Towards Efficient, Multi-Language Dynamic Taint Analysis

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JOHANNES KEPLER UNIVERSITY LINZ

ORACLE Labs

Dynamic Taint Analysis

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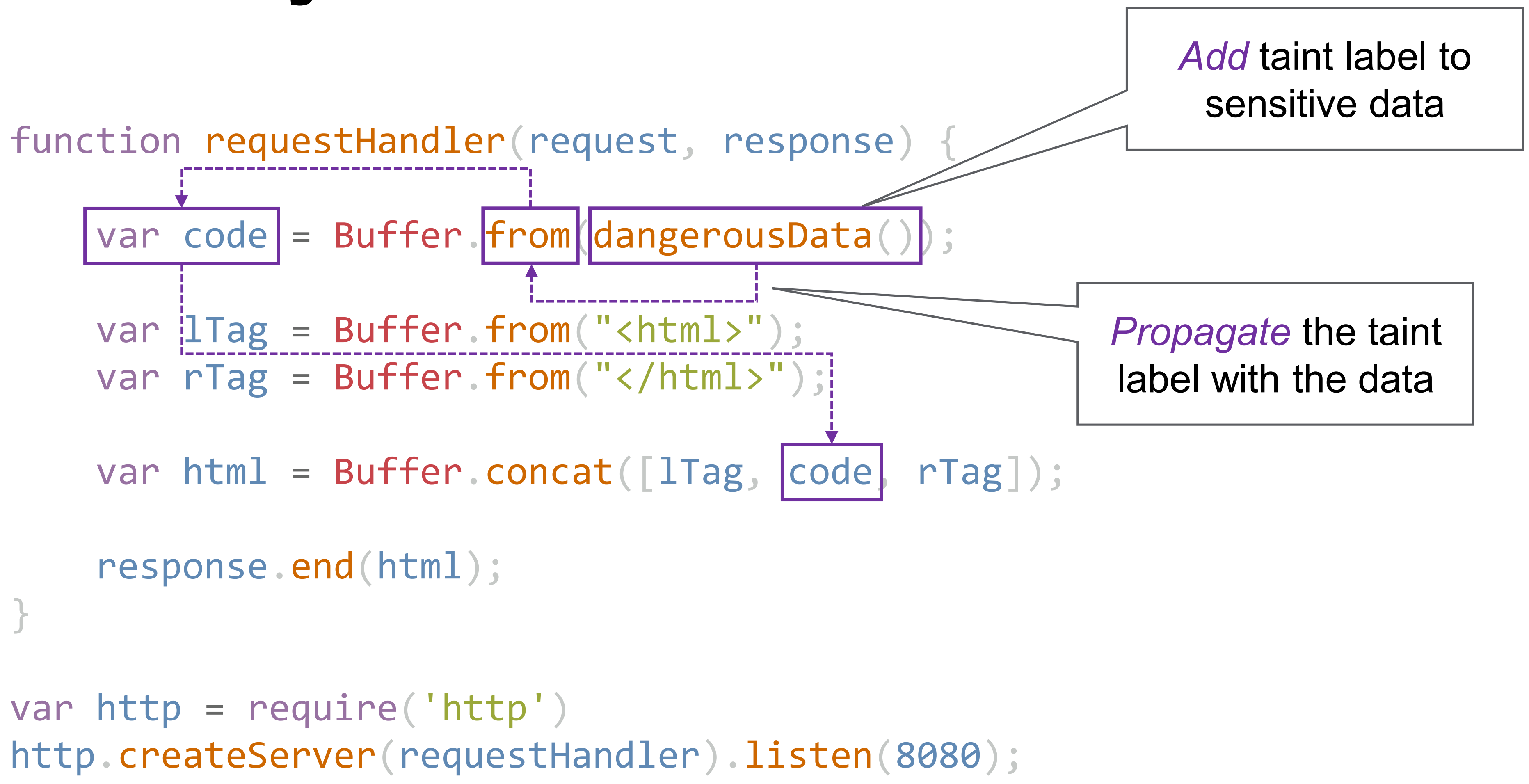

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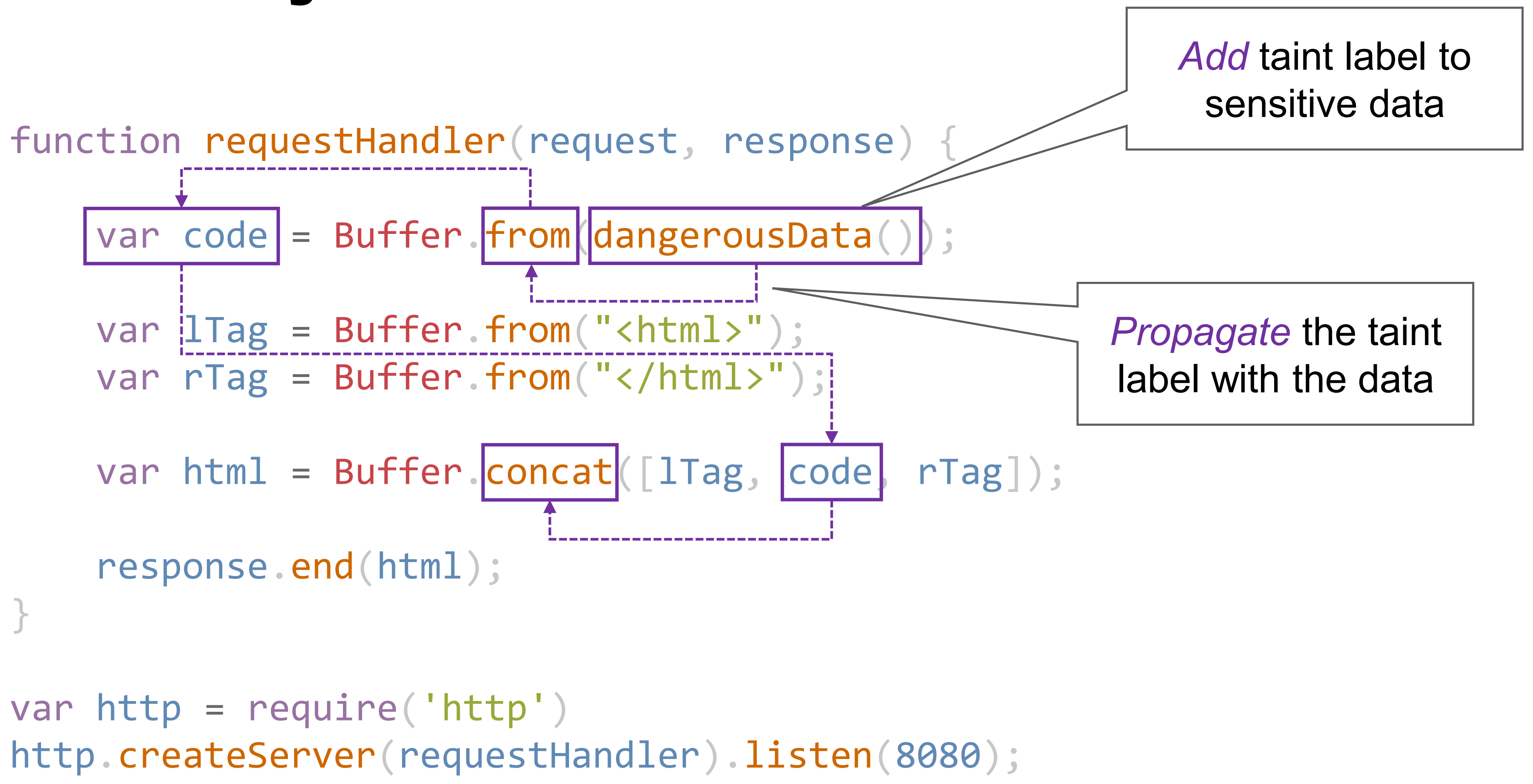

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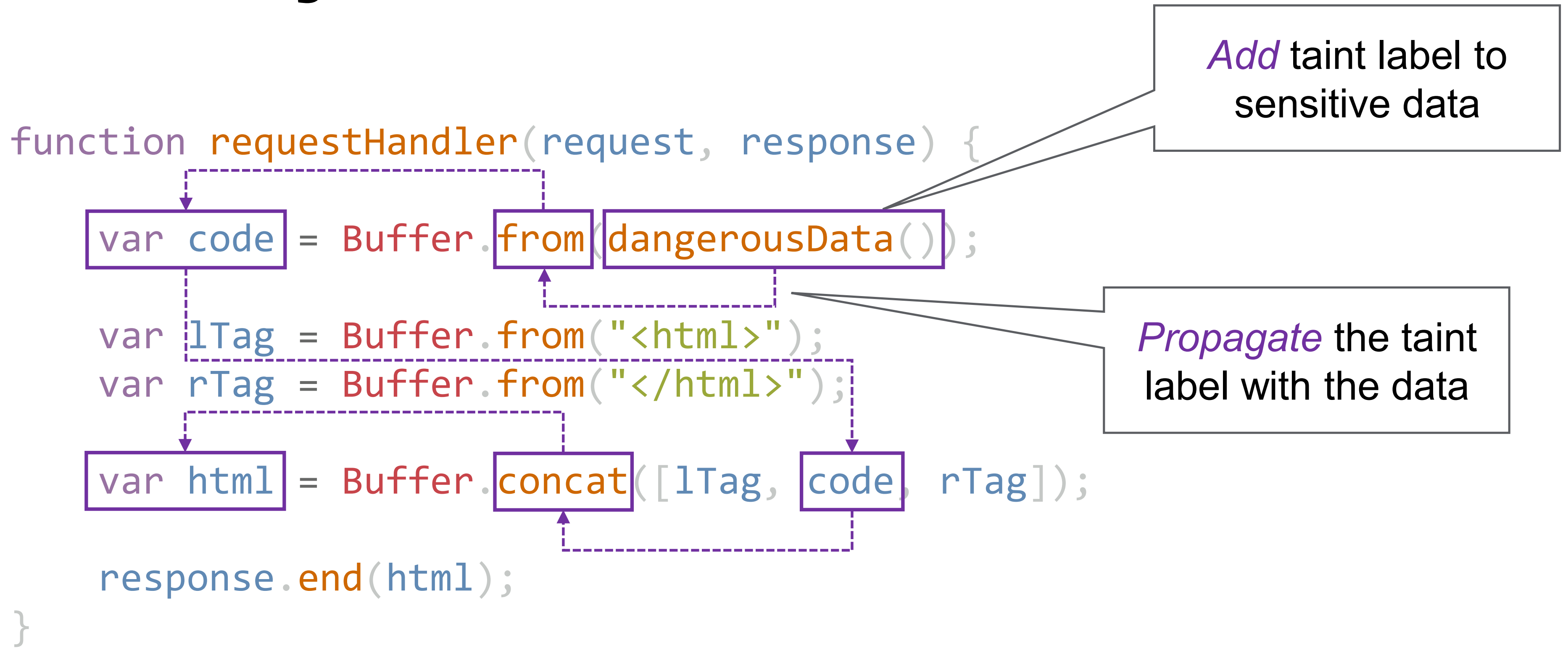

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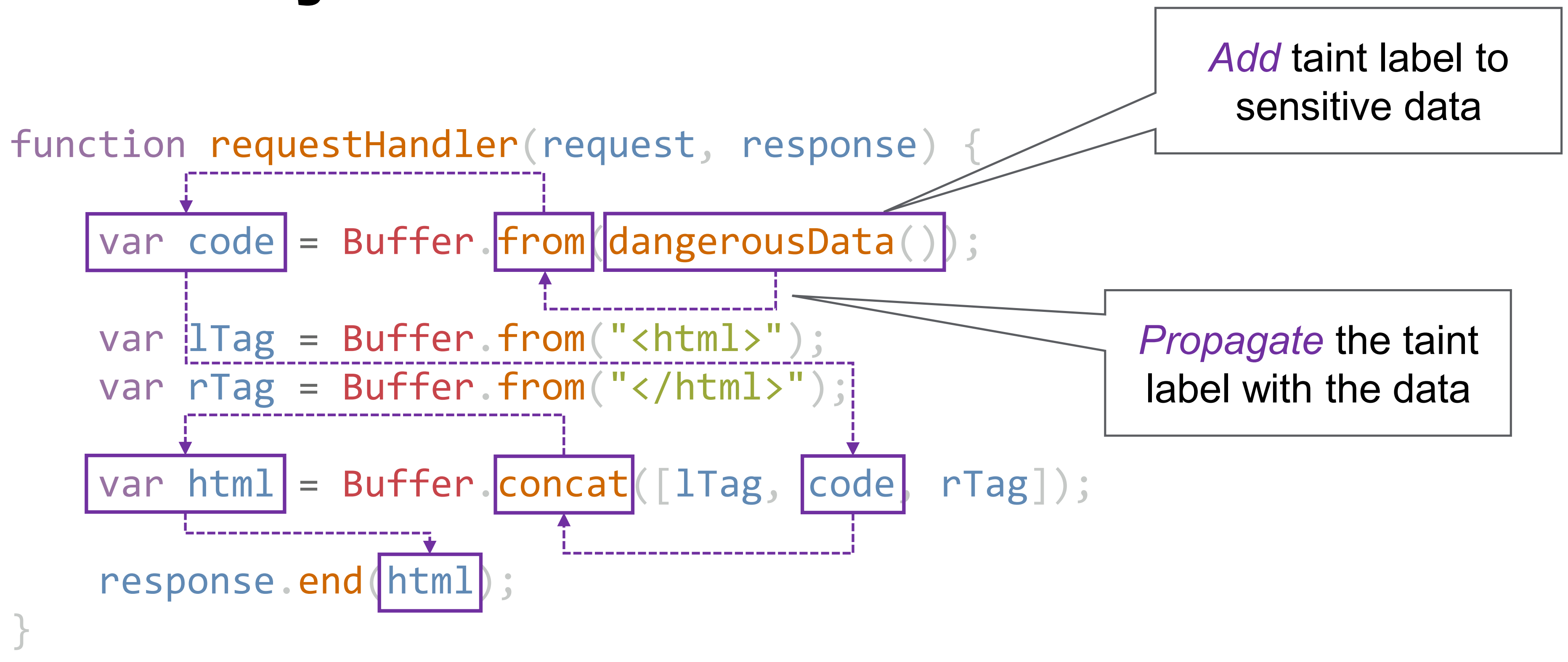

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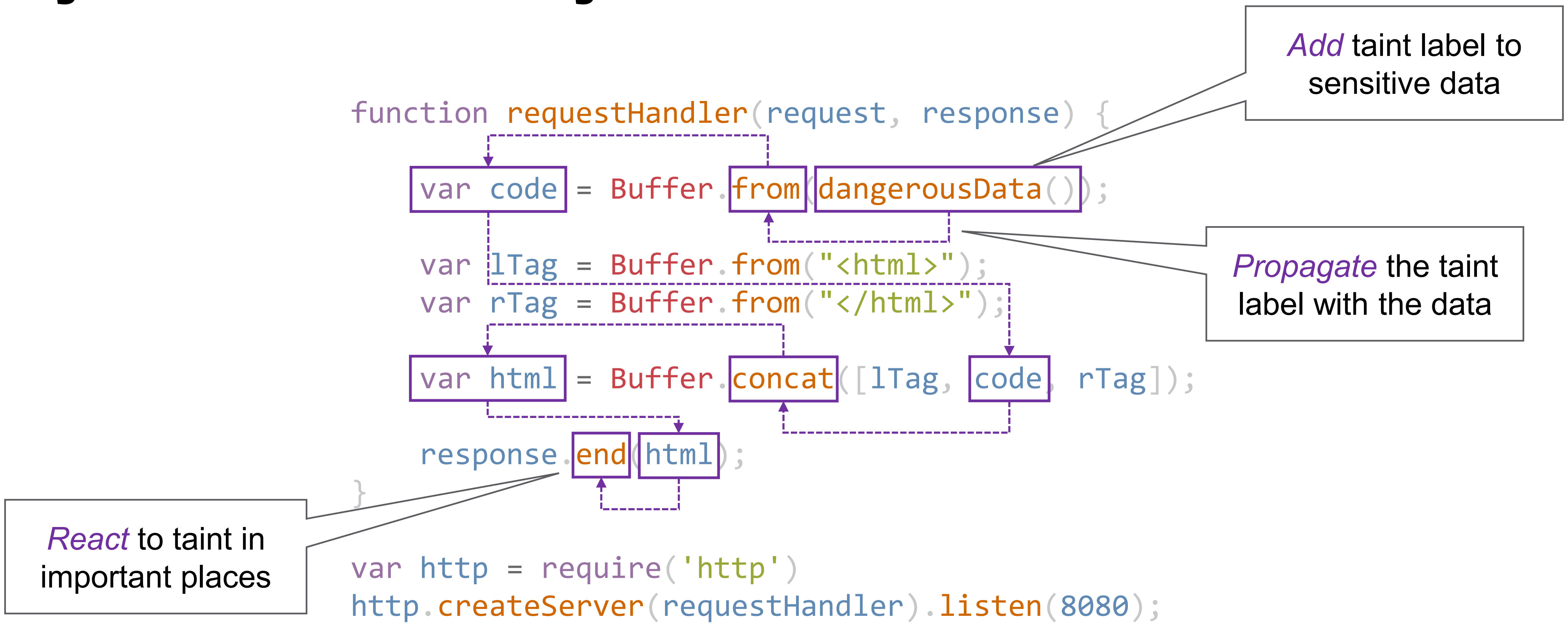

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React to taint in important places

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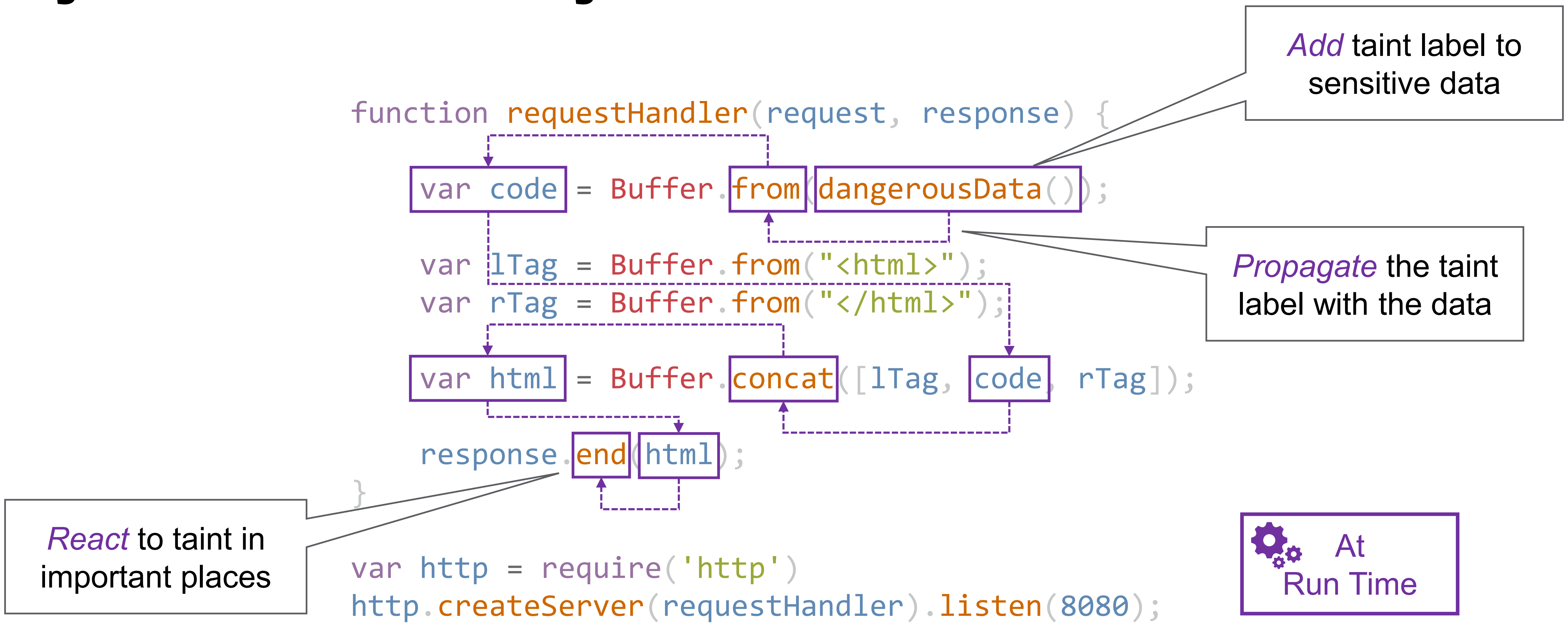

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At Run Time

Applications

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Applications

Prevent Data Leaks

„<body>secret: … </body>"

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Trace Origin of Data

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Prevent Data Leaks

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Trace Origin of Data

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Detect vulnerabilities

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<html>
<body onLoad=\"installMalware();\"/>
</html>
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Language Embeddings

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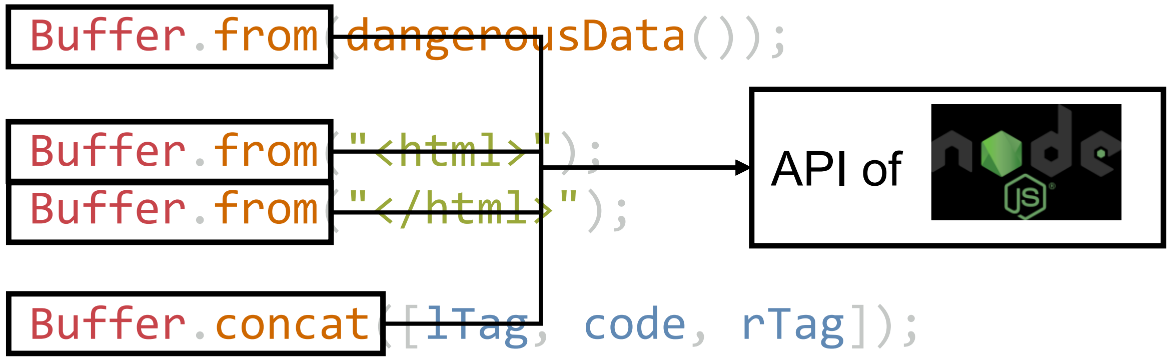

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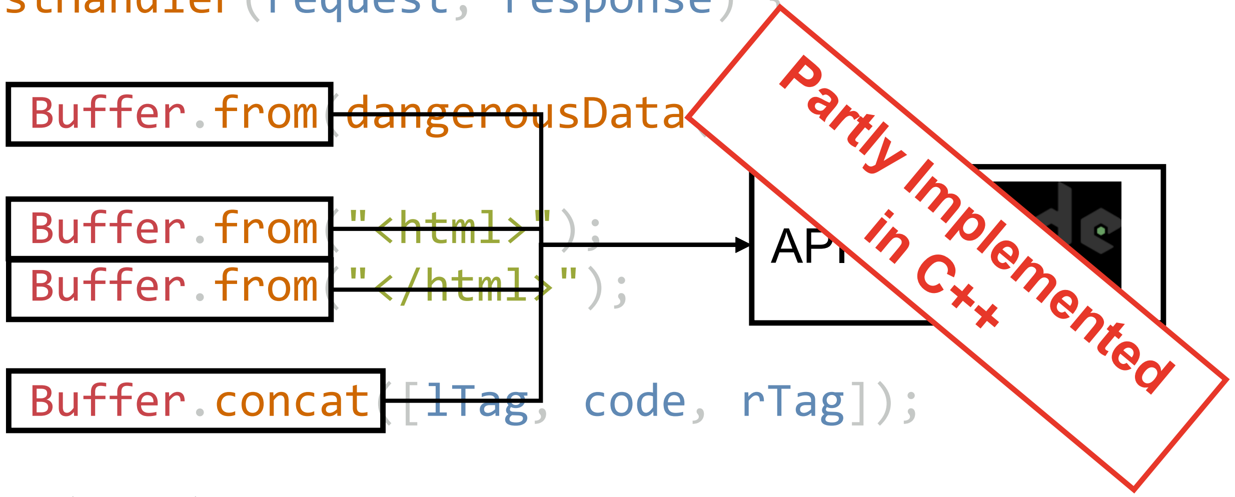
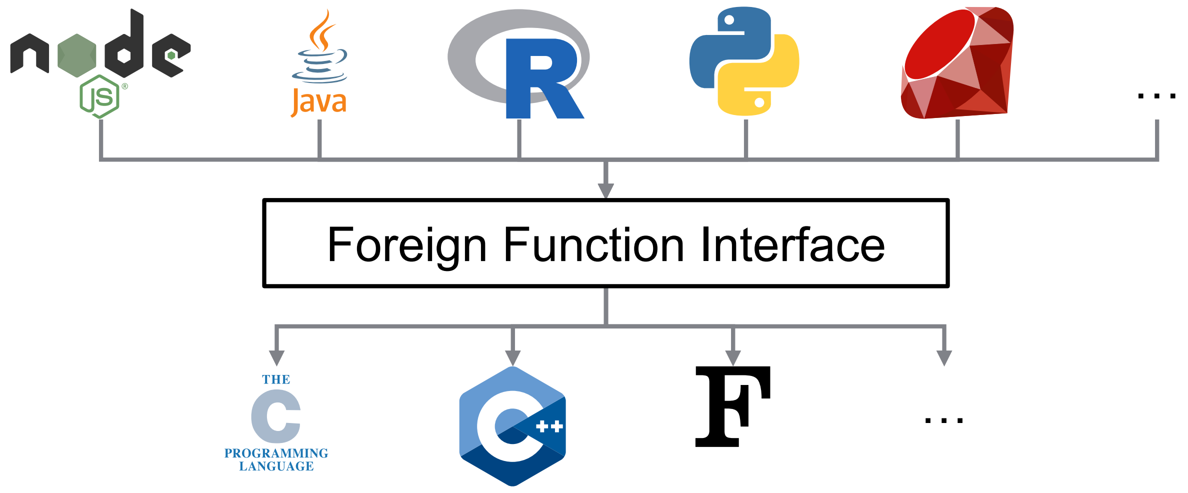


Language Interaction



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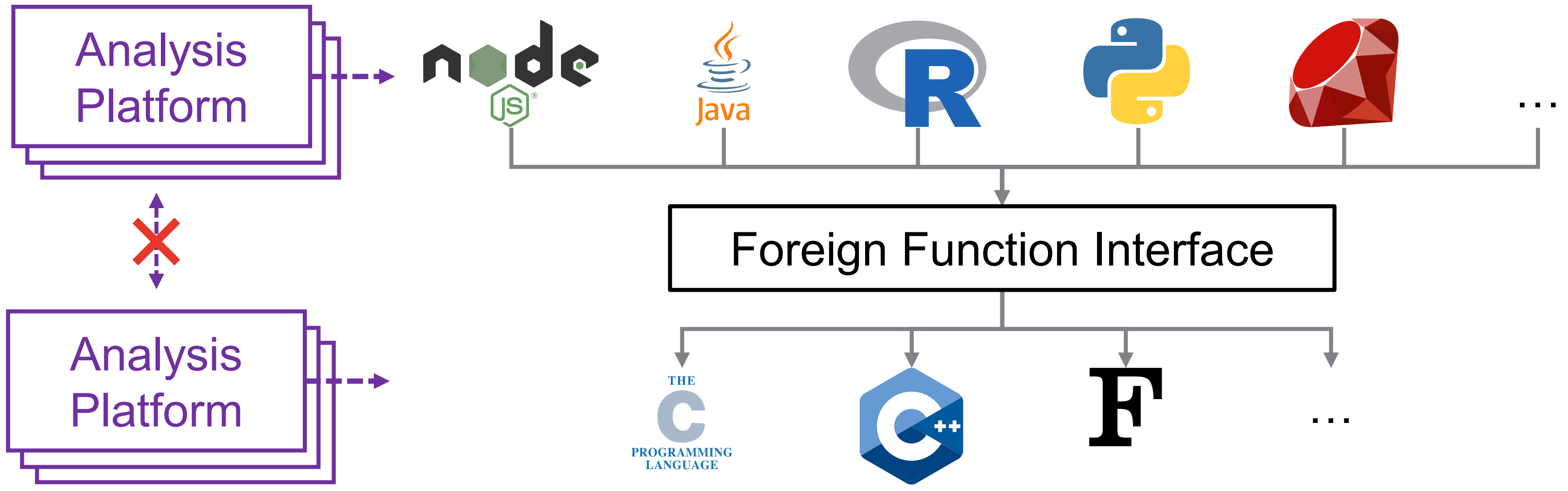
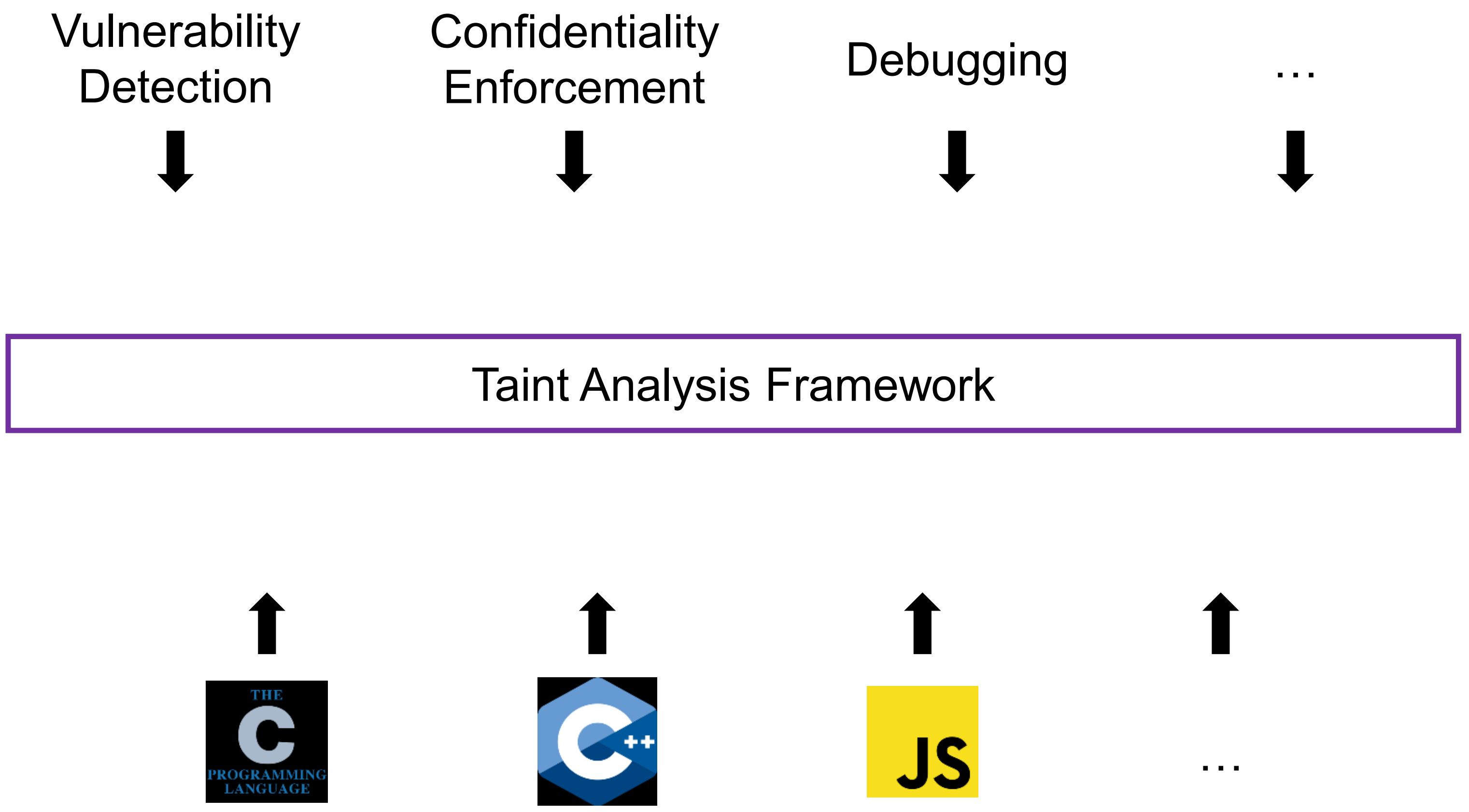


A Generic Platform for Multi-Language Dynamic Taint Analysis



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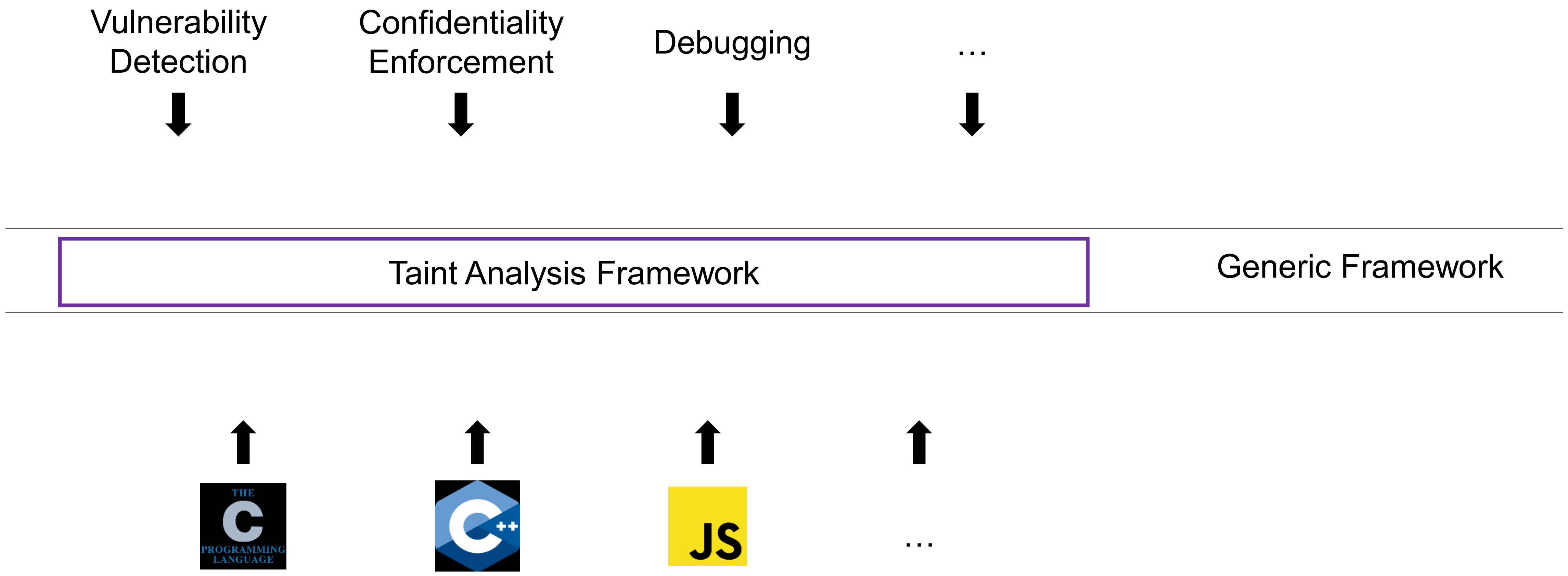

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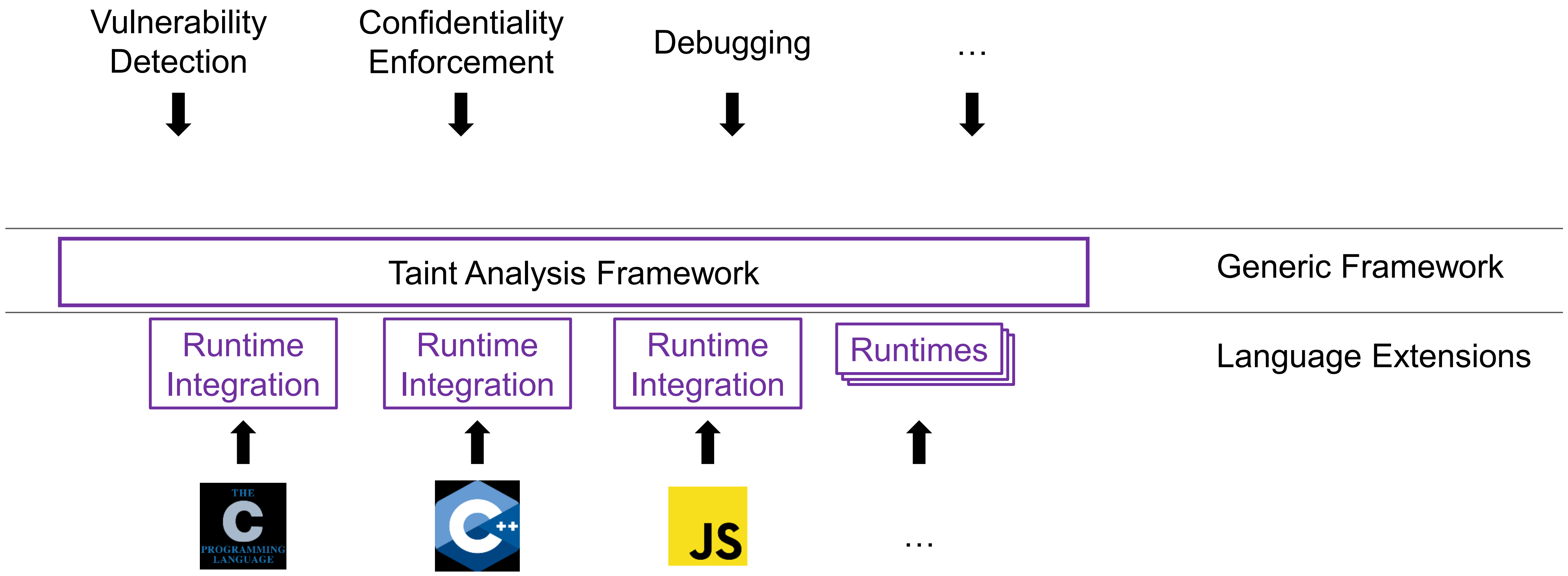

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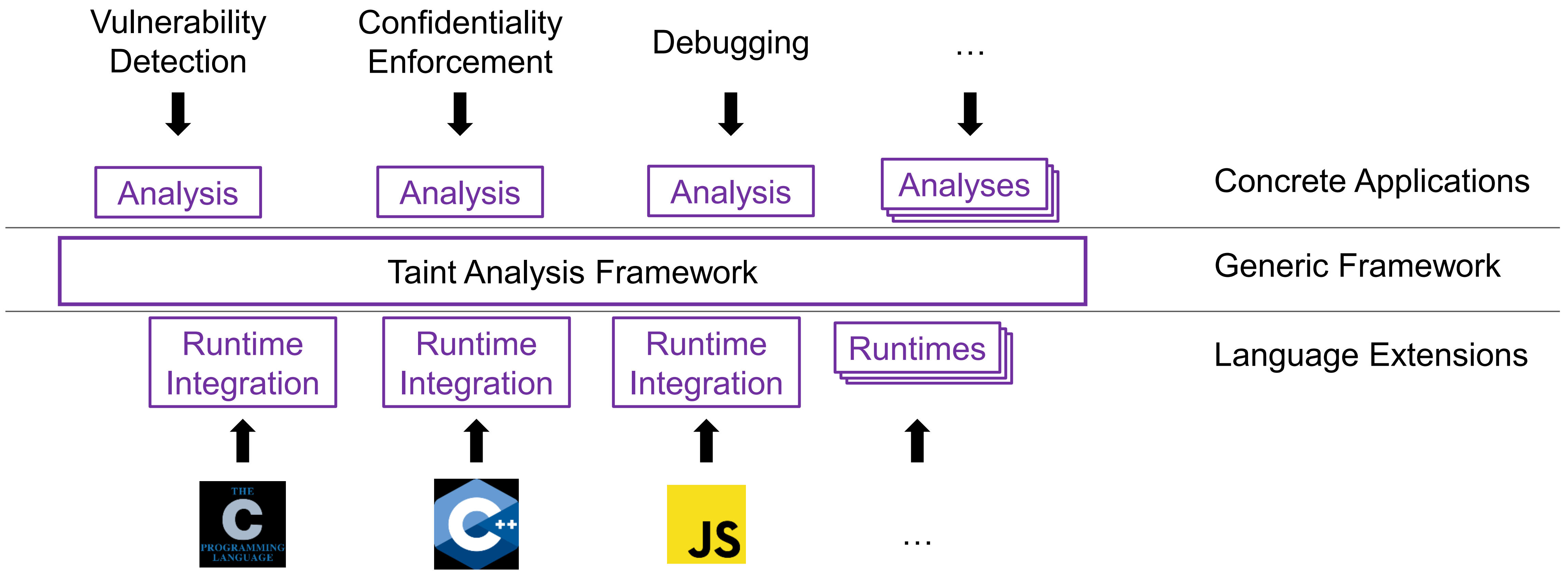
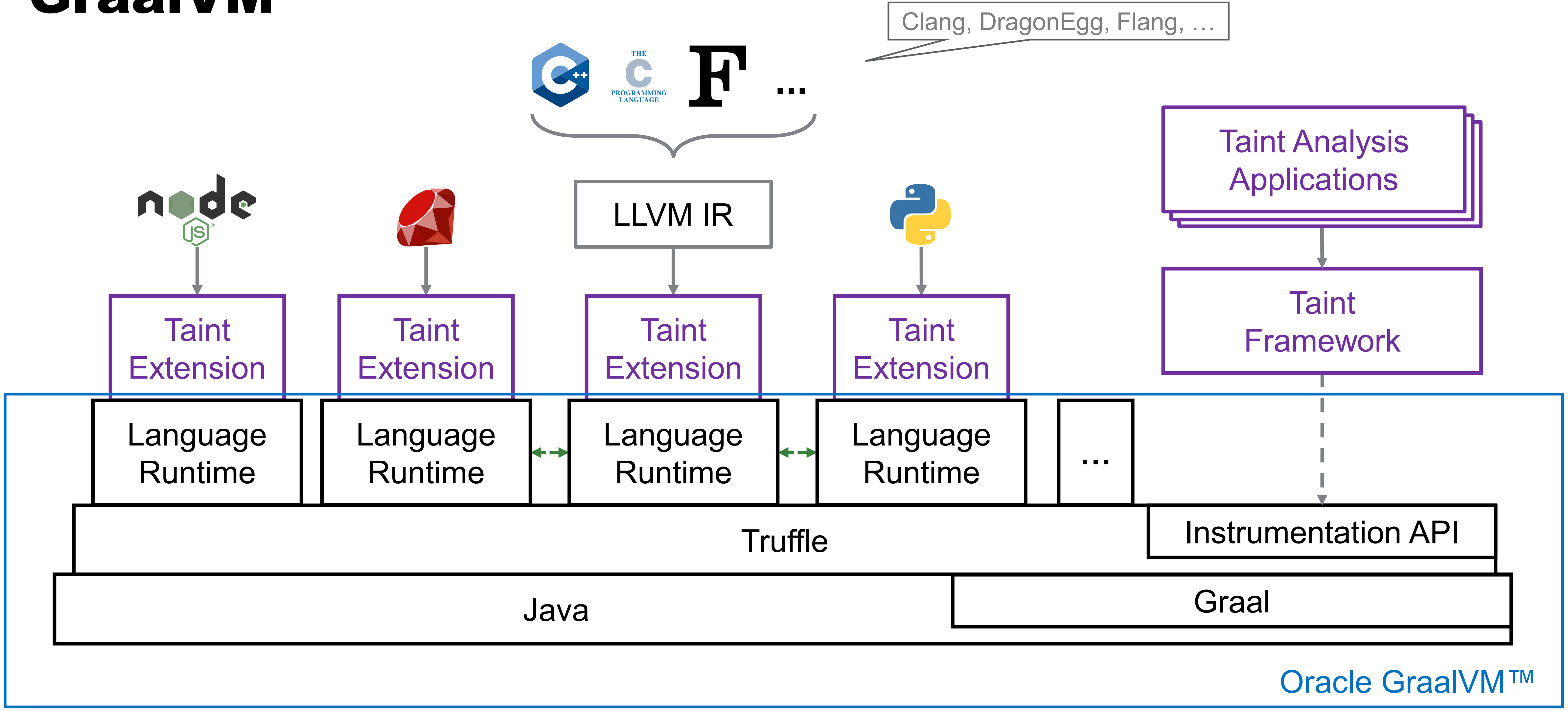


GraalVM


Clang, DragonEgg, Flang, …
THE C PROGRAMMING LANGUAGE
F
…
LLVM IR
Taint Analysis Applications
Taint Extension
Taint Extension
Taint Extension
Taint Extension
Taint Framework
Language Runtime
Language Runtime
Language Runtime
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…
Truffle
Instrumentation API
Java
Graal
Oracle GraalVM™

Truffle Instrumentation

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$\longrightarrow$ Truffle Front-End $\longrightarrow$

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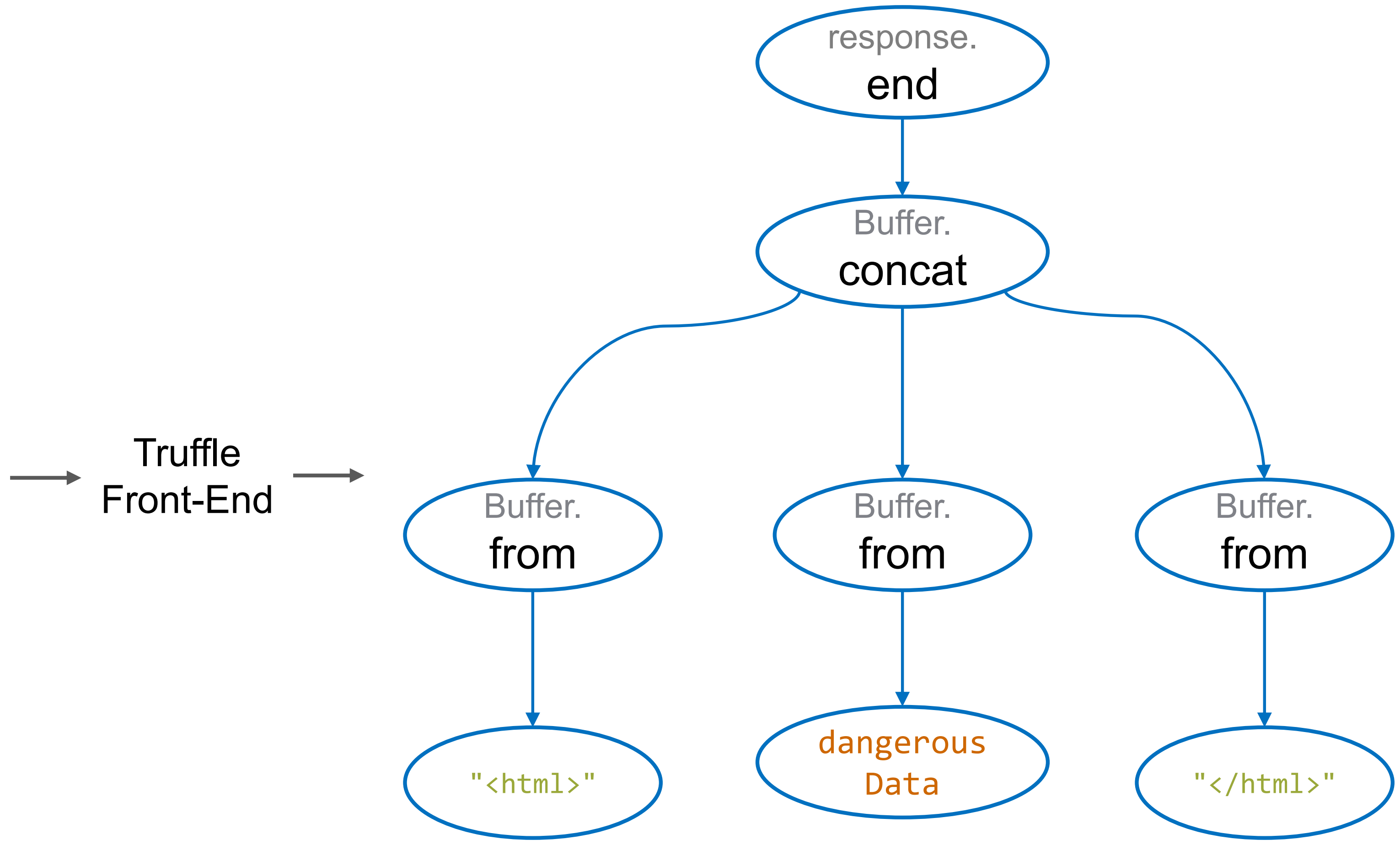

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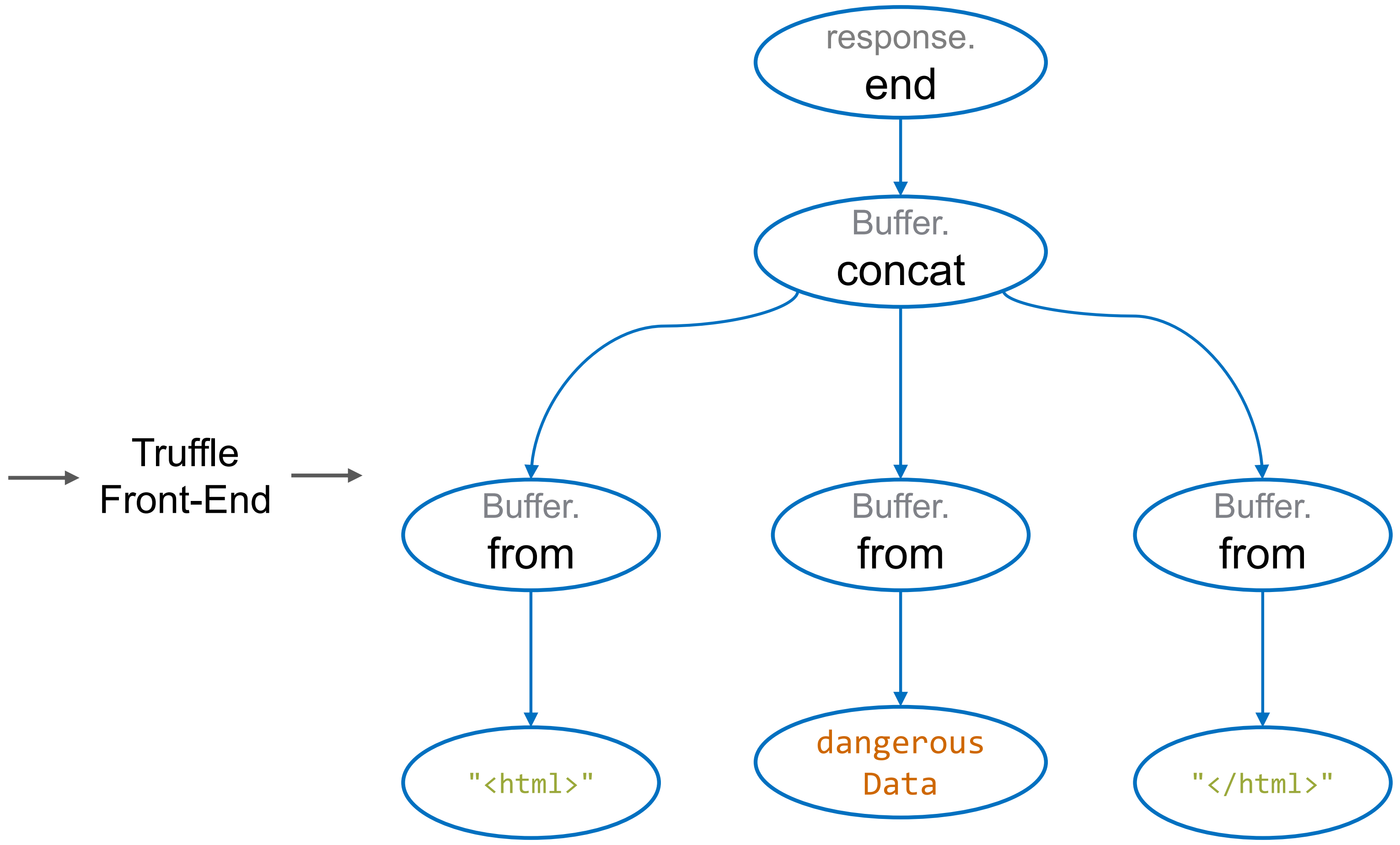

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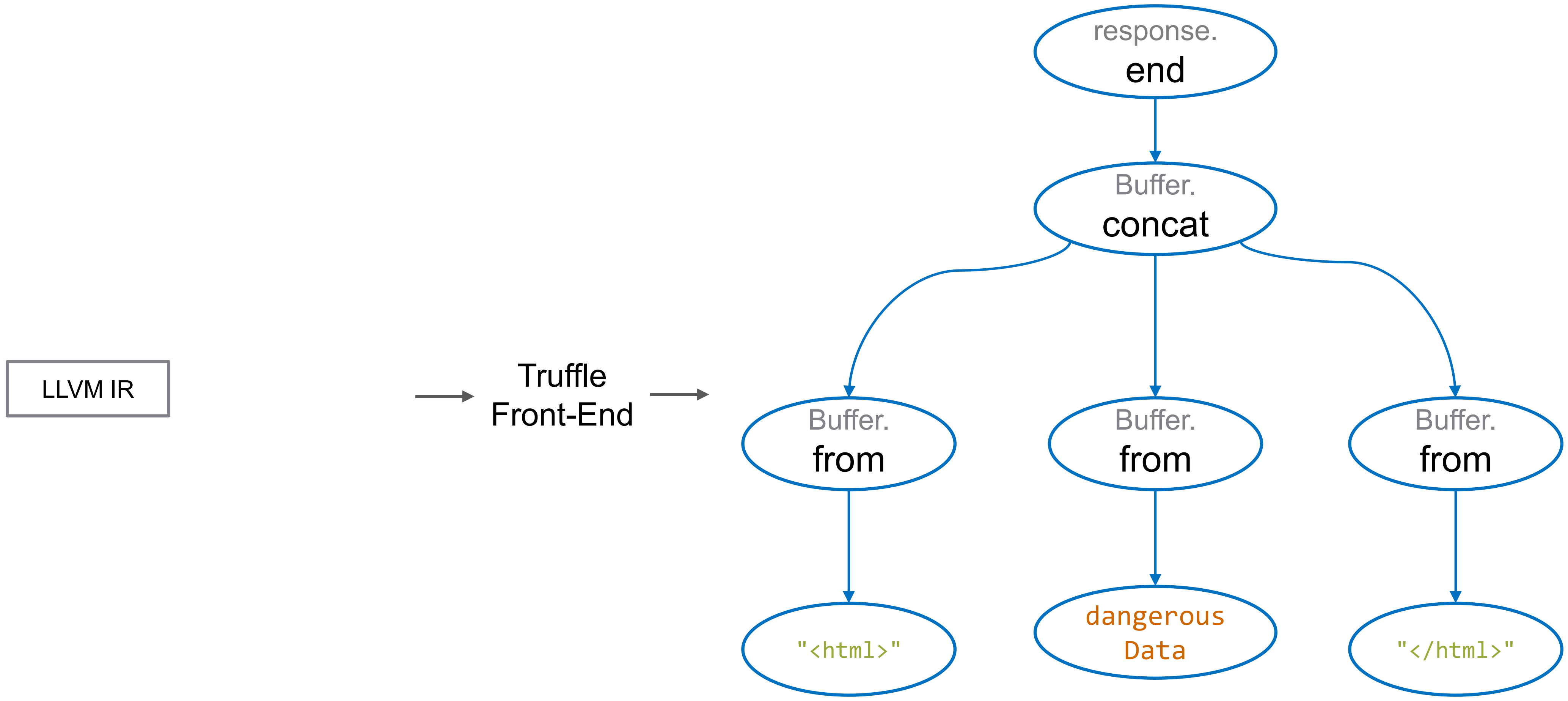

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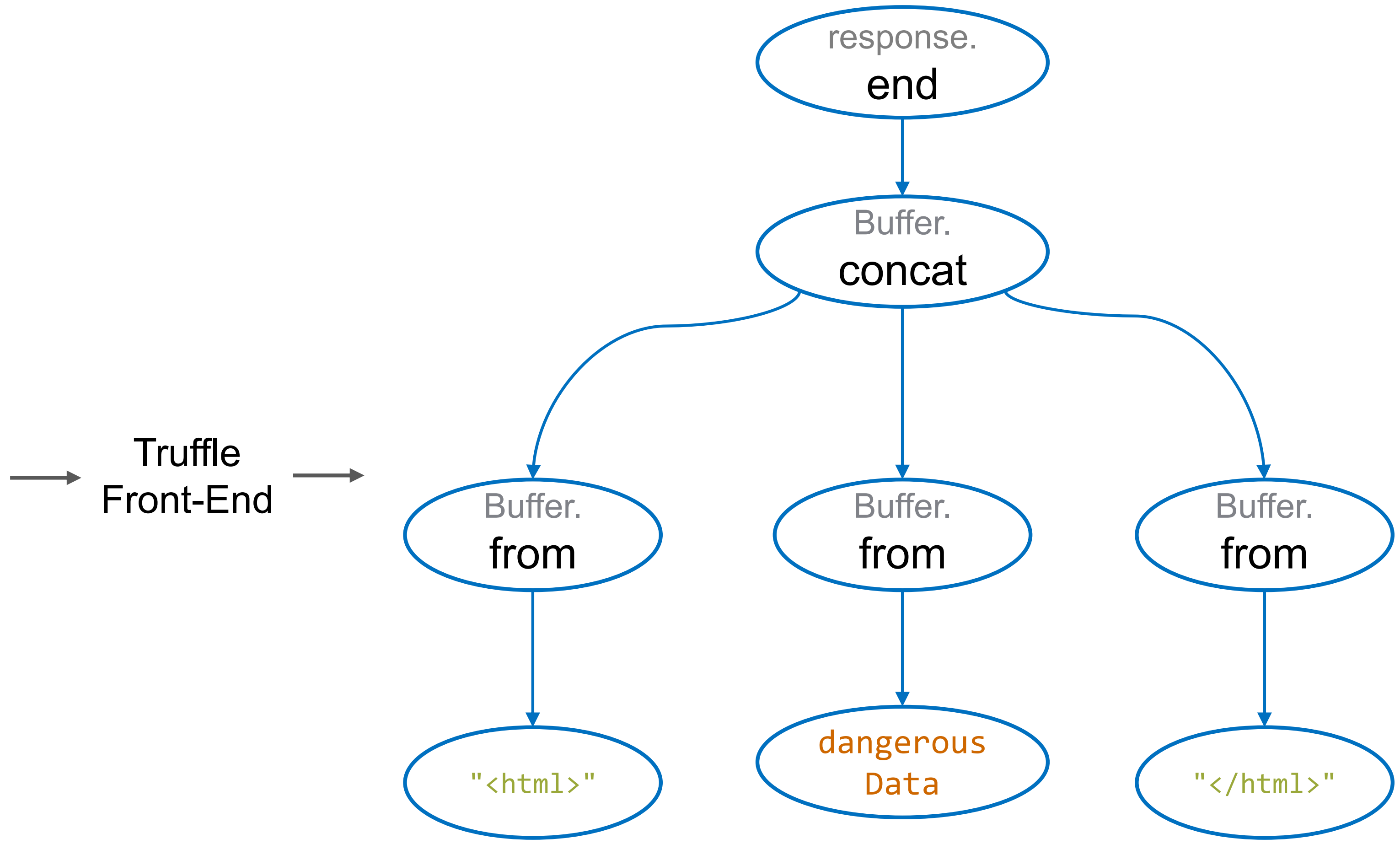

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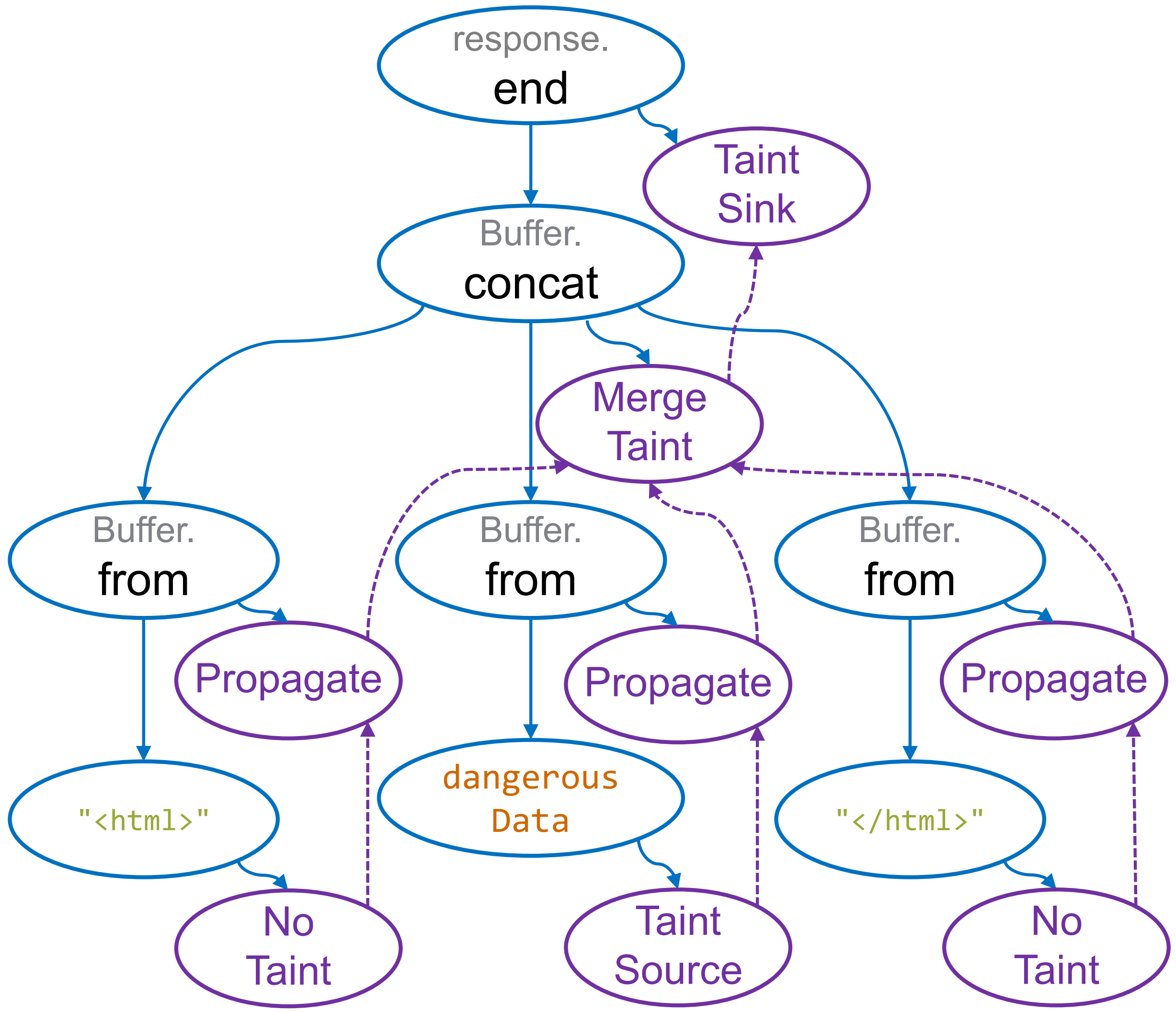

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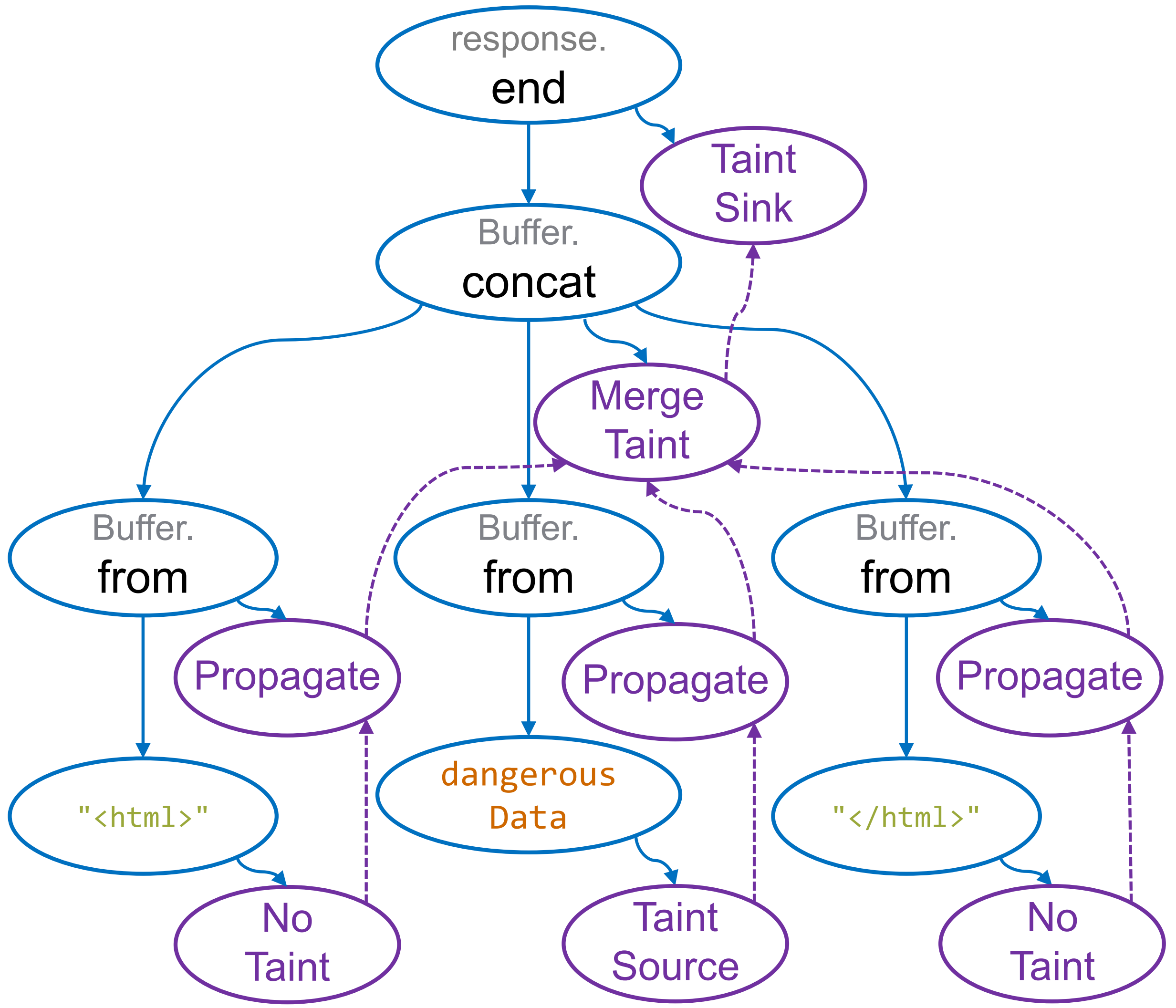
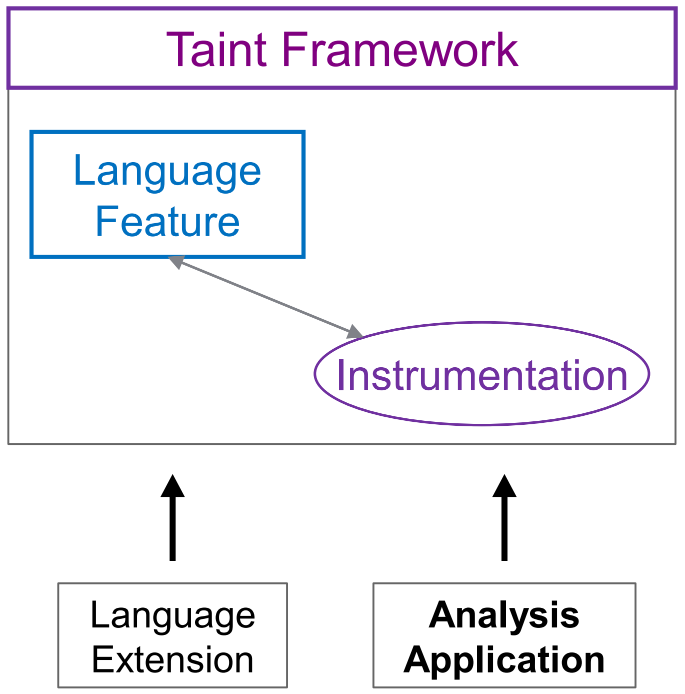


- Insert nodes to propagate taint labels
- Language-level instrumentation
    - Footprint

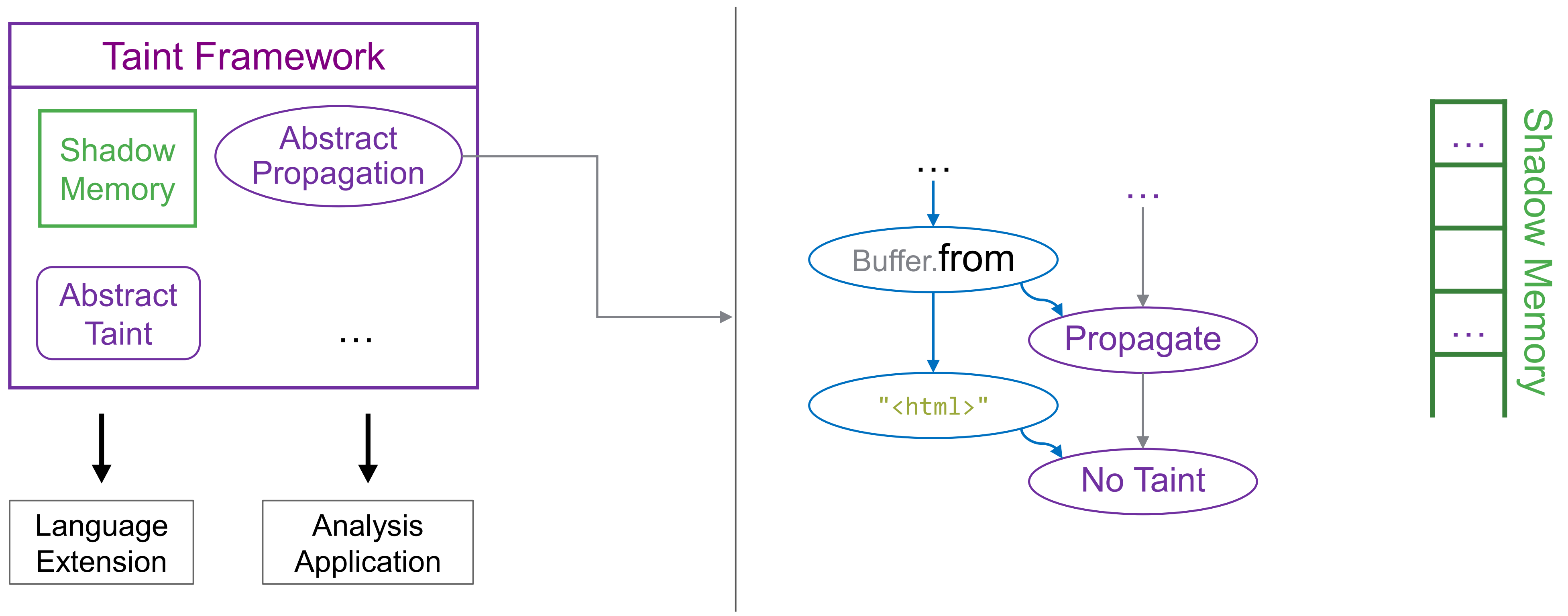
Instrumentation Strategy

- Adaptable instrumentation
  - Language-Level
  - Taint Sources and Taint Sinks
  - Default propgation strategy
  - Full control to analysis applications
  - Code reuse

- Language-agnostic taint analysis
  - Abstractions for common language features



Reusable Functionality



- Support multiple languages and applications
- Efficient implementation

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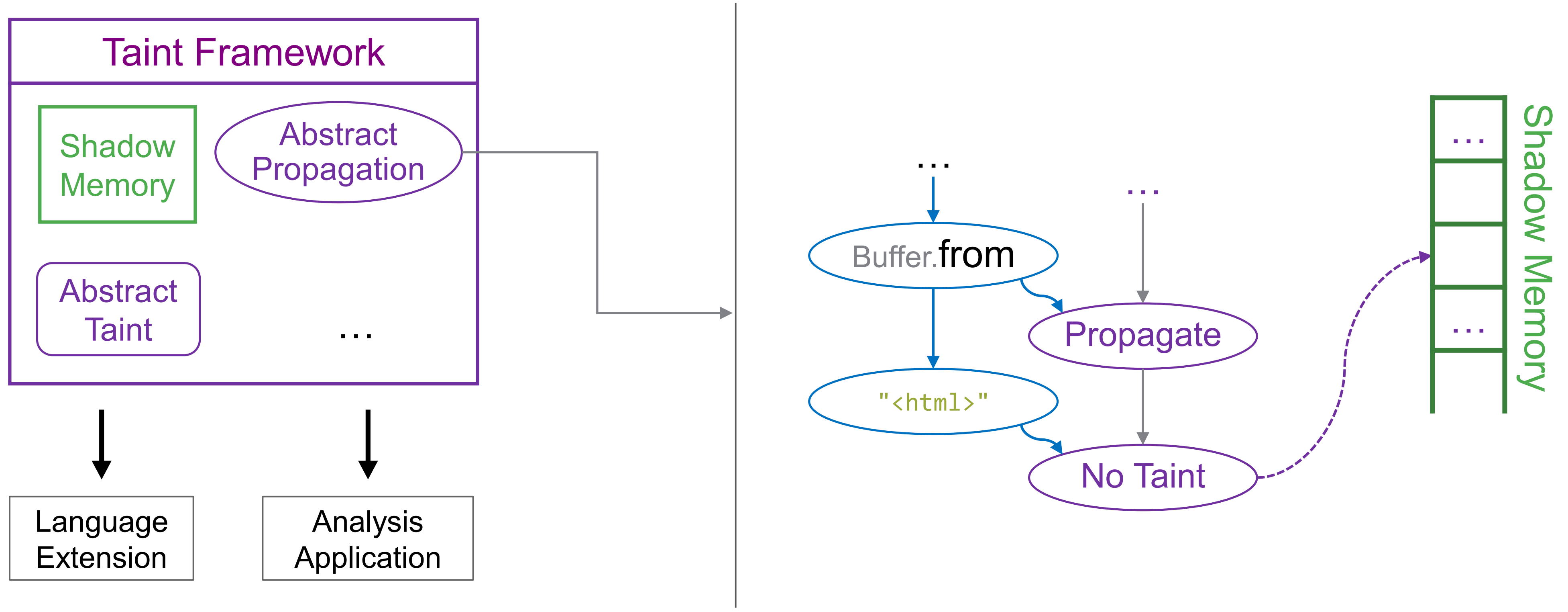

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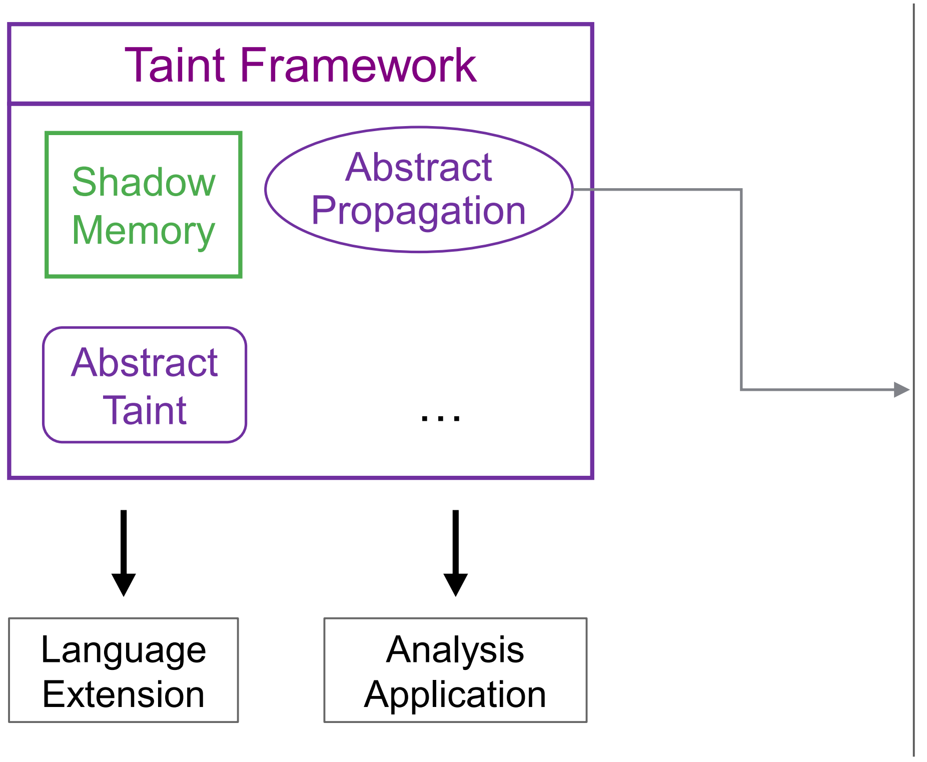

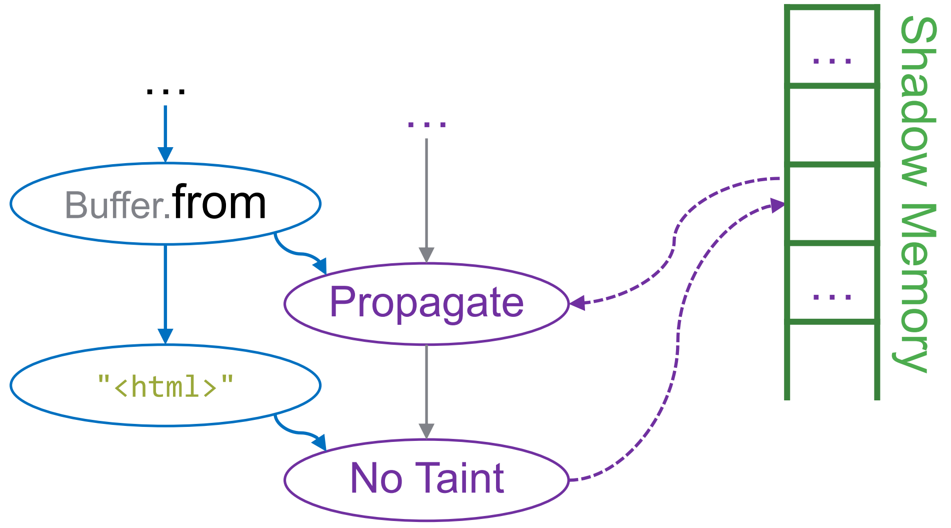

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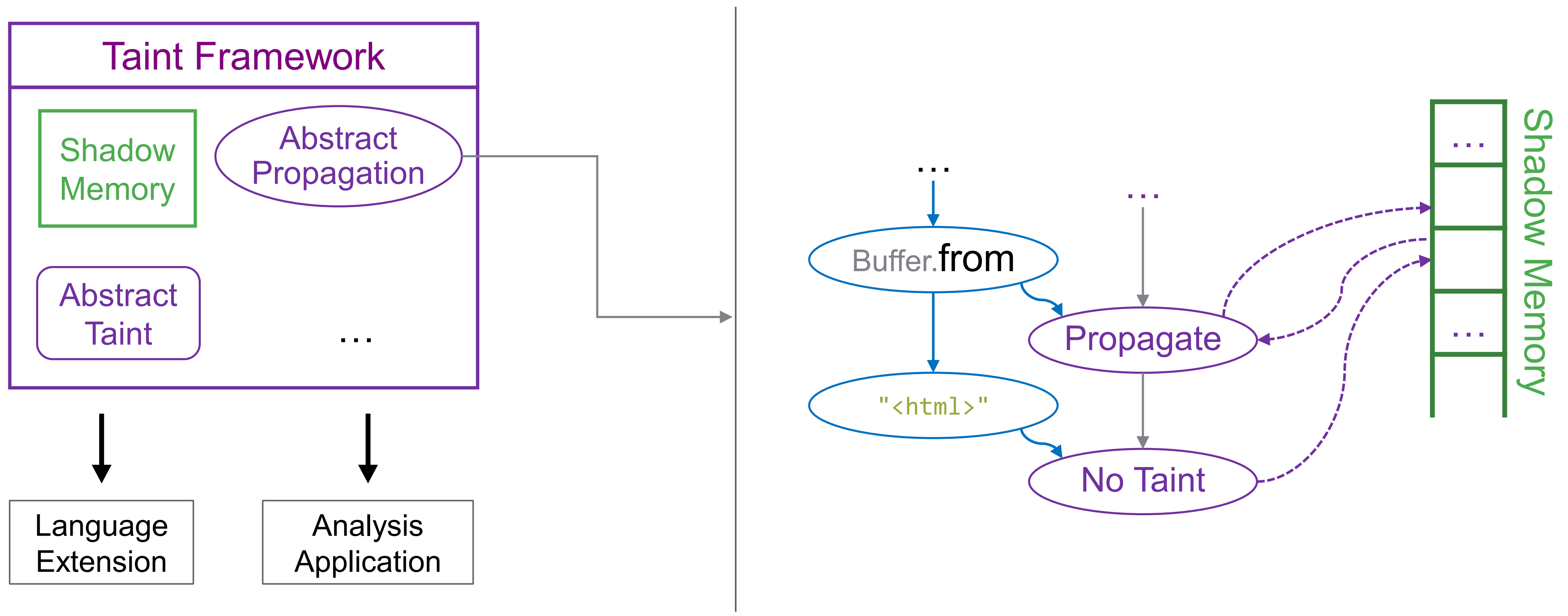

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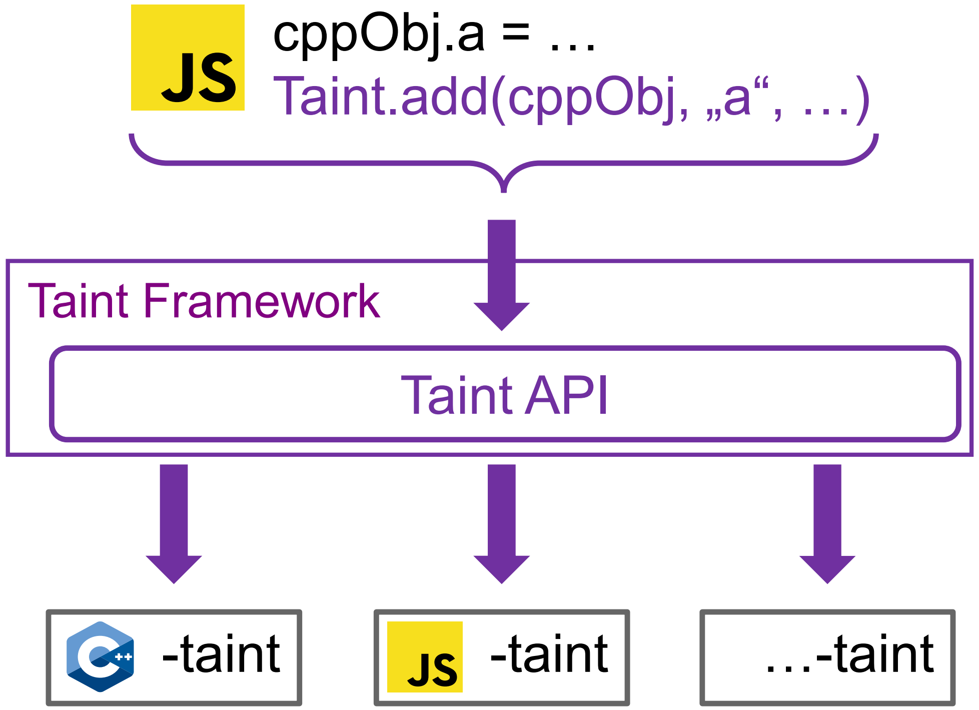
Language Integration

- Truffle Interoperability

- Language-specific storage of member taint
  - Distinct objects vs. memory pointers
  - Granularity

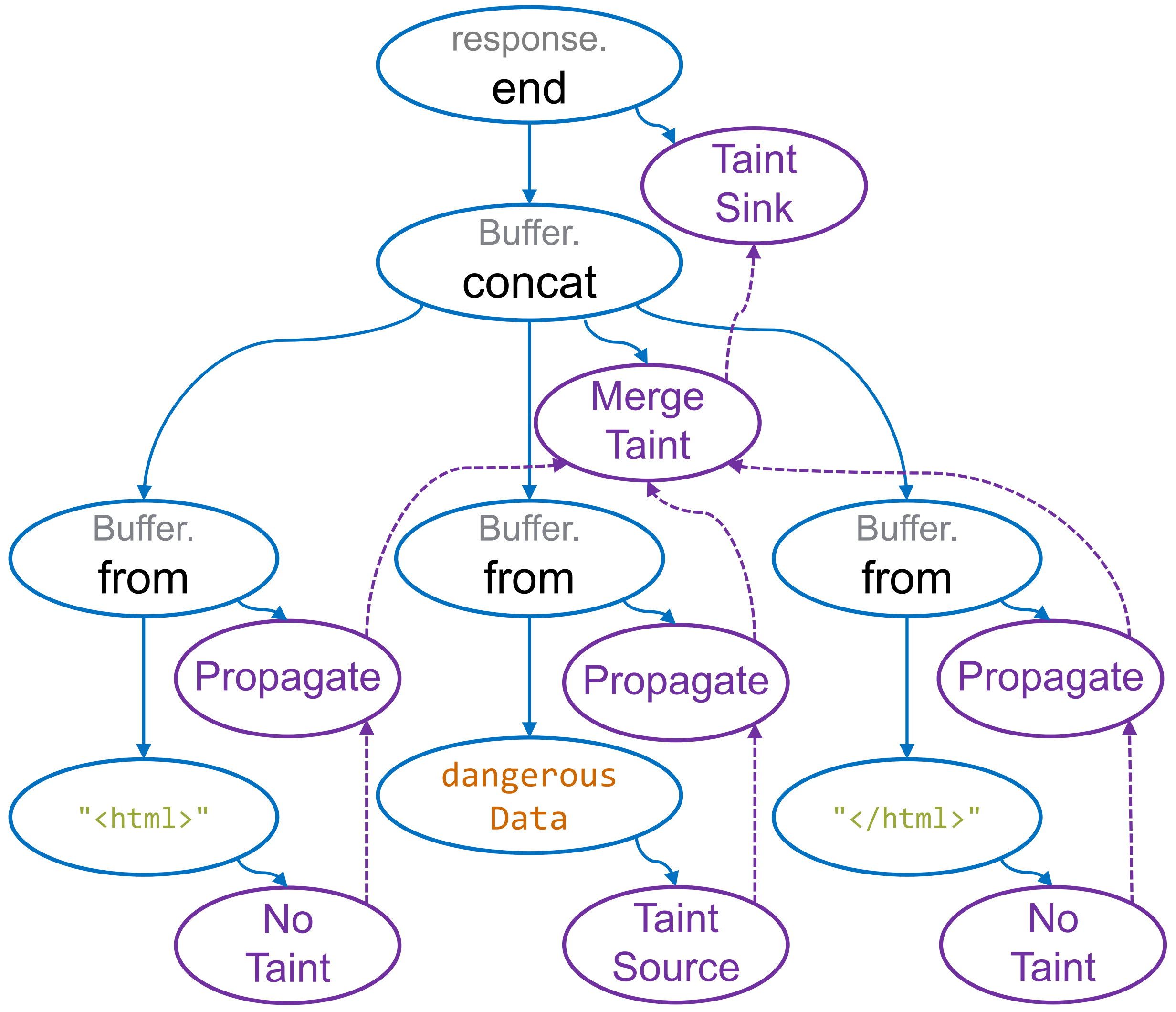


Performance

- Can we just leave it to the compiler?
  - Inlining
  - Partial Evaluation
  - Escape Analysis
  - …

- Optimize code and instrumentation together

- Implement common functionality amenable to Graal compilation



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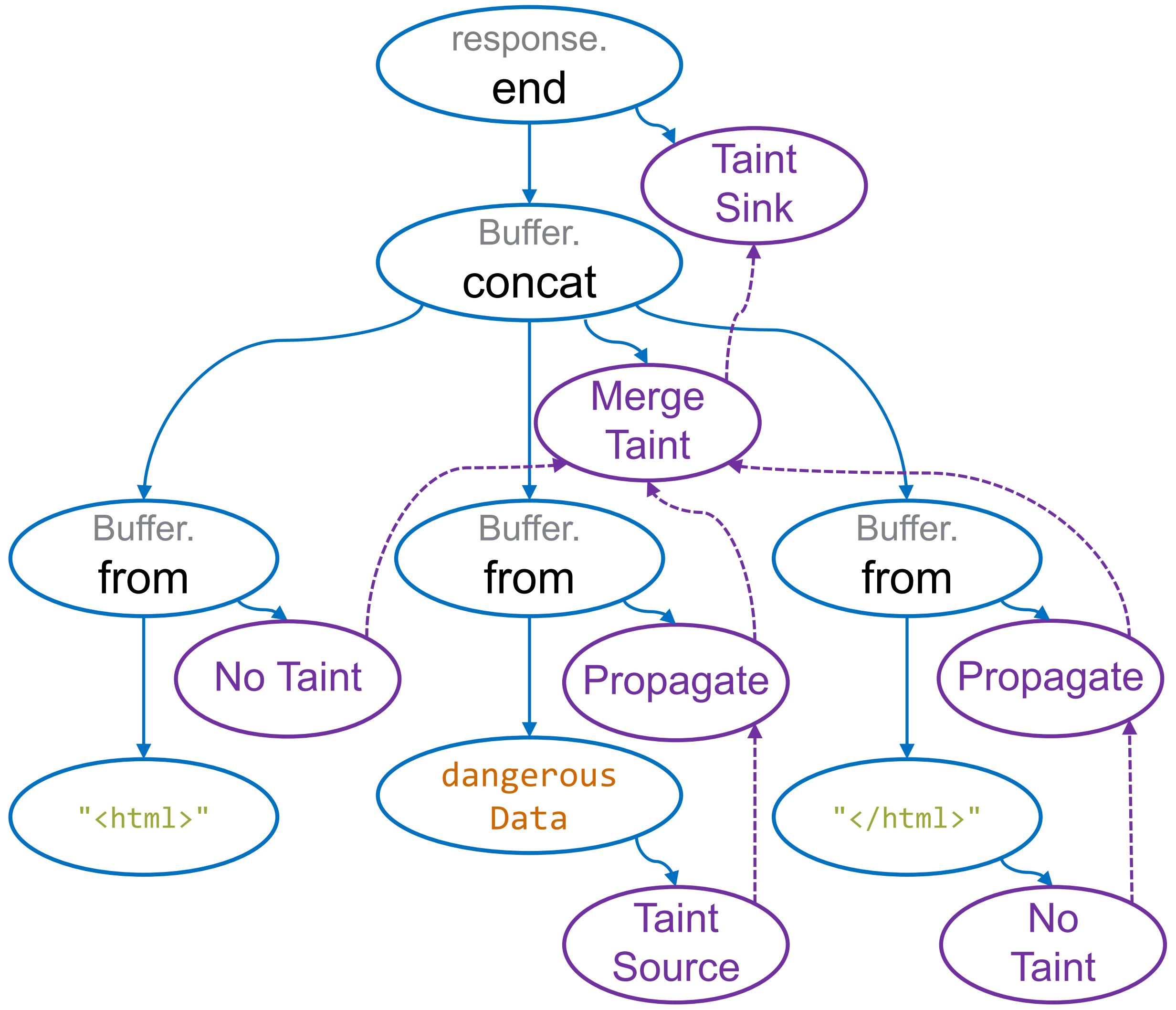

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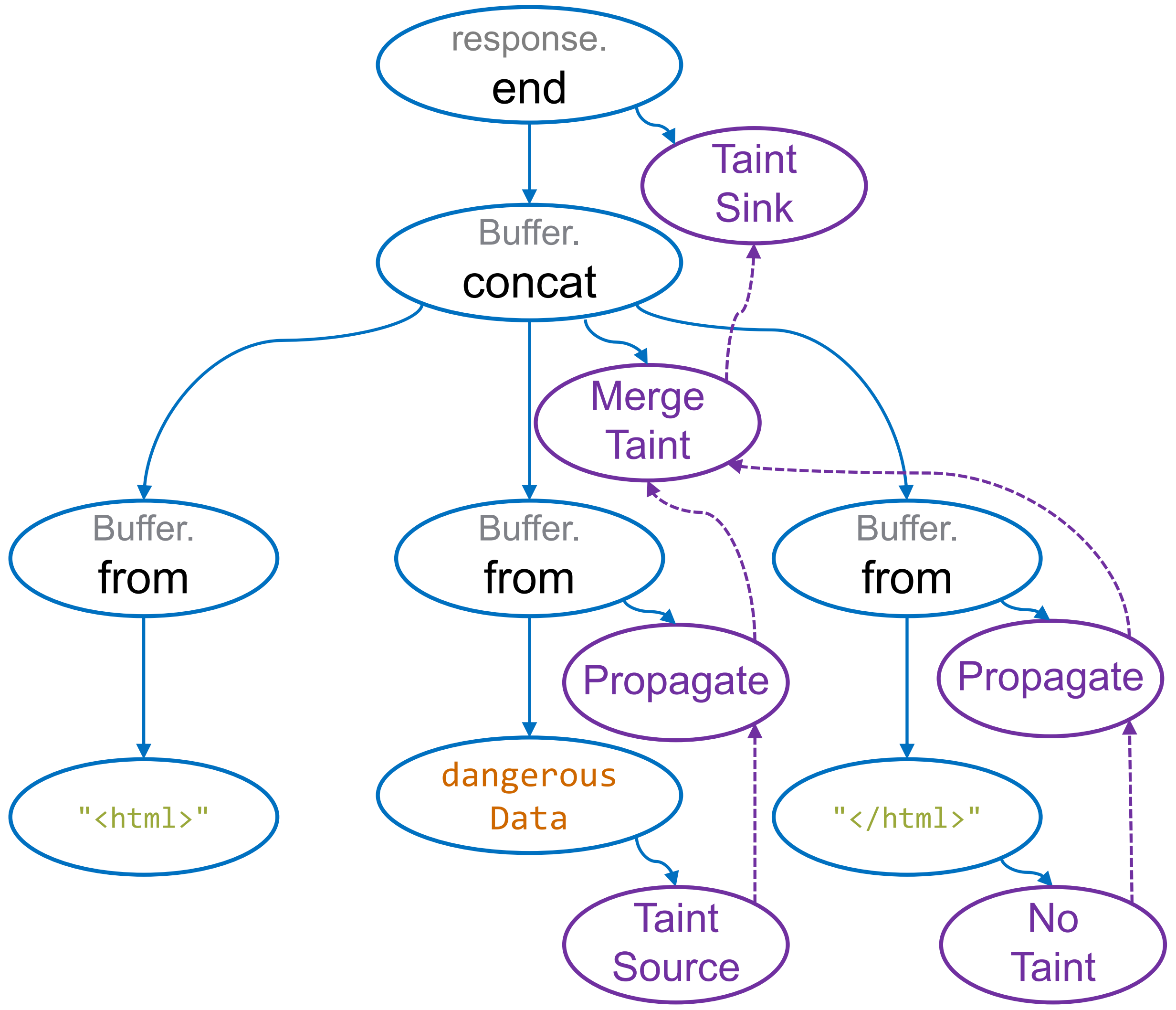

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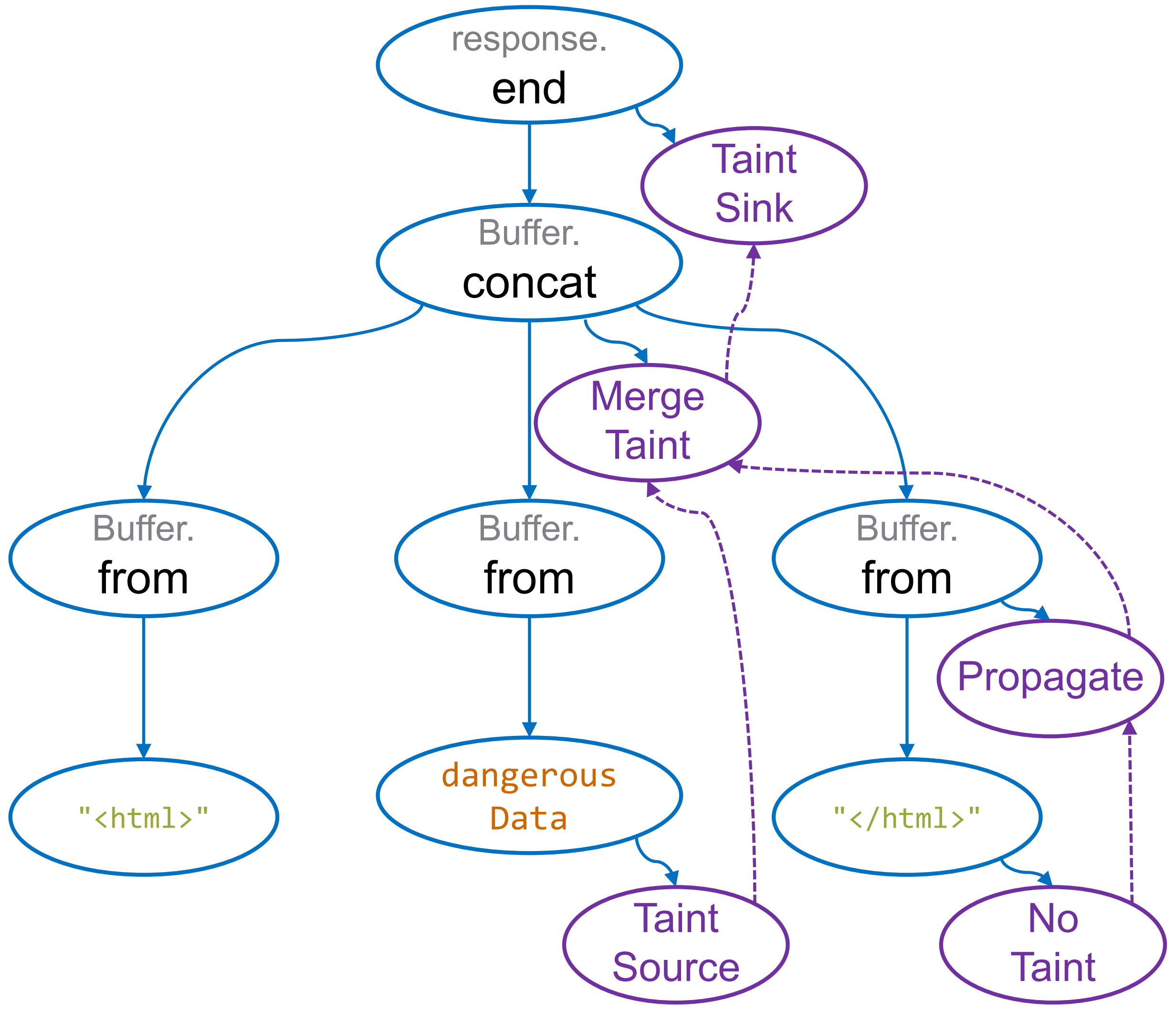

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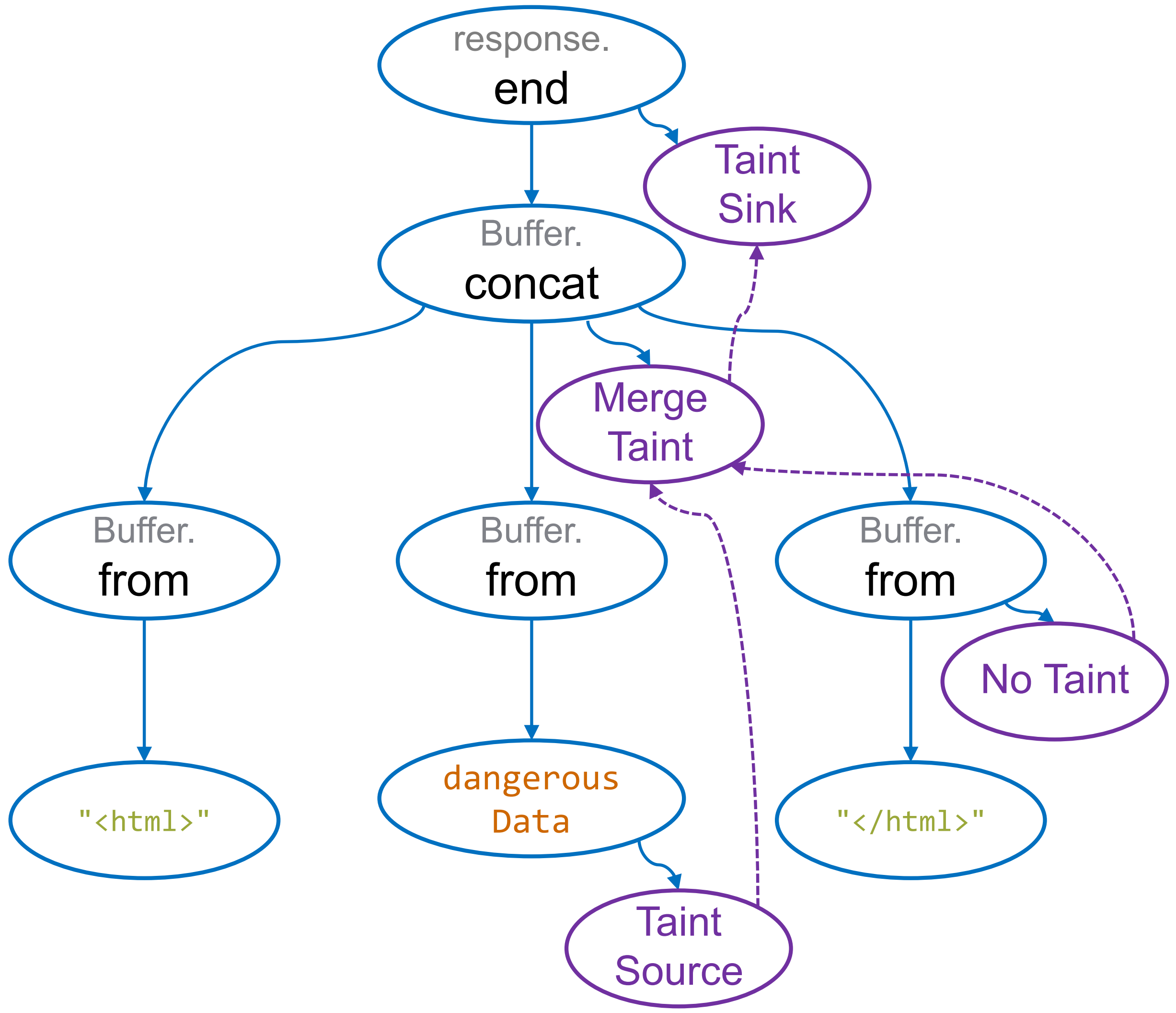

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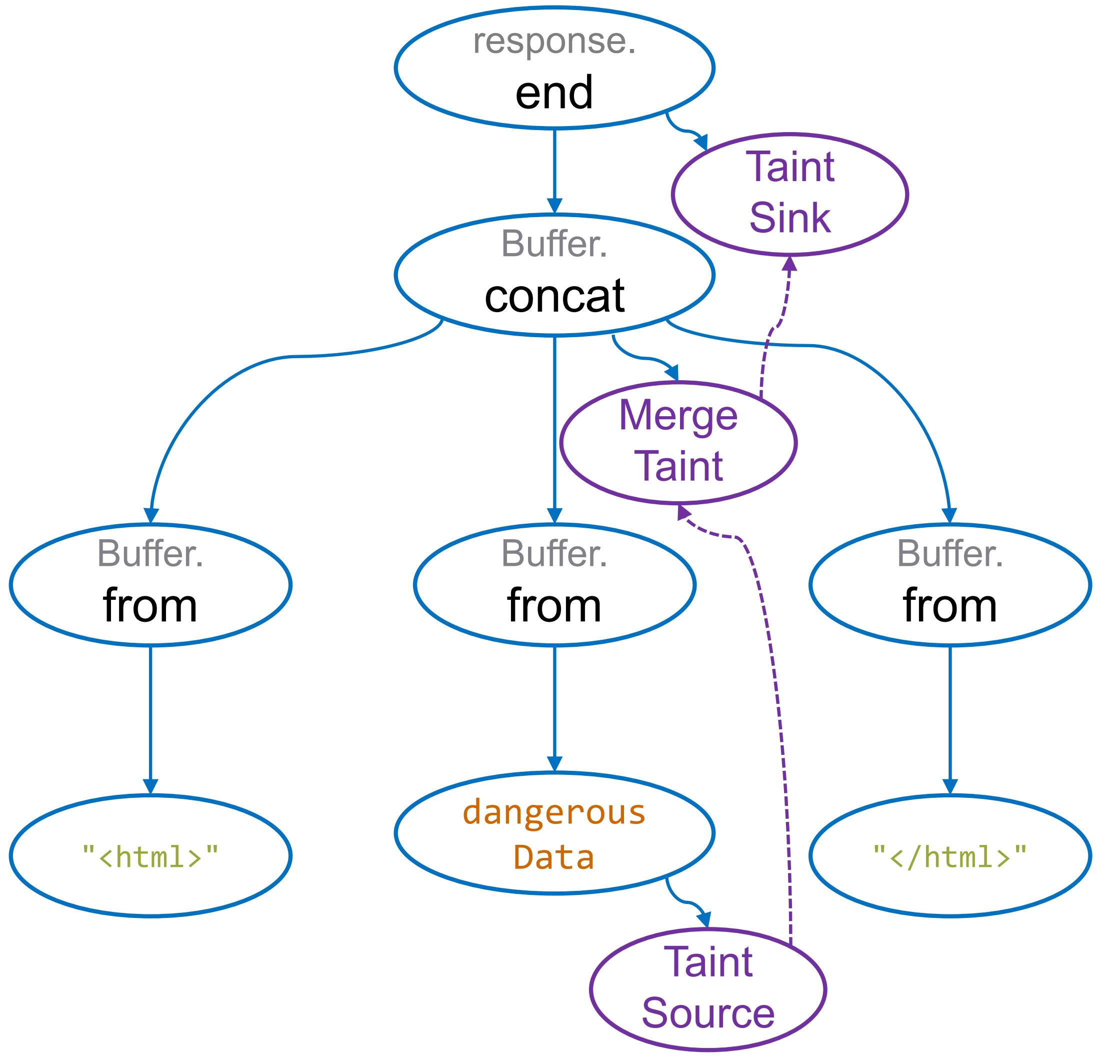

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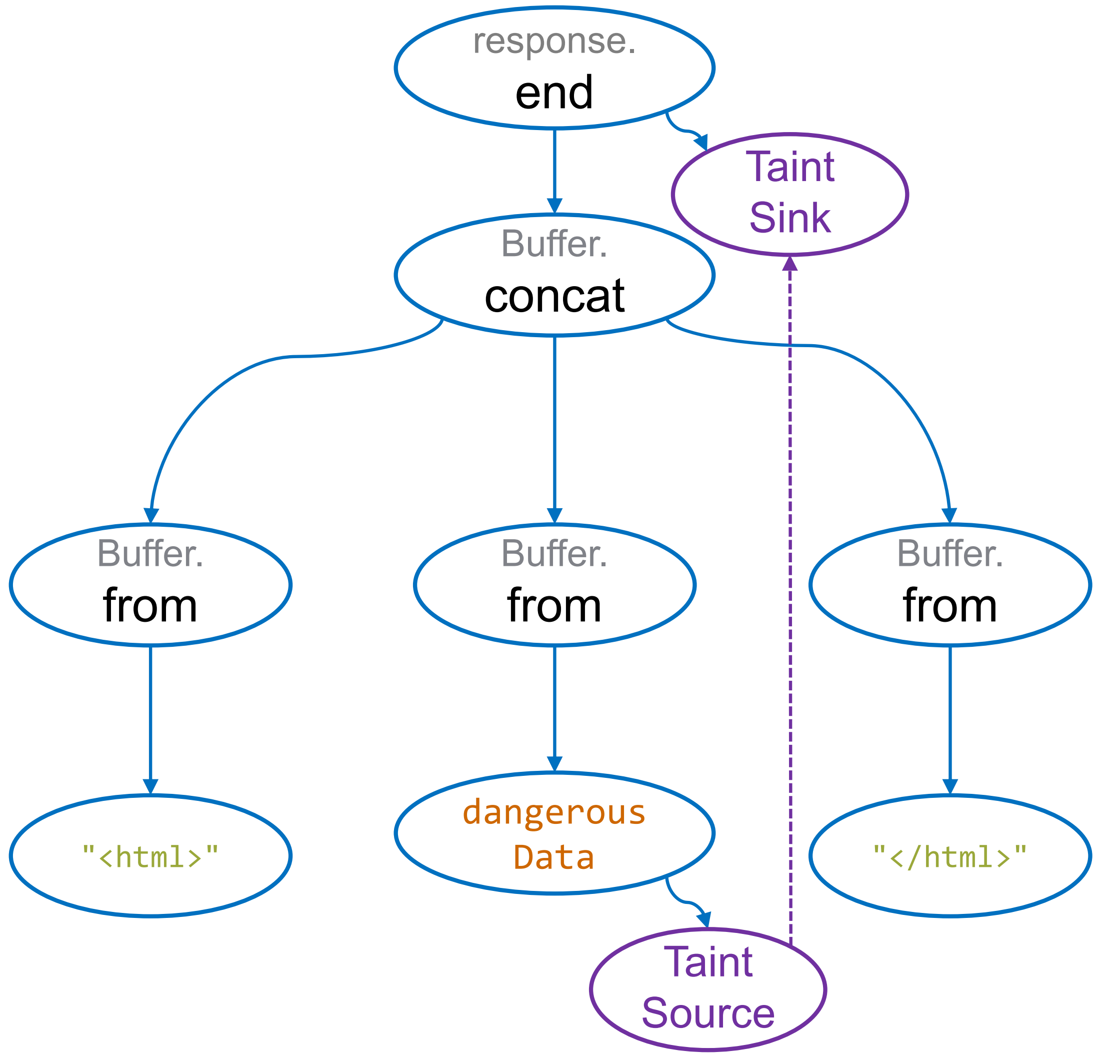

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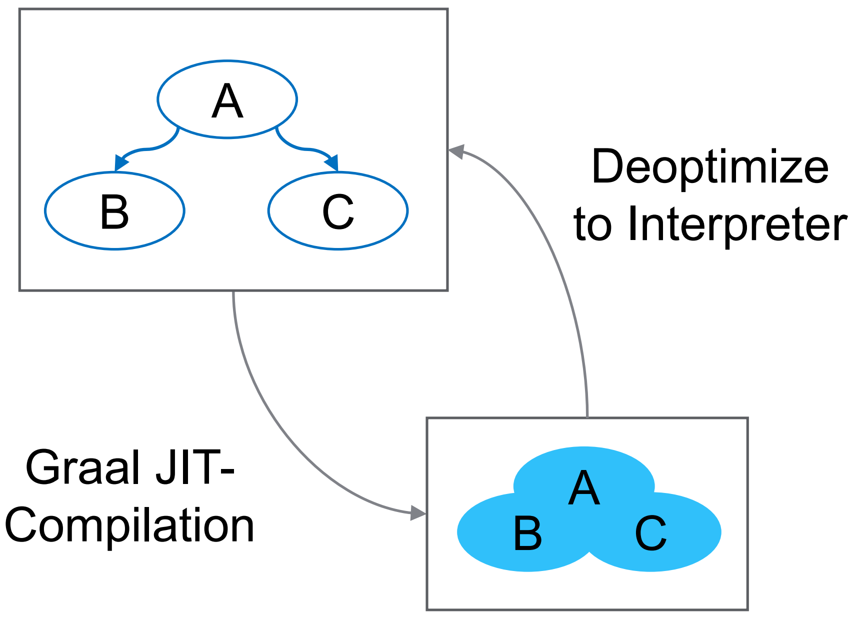

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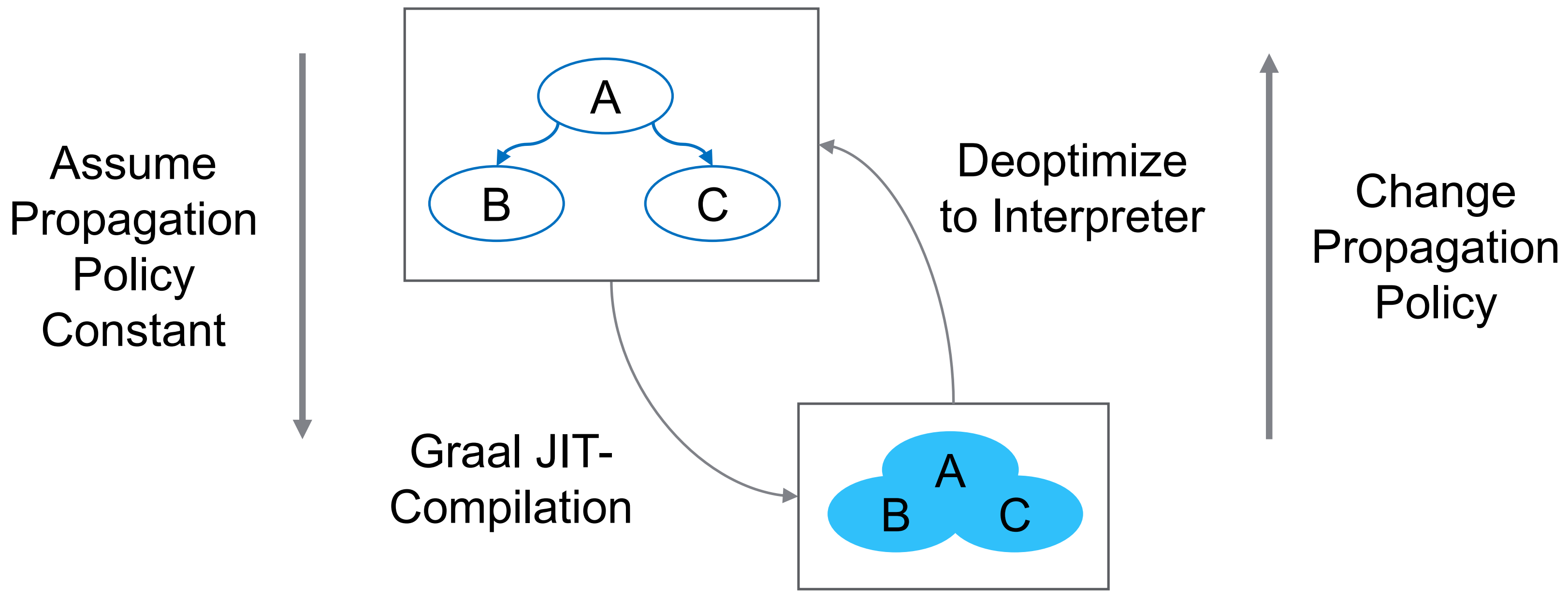
  - Assume instrumentation constant for JIT
  - Deoptimize on changed instrumentation

- Runtime-configurable propagation policies
- Assume value properties
- And more to come

Speculative Optimization and Dynamic Compilation


Assume Propagation Policy Constant
A
B
C
Deoptimize to Interpreter
Change Propagation Policy
Graal JIT-Compilation
A
B
C

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Summary

- Programs often use **code of multiple languages**
  - But current taint tracking systems are limited to only one

- In progress: **multi-language taint analysis platform**
  - Choosing suitable abstractions
  - Integrating multiple languages
  - Language-agnostic taint analysis

- In progress: **reduce overhead** by dynamic compilation and speculative optimization
  - Efficient strategies for storing and propagating taint
  - Make use of existing compiler