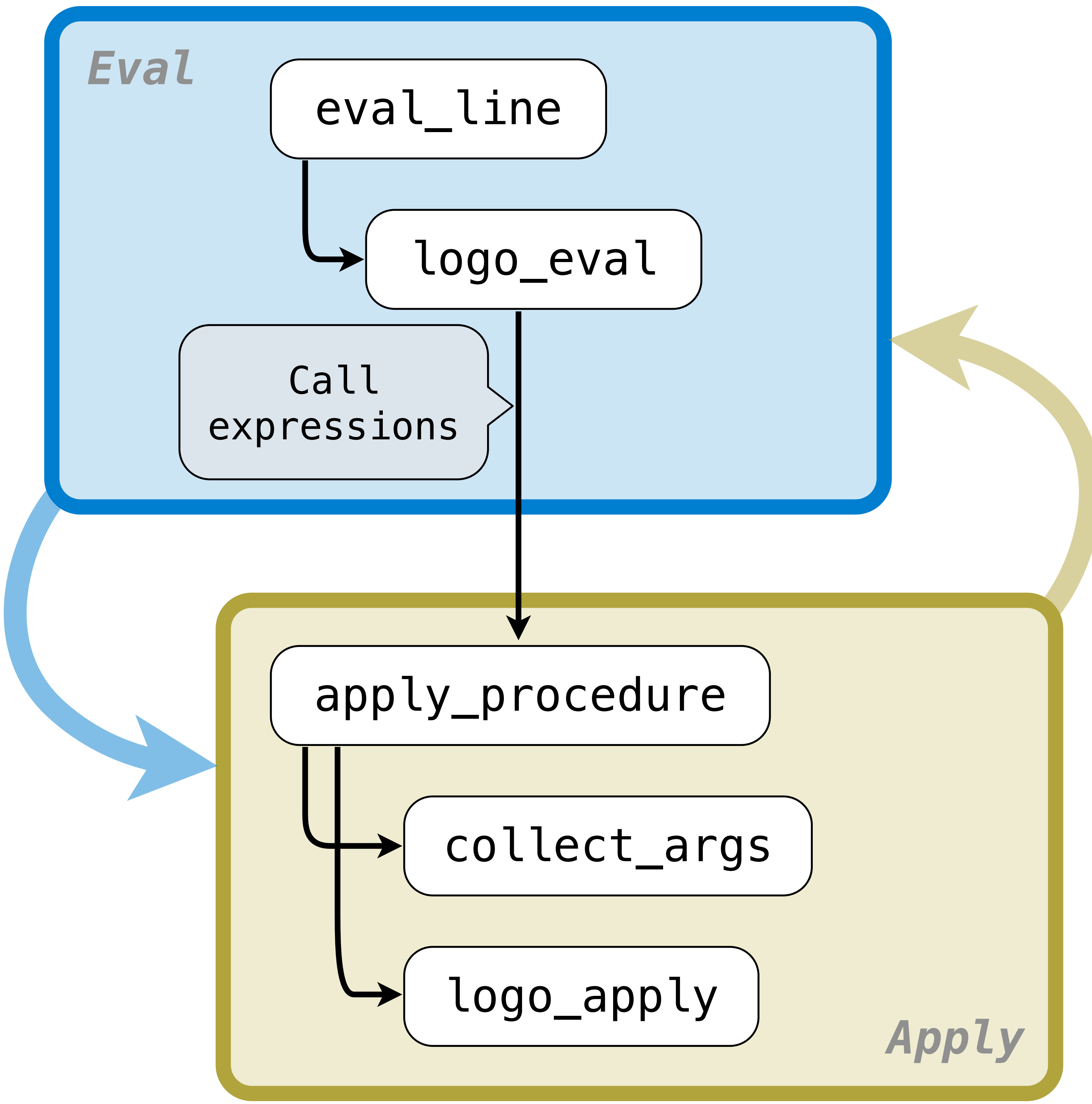
Eval/Apply in Lisp 1.5

```
apply[fn;x;a] =
     [atom[fn] → [eq[fn;CAR] → caar[x];
                  eq[fn;CDR] → cdar[x];
                  eq[fn;CONS] → cons[car[x];cadr[x]];
                  eq[fn;ATOM] → atom[car[x]];
                  eq[fn;EQ] → eq[car[x];cadr[x]];
                  T → apply[eval[fn;a];x;a]];
     eq[car[fn];LAMBDA] → eval[caddr[fn];pairlis[cadr[fn];x;a]];
     eq[car[fn];LABEL] → apply[caddr[fn];x;cons[cons[cadr[fn];
                                                   caddr[fn]];a]]]
eval[e;a] = [atom[e] → cdr[assoc[e;a]];
     atom[car[e]] →
               [eq[car[e],QUOTE] → cadr[e];
               eq[car[e];COND] → evcon[cdr[e];a];
               T → apply[car[e];evlis[cdr[e];a];a]];
     T → apply[car[e];evlis[cdr[e];a];a]]
```

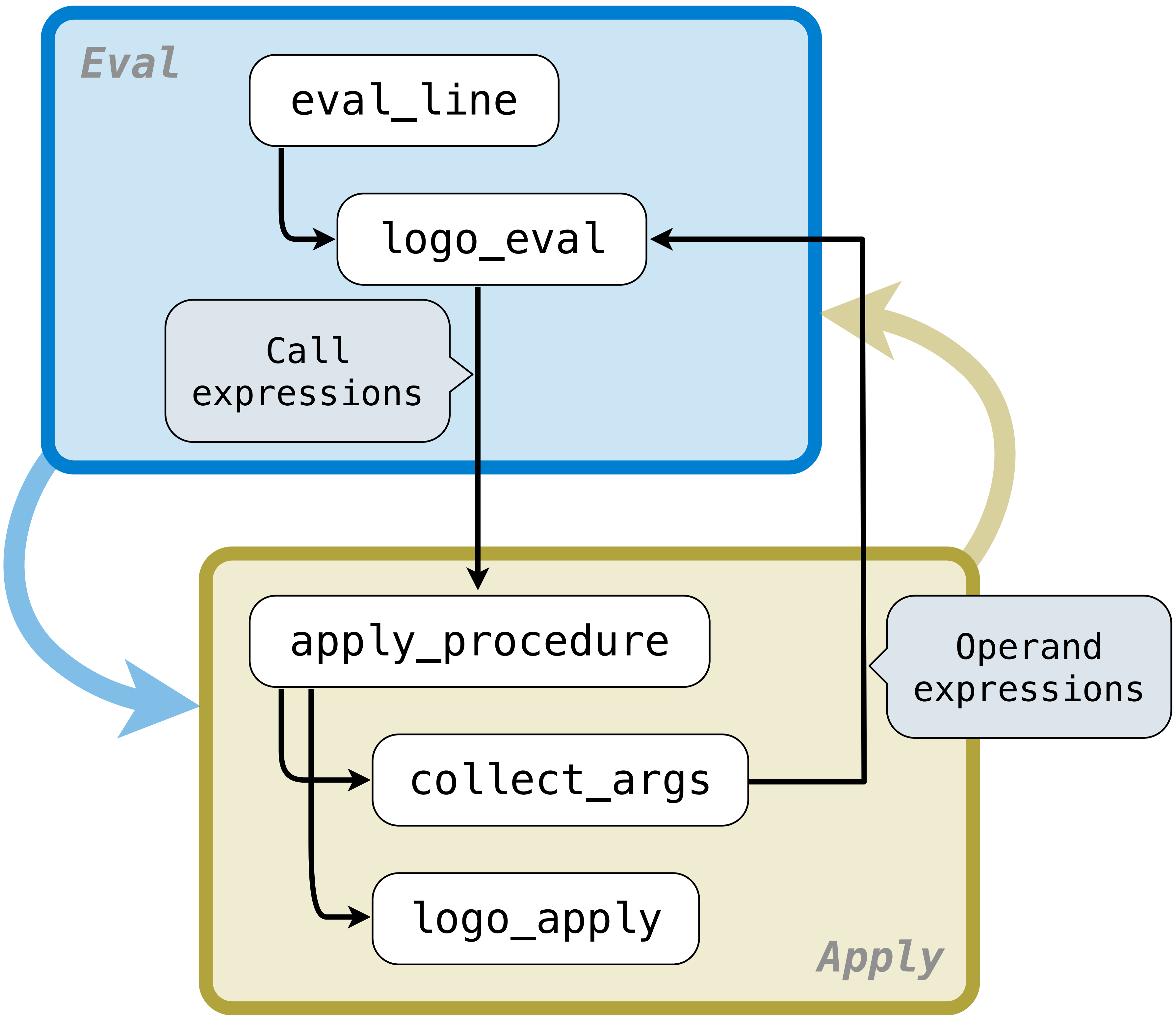
Eval/Apply in Logo



Eval/Apply in Logo



Eval/Apply in Logo



Eval/Apply in Logo